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Assessing the spatial distribution of urban parks using GIS

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Abstract

The total area of urban parks in Seoul is approximately 158 km^2 which is fairly large compared to those in other cities around the world. Although this figure may seem favorable, in actuality major portions of the parks in the city are located in outer areas so that frequent opportunities to visit them are relatively minimal. Such disparity between statistics and actual usability comes mainly from the inconvenient location of the parks.

Using the network analysis method of GIS, this study analyzed pedestrian accessibility to urban parks in Seoul and the subsequent serviceability of the parks. Study results indicated that first, the total service area of the urban parks identified by network analysis was 249 km^2, which was approximately half of the service area analyzed by the conventional simple buffering method. Next, the spatial distribution of parks in the five sub-regions (northwest, northeast, central, southwest, and southeast) of Seoul was then evaluated in terms of serviceability indices—i.e. service area ratio, service population ratio, and service floor area ratio. Finally, urban parks in Seoul were found to have been inadequately distributed in relation to population, land use, and development density. Park serviceability in the northern part of the city in particular was determined to be the most problematic. Considering the actual locations of parks and the corresponding local population and land use, the approach conducted in this study provided practical ways of understanding and managing spatial distribution of urban parks.

Keywords: Urban parks; Service area; GIS; Network analysis

1. Introduction

When internationally evaluating cities in terms of competitiveness, one major aspect to take into account is the presence of public facilities such as urban parks. Another consideration is citizen accessibility to these parks. These notions can be viewed as differences between an industrial society, in which the primary focus is on economic efficiency and productivity, versus a more cultural oriented society where a higher quality of life is prioritized. Providing parks near neighborhoods is vital for their function as recreational areas for citizens to congregate and socialize, while aesthetically upgrading the vicinity.

Previous studies that have evaluated the serviceability of urban parks often employed statistical indices such as total park area, park area per capita, and number of parks. Based upon these indices, the total area of all urban parks in Seoul was calculated to be approximately 158 km^2. This cumulative figure is comparably large and is seemingly favorable to those in other cities around the world (Fig. 1). However, most of the parks within Seoul are typically located in the outer areas and thus inconvenient to access. Consequently, frequent opportunities to patron these parks have been relatively minimal. Therefore, in order to establish more effective urban park policies, an accurate understanding of the relevance of their distribution is a primary task.

Several issues have been raised regarding the relevance of park distribution. First of all, conventional statistical indices do not reflect the exact locations of parks, and statistics do not consider how citizens benefit from them. In addition, previous studies that assessed the accessibility to urban parks and determined their service areas often employed the so-called "simple buffering method" which focuses on the linear distance from parks rather than considering citizens' actual routes to them. Moreover, aspects of the surrounding areas of parks, including the number of benefited users, land uses, or development density are not considered. Using the network analysis method of GIS, this study analyzed the actual accessibility of pedestrians to urban parks in Seoul and the resulting rate of patronage to them.

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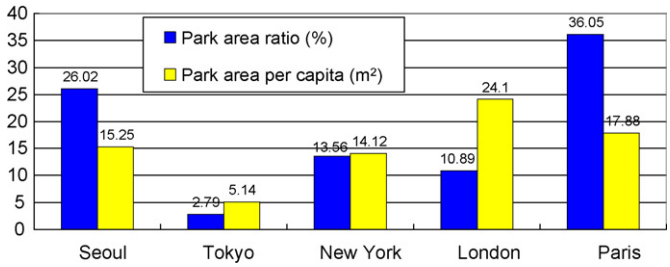

Fig. 1. Comparison of statistical indices of urban parks in major world cities (2002).

2. Previous studies on the location of parks

A number of studies on public facilities such as urban parks have been conducted in terms of their location standards, location methods, and relevance of their distribution. For instance, McAllister (1976) employed the concept of equity and efficiency for location standards of public facilities, whereby the former concept refers to the existence of a larger number of small parks, and the latter concept, the presence of a lesser number of larger parks. He concluded that equity has greater importance because it was more sensitive than efficiency in the selection of size and spacing within a given area. Furthermore, Bach (1980) developed the location-allocation model with the concepts of accessibility and access opportunity that focused on pursuing the minimization of collective friction of space. This notion can be useful for assessing the distribution of parks in Seoul when determining the amount of time needed to access them.

Lucy (1981) also emphasized equity in locating public facilities and presented five sub-concepts that include equality, need, demand, preference, and willingness-to-pay. In terms of equality however, a proper limit of distance is needed because a strict or perfect equality of distance to physical facilities is impossible to achieve (Lucy, 1981). Therefore, he suggested that thresholds of adequacy be constructed. An example of such thresholds is presented by the National Recreation and Park Association (NRPA) in North America, in which a specific number of acres for a specified number of people for park planning—i.e. a maximum distance standard (one-half mile service radius) with an acre per population standard (one acre per 800 persons) is recommended, reflecting an equality concept of equity. In Korea, such thresholds for different levels of urban parks have been suggested by Urban Park Law (Table 1).

Table 1
Urban parks and their thresholds (Korean Urban Park Law)

Parks	Catchment distance	Area (m^2)
Children's parks	Less than 250 m	Over 1500
Neighborhood parks	Less than 500 m	Over 10,000
Walkable area parks	Less than 1000 m	Over 30,000
Local parks	No limit	Over 100,000
City-level parks	No limit	Over 1,000,000
Urban natural parks	No limit	Over 100,000
Cemetery parks	No limit	Over 100,000
Sports complex parks	No limit	Over 10,000

Service area is the service range of a public facility which is equivalent to the accessibility to a public facility such as a park or school that supplies service via traffic networks (Talen and Anselin, 1998). GIS has been widely used for analyzing the service area of parks by simple buffering which involves drawing lines around parks at a given distance. For example, Ahn et al. (1991) measured accessibility to open spaces including green belts, rivers, and lakes from residential areas in Seoul. The study results revealed that areas within a linear distance of 700 m from open spaces composed 98.6% of the entire area of Seoul, and thus the provision of open spaces in Seoul was judged to be more than adequate. However, because the study relied mainly on uniform distance from parks, measuring actual travel routes of park users was not possible, and thus the service area of parks tended to be inaccurate.

Nicholls and Shafer (2001) adopted GIS technology in their study of urban parks and recreational services to evaluate accessibility and equity in a local park system. They used the simple radii buffering method to ascertain the number of facilities and the proportion of the population in the selected area. They also performed network analysis to calculate the actual travel distance along streets to local parks. Moreover, Van Herzele and Wiedemann (2003) constructed an urban core, green spaces, barriers, and crosswalks of four Belgian cities. They implemented qualitative and quantitative assessments by drawing "access possibility areas" and analyzing levels of green-spaces. In their study, the access distance from urban parks was calculated using a cost map which considered physical barriers in raster-based GIS.

Despite the various studies mentioned above, potentially restricting barriers for pedestrian movement such as crosswalks, overpasses, and underpasses were not considered and applied to linear distance when using the location-allocation model for instance, or when conducting buffering analysis in the study of service areas and accessibility. Moreover, these analyses did not take into account potential users who can benefit by the existence of urban parks.

3. Methods

3.1. Network analysis

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 (Fig. 2).

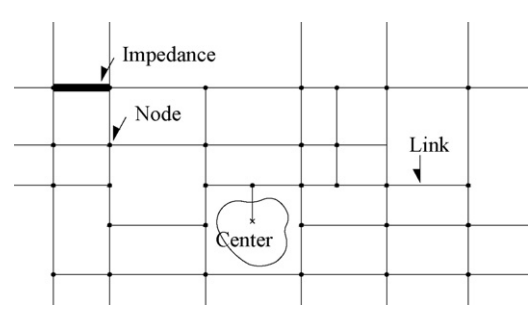

Fig. 2. Elements of network analysis.

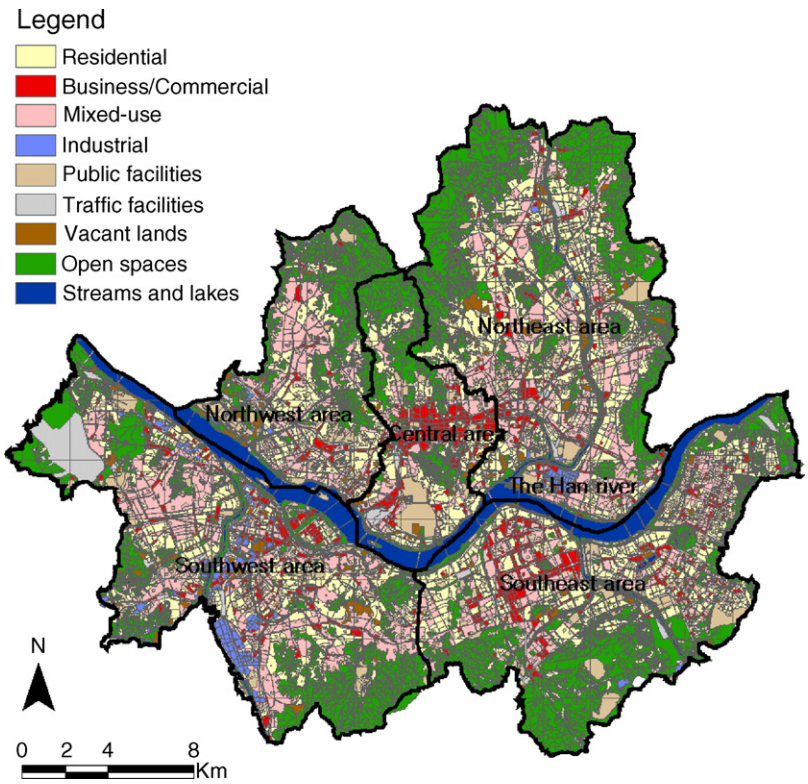

Fig. 3. The study area.

In this research, centers are defined as the central locations of urban facilities to use or resources to distribute, which are viewed as urban parks. Links are pedestrian routes that connect citizens to the parks. Nodes are intersections of links. Impedance refers to barriers that prevent movement between links, and different impedance values were assigned according to route types such as pedestrian roads, crosswalks, underpasses, and overpasses. Thus time-lags required for walking and crossing roads, underpasses, and overpasses were considered impedance. Normal walking speed is considered to be between 0.75 and 1.2 m/s in transportation engineering. In this study, the walking speed of 1 m/s was applied. Waiting time at a crosswalk was presumed

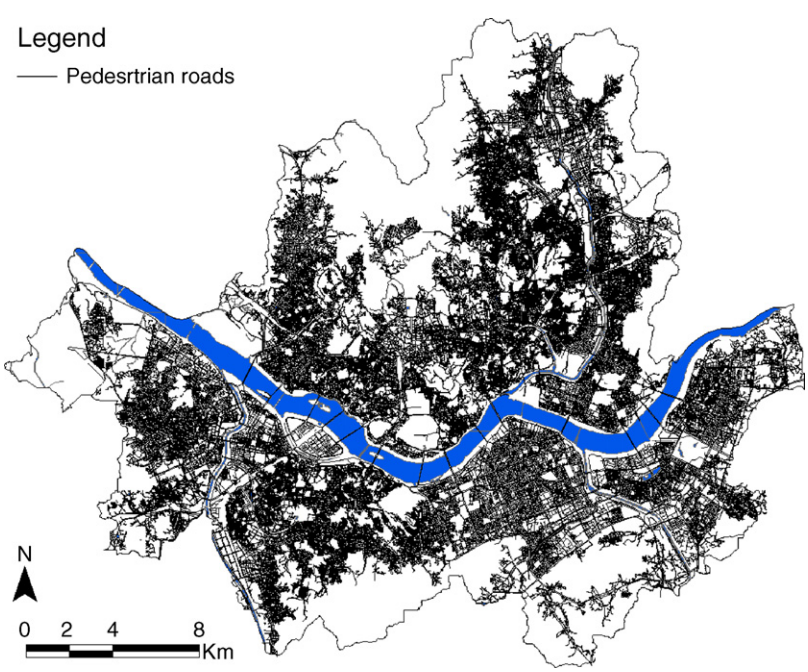

Fig. 4. Pedestrian roads in Seoul.

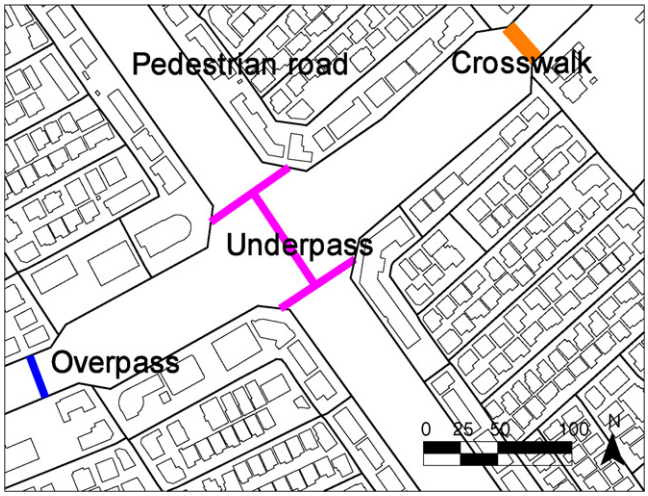

Fig. 5. An example of network data.

to be 2 min on average, while an extra 40 s were added at overpasses and underpasses. Network extent was delineated when the sum of all impedance values reached the specified maximum value. The network extent is line-shaped, so service areas of parks were determined by 20 m[1] buffers of pedestrian routes within the network extent. Consequently, it was determined that network analysis can be used to provide the boundaries of service areas of parks where citizens can access them within a given distance or certain amount of time through actual routes.

3.2. Data preparation

The study area of Seoul is the largest and the most densely developed city in Korea (Fig. 3). The total area of Seoul is approximately 606 km^2 and the city recorded 10,280,000 residents in 2002. There are 5 sub-regions and 25 local districts in the city.

The network data of pedestrian routes (Fig. 4) was prepared from digital and paper maps scaled 1:1000. Fig. 5 is an example of network data for pedestrian roads, crosswalks, overpasses, and underpasses.

Users of urban parks can differ according to their settings. For example, while residents are the target group for parks that are created in local residential areas, workers and visitors are regarded as the main patrons of parks in business/commercial areas. In order to calculate those who actually benefit from parks, the number of residents was assigned to nodes in residential areas. Floor area of buildings was inputted as a substituted indicator to the number of park users in business/commercial areas because the number of workers and visitors can very much vary. Fig. 6 shows the data preparation process from constructing network data to attaching attribute data that includes population numbers and floor areas of buildings.

[1] The average distance from roadsides to the end of residential parcels in Seoul is approximately 20 m.

3.3. Establishment of urban park service indices

3.3.1. Maximum distance

In planning neighborhood parks, various standards for the areas necessary per capita and maximum distance are used (Lucy, 1981). Perry (1966) presented the concept of Neighborhood Unit in which facilities such as parks and playgrounds were within a 400 m radius surrounding a primary school as the center. The NRPA recommended that the maximum distance for park accessibility be 0.5 mile or 800 m (Gold, 1973). In this study, the maximum distance from neighborhood parks was set at 1000 m based on the Korea Urban Park Law. Such distance was then converted into time.

3.3.2. Analysis standards and estimation indices

The concept of urban park service indices in this study refers to the efficiency of parks based on their location and includes service area ratio, service population ratio, and service floor area ratio. Urban park service indices were formulated with a population number and floor area within the service area of parks.

Service area ratio is the percentage of service area within the area of analysis excluding park areas:

$$\text{service area ratio } (\%) = \frac{\text{service area by parks}}{\text{total area} - \text{park area}} \times 100 \quad (1)$$

Service population ratio indicates the percentage of service population by parks among the total population within the area of analysis:

$$\text{service population ratio } (\%) = \frac{\text{service population by parks}}{\text{total population}} \times 100 \quad (2)$$

Service floor area ratio on the other hand, assumes that the population in business/commercial areas is proportional to the floor area of business/commercial areas. Service floor area ratio is thus the percentage of floor area within service area by parks among the total floor area of business/commerce:

$$\text{service floor area ratio } (\%) = \frac{\text{service floor area by parks}}{\text{floor area of business/commerce}} \times 100. \quad (3)$$

4. Case study

4.1. Service area analysis

4.1.1. Comparison between simple buffering and network analyses of the service area of urban parks

Service areas within a linear distance of 1000 m from parks were measured by the simple buffering method (Fig. 7). The service area including parks was 493 km^2 which was about 81% of the entire area of Seoul (606 km^2). The number and locations of urban parks in Seoul are deemed to be fairly sufficient.

Fig. 6. Data preparation process.

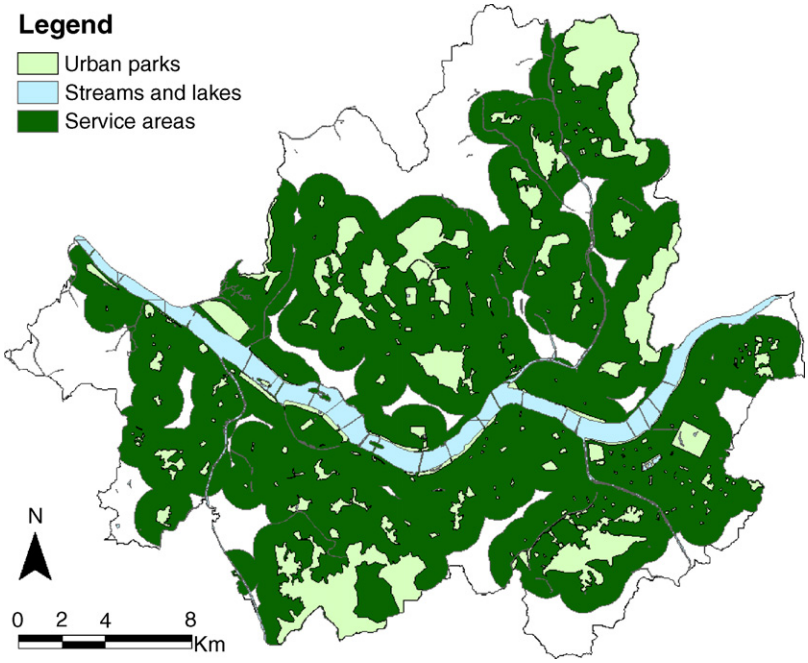

Fig. 7. Service areas by simple buffering.

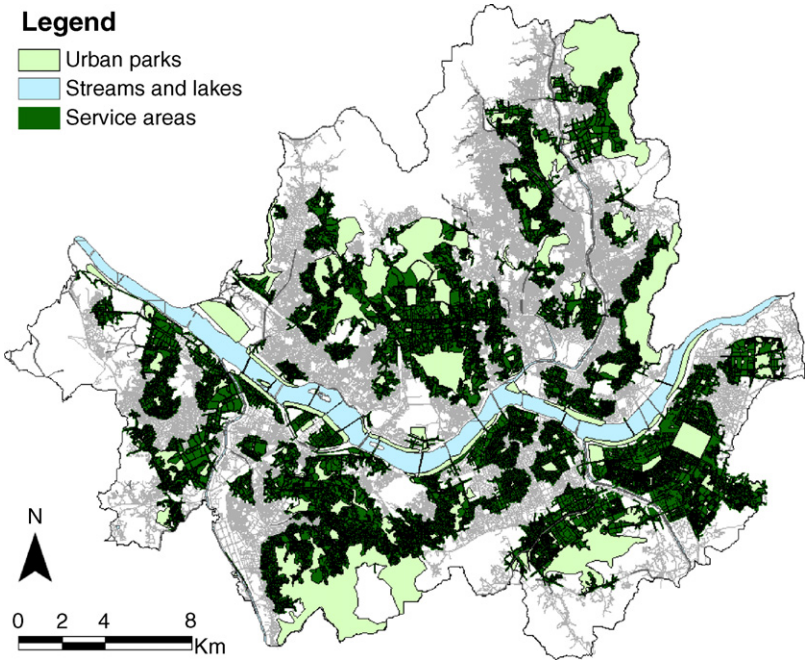

Fig. 8. Service areas by network analysis.

However, in the case of pedestrian accessibility, roads are hardly direct in actuality and consequently more time is spent accessing the parks than if linear routes existed and could utilized.

Service areas of urban parks including neighborhood parks, natural parks, and other parks were analyzed by employing the network analysis method (Fig. 8). The service areas were found to be 249 km^2 including park areas. This was about 41% of the area of Seoul and approximately half of the service area was determined by the buffering method with a 1000 m threshold.

These results can be viewed as a difference in thresholds, but the major questions that arise regarding the calculated service areas determined through simple buffering and network analysis are whether or not to include the inaccessible areas. In network analysis, the access routes are determined by pedestrian road networks but the simple buffering method includes areas that are inaccessible in reality.

4.1.2. Comparison in terms of urban park service indices

The central area of Seoul is the CBD in which administrative buildings such as central governmental agencies, City Hall, and head offices of companies are located. Given the congested environment, former royal palaces and many historical spots have been used as parks. The southeast area of Seoul is a strategically developed area that has been governed by development policies of the 1970s, so the living environment in that area has been comparatively better than other areas in Seoul.

In this study, comparisons are rendered between standardized values of the park area ratio and park area per capita, which have been used as the main indices in current regulations and planning practices for urban parks. The results (Fig. 9) reveal that the service area ratio and the service population ratio have a similar tendency yet are different from the park area ratio and park area per capita. Such results can be viewed as a difference between conventional indices that use only the amount of park area and service indices that consider the benefits to the surrounding population according to the spatial location of parks. Therefore, the service area ratio and the service population ratio which reflect area and population serviced through footpaths based on the location of the parks is deemed to more effectively explain park distribution.

In the northwest and southeast areas of Seoul, the park area ratio and park area per capita are similar. However, in terms of the service area ratio and service population ratio, the two areas showed a vast disparity; the southeast was found to have a 21% higher service area ratio and a 42% higher service population ratio than the northwest (Table 2). Although the park area ratio

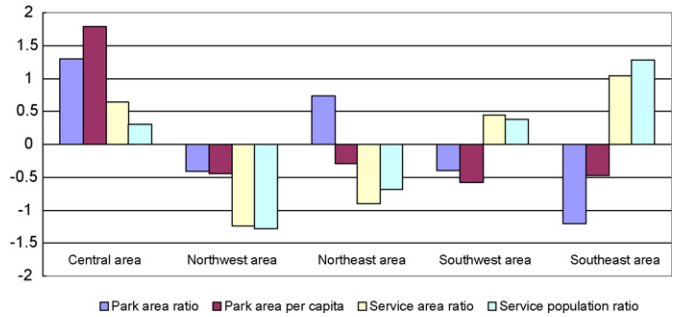

Fig. 9. Comparison of standardized values of urban park service indices.

and park area per capita of the southeast area is lower than the other sub-regions, the service area ratio and service population ratio appears to be the highest. In the case of the southeast area, the entire area of all parks there was found to be small yet consisted of 95 parks which is the largest number among all the areas, and consequently that area's park service level appears high. This means that the effect of a park's location and distribution is as important as the size of the park. It was determined therefore, that properly arranging small scaled parks equally within residential districts can promote higher numbers of resident patronage by making accessibility to nearby parks more favorable.

4.2. Land use and the distribution of urban parks

4.2.1. Urban parks in residential and business/commercial areas

Urban parks have different purposes according to their users and land uses. Urban parks located in residential areas offer places for rest and leisure to mainly neighborhood inhabitants, whereas urban parks located in business/commercial areas are more appealing to workers and visitors who frequent the downtown area. Therefore, in this study service area ratio, service population ratio, and service floor area ratio were calculated according to the two types of land use—i.e. residential and business/commercial.

4.2.2. Land uses and urban park locations classification

After dividing Seoul into five sub-regions, the service area ratio of residential areas in the sub-regions was analyzed in the following order; southeast (68.52%), southwest (57.24%), central (57.16%), northeast (37.82%), and northwest (33.65%). The service population ratio of the residential areas appeared as follows: southeast (75.90%), southwest (60.92%), central

Table 2
Comparison of urban park service indices

Regions in Seoul	Area	Population	The number of urban parks	Park area (km^2)	Park area ratio (%)	Park area per capita (m^2)	Service area ratio (%)	Service population ratio (%)
Central area	55.74	571,045	29	9.94	17.84	17.41	37.17	59.78
Northeast area	171.04	3,385,643	46	27.63	16.16	8.16	23.33	43.16
Northwest area	71.19	1,218,651	11	9.11	12.79	7.47	20.31	33.48
Southeast area	145.16	2,067,288	95	15.14	10.43	7.32	40.71	75.90
Southwest area	162.39	3,037,896	55	20.87	12.85	6.87	35.30	60.92

Table 3
Service floor area ratio of business/commercial areas

Regions in Seoul	Floor area of business/commercial area (m^2)	Service floor area of business/commercial area (m^2)	Service floor area ratio of business/commercial area (%)
Central area	21551192.32	18185177.77	84.38
Northeast area	15969211.78	3609193.32	22.60
Northwest area	6591757.73	2326790.65	35.30
Southeast area	39901811.94	25881367.85	64.86
Southwest area	23274916.45	14090998.29	60.54

(59.78%), northeast (43.16%), and northwest (33.48%). In terms of business/commercial area, the service floor area ratio of the central area showed the highest rate (Table 3). The service floor area ratio was determined to be in the following order: central (84.38%), southeast (64.86%), southwest (60.54%), northwest (35.30%), and northeast (22.60%).

To determine the distribution of urban parks according to land use by region, standardized values of the service population ratios of residential areas and service floor area ratios of business/commercial areas were calculated and then classified into four groups. A high service population ratio means that inhabitants of residential areas could benefit more, and a high service floor area ratio means greater accessibility of the population in business/commercial areas to urban parks.

In this study, the five sub-regions of Seoul were divided into four quadrants with the first and third demonstrating conspicuous general tendencies (Fig. 10). The first quadrant consists of the central, southeast, and southwest area while the third is made up of the northwest and northeast areas in general. In the southeast area, parks were found to be equally well provided for both the business/commercial and residential areas. In the northwest and northeast areas, however, urban parks were found to be lacking both in residential areas and in business/commercial areas.

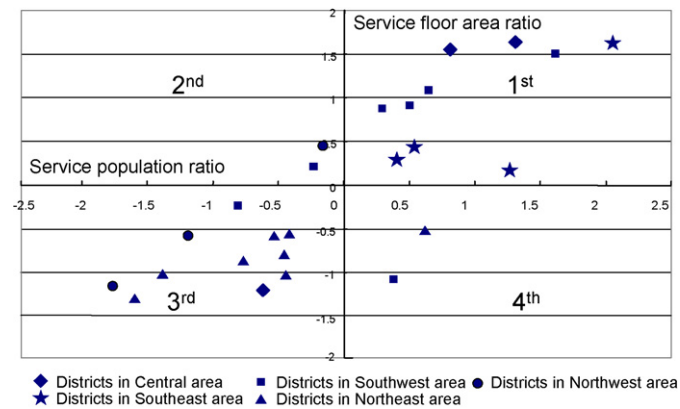

Fig. 10. Land use and urban park distribution.

In the central area, which has the highest business/commercial area ratio in the first quadrant, it was found that urban parks were well distributed in the business/commercial areas.

The analyses of urban park distribution in Seoul revealed that definite differences appeared between the southern and northern areas. In particular, the southeast area was found to be providing the most superior urban park services. In early 1970s, Seoul

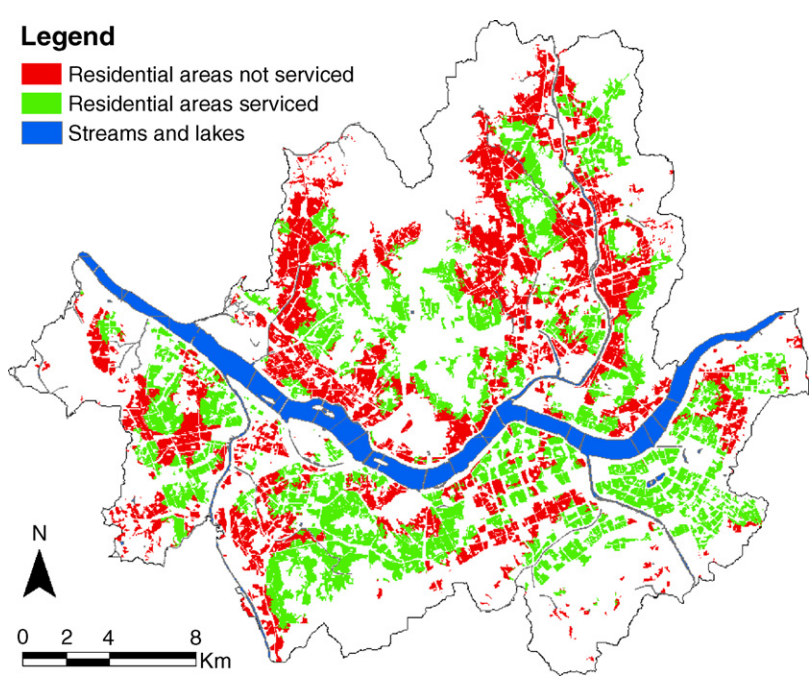

Fig. 11. Service areas of neighborhood parks in residential areas.

enforced a decentralization policy of the downtown population. Subsequently, many educational facilities and companies moved from the northern area to the southern area of the Han River in the 1970–1980s. In the southern area of the Han River, small but numerous neighborhood parks were newly created through land and housing development projects.

4.3. Insufficient areas of neighborhood park service

Neighborhood parks play a significant role for their use as resting places. They also promote community welfare among neighborhood residents. Needless to say, it is desirable that such neighborhood parks be easily and conveniently accessed. Bearing this in mind, the accessibility of neighborhood parks from residential areas was analyzed to evaluate the distribution of neighborhood parks.

In order to identify the service area of neighborhood parks in residential areas, large scaled parks such as urban natural parks, and mountain areas and their service areas were excluded in the analysis. Fig. 11 shows residential areas where the service of neighborhood parks is not provided. In northern and southern riverside areas, major highways prohibit the access of residents from the Han River. Therefore, accessibility from some residential areas to riverside parks is low. From this analysis, it was found that approximately half of the inhabitants do not directly benefit from patronage to their neighborhood park. Thus in those areas, the creation of new neighborhood parks should be made a priority.

5. Conclusion

This study assessed the level of serviceability of urban parks using the equity concept, and the assessment method focused on park distribution. The main issues involved the number of patrons to urban parks, and the amount of area that is serviced in them. The distribution of urban parks was assessed in terms of the population density of residential areas, land use, and development density through GIS network analyses. The following results were obtained: First, network analysis covered about half of the service area of parks determined by the simple buffering method. This is due to the fact that actual pedestrian traveled routes are indirect and thus cover much less area.

Second, the urban park service indices, i.e. service area ratio, service population ratio, and service floor area ratio, were found to be particularly useful in determining the distribution of urban parks and the volume of patronage due to accessibility, unlike statistical indices which have been conventionally used.

Third, the relationship between land uses and the distribution of urban parks were examined, and the results revealed that the southern area of the Han River has favorable urban park distribution in both residential and business/commercial areas. In regard to the distribution of urban parks and their service areas, this study determined the existence of regional inequality. This is presumed to be the result of urban development policies of Seoul in the 1970–1980s.

Finally, insufficient areas of parks were spatially identified. Subsequently, the distribution of neighborhood parks was analyzed and classified by residential areas where neighborhood park service is not provided. Policies for providing neighborhood parks should be developed for these areas.

In this study, urban park service indices were applied to appraise the distribution of urban parks, while not using statistical indices. By synthesizing census data, land uses, and development density based upon actual locations, the assessment method utilized in this study can be useful in helping to understand spatial distribution of urban parks more accurately and to establish effective policies on urban park management.

Acknowledgement

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