Local Environment

The International Journal of Justice and Sustainability

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cloe20

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To cite this article: Fatma Şenol & İlgi Atay Kaya (2021) GIS-based mappings of park accessibility at multiple spatial scales: a research framework with the case of Izmir (Turkey), Local Environment, 26:11, 1379-1397, DOI: 10.1080/13549839.2021.1983793

To link to this article: https://doi.org/10.1080/13549839.2021.1983793

Published online: 07 Oct 2021.

LOCAL ENVIRONMENT
2021, VOL. 26, NO. 11, 1379–1397
https://doi.org/10.1080/13549839.2021.1983793

GIS-based mappings of park accessibility at multiple spatial scales: a research framework with the case of Izmir (Turkey)

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ABSTRACT

With a concern of social needs in the redistribution of benefits of parks, recent research assesses park accessibility but usually at one spatial scale (e.g. city, neighbourhood, or park). As a case in Izmir (Turkey), this study explores how to develop research with a multi-scalar focus on park accessibility. It proposes a framework with the research stages deploying GIS-based tools. The first stage identifies "park-rich", "park-moderate" and "park-poor" neighbourhoods. The second and third stages evolve in three park-rich neighbourhoods and at 112 local parks. All stages deal with preparing various socio-spatial data from online sources and field observations and assess the data according to a list of themes about "accessibility" and "diversity". The results highlight that regardless of their high park coverages per person, park-rich neighbourhoods have multiple blocks, buildings, and parks with the features hindering park accessibility for some local groups with different walking capacities and needs. The GIS-based mappings of these features can provide decision-making tools about local parks and neighbourhood interventions.

ARTICLE HISTORY
Received 22 February 2021
Accepted 6 September 2021

KEYWORDS
Park accessibility; geographic information systems; neighbourhood parks; social needs; spatial equity; spatial scales

Introduction

About public health, green infrastructures, biodiversity, or socio-spatial equities, many researchers examine multiple characteristics of public green areas. Due to their location within walking distances to local dwellings, neighbourhood parks are significant for the daily uses of various groups. With Geographic Information Systems (GISs), the recent research underlines the inequities among social groups with park access and use, or "park accessibility" as this paper calls from now on. Overall, the traditional views identify public greens as public service areas allocated across city districts according to the measures per dweller in those districts. Recent research about park accessibility considers new concepts, socio-spatial attributes, and ways for measuring and assessing park accessibility. Accordingly, public parks are part of environmental amenities (e.g. Boone et al. 2009) necessary for the well-being of everybody but particularly of disadvantaged groups. To guide their spatial analysis with the concern of social needs, this group of research has the view of "need-based equity" that prioritises park accessibility for children, the elderly, low-income, and other groups disadvantaged by traditional allocation of public goods and services (see Lucy 1981; Talen and Anselin 1998).

However, most of the research examines the socio-spatial features of park accessibility at a single socio-spatial scale, such as the city, neighbourhood, or park scale. A few (see Kimpton 2017) consider

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the multi-scalar nature of park accessibility. Reducing the relevant assessments to one spatial scale ignores the nature of park accessibility as part of totalised socio-spatial experiences and inequities. For integrated public policies about public greens and public health and well-being, the research about park accessibility needs to develop at multiple spatial scales with multiple socio-spatial variables.

Concerning this research gap, our study investigates how to examine and assess the socio-spatial determinants of park accessibility at multiple socio-spatial scales of parks. With its case study[1] in Izmir (Turkey), this investigation aims to present a research framework for data gathering and analysis with GIS-based and other research tools at the city, neighbourhood, and park scales.

For its research framework, the study relies on GIS-based research about park accessibility concerning social needs. Overall, this group of research focuses on how various population and park characteristics interrelate at the city, district, neighbourhood, or park scales. In high numbers, the studies at the city or district scales relate the location and size of parks to the spatial distribution of population characteristics. Their produced city maps concerning need-based equity are called "spatial equity mapping" by Talen and Anselin (1998). A few studies examine socio-spatial physical characteristics at the neighbourhood level (e.g. Kaczynski, Potwarka, and Saelens 2008; Sister, Wolch, and Wilson 2010). The studies at the park scale investigate multiple physical characteristics of parks, including kind of facilities, landscape elements, surface characteristics, or amenities (e.g. Weiss et al. 2011; Zhou and Kim 2013).

This paper is one of the few that integrates the literature findings across different spatial scales and produces a research framework with consecutive stages at the city, neighbourhood, and park scales. Besides the scholarly research, policymakers and community organisations can deploy versions of this framework for data collection, simultaneous monitoring of the socio-spatial inequities, and management of environmental risks and public resources (e.g. Louis and Magpili 2002). Furthermore, this study in Turkey is an example for how to work through limited socio-spatial data for GIS-based mappings. Deployed by the research in data-rich countries, the data about income level, ethnic origin, religious affiliation, or car ownership are not available at any spatial scale in Turkey. Also, the "neighbourhood" is the smallest data unit but with various geographical shapes and sizes bigger than any comparable geocoded units (e.g. census tracts) in the US, UK, or New Zealand. With research details about the production of data at multiple spatial scales, this study can guide similar efforts in the countries with limited data.

After the literature review, the section about study site and methodology details the data preparation and analysis tools for the research at the city, neighbourhood, and park scales. The results with the output maps present the details about how to process various kinds of data at three spatial scales with GIS tools. The discussion and conclusion parts underline the potential contribution of study results for the literature, policymakers and local communities, and community organisers.

GIS-based research about park accessibility

With concern about socio-spatial equities through public parks, various scholarly studies deploy GIS tools and analyse current conditions for park accessibility at different spatial scales. The paper reviews those studies investigating park accessibility concerning social differences and needs, or the view of "need-based equity". The research within this view urges to prioritise park accessibility for children, the elderly, low-income, and other groups disadvantaged by the traditional allocation of public goods and services. Thus, they challenge the "equality-based" allocation (see Lucy 1981) that determines the park accessibility only with the number of dwellers within 400–800 or 1600 m to parks (or service catchment areas).

GIS-based research supporting the need-based equity varies with its selection of types of public greens, spatial scales of study sites, kind of data, methods for data gathering, analysis tools, and the kinds of produced maps. Research on public green areas includes parks (e.g. Wen et al. 2013; Wolch, Wilson, and Fehrenbach 2005), neighbourhood parks (e.g. Zhang, Lu, and Holt 2011), urban green spaces (including parks, public gardens, green corridors, and cemeteries) (e.g. Barbosa et al. 2007; Comber, Brunsdon, and Green 2008; Dai 2011; Heckert 2013), recreational amenities (e.g. Hewko, Smoyer-Tomic, and John Hodgson 2002), and natural green spaces excluding unnatural sites (such as children's playgrounds, school fields and yards) (e.g. Higgs, Fry, and Langford 2012).

To examine its selected public green areas, the literature develops at different spatial scales for study sites and the data deployed. The following section considers those at the city, neighbourhood, and park scales.

Spatial scales

At the city scale, most GIS-based studies analyse the spatial distribution of parks across city districts (e.g. Boone et al. 2009; Hewko, Smoyer-Tomic, and John Hodgson 2002; Higgs, Fry, and Langford 2012; Javed et al. 2013; Martori, Apparicio, and Séguin 2020; Nicholls and Scott Shafer 2001; Wen et al. 2013). They take the location and size of parks as its primary data (e.g. Cetin 2015; Kaczynski, Potwarka, and Saelens 2008; Koohsari et al. 2013; Lara-Valencia and García-Pérez 2015; Thawaba 2014). Others interrelate the spatial distributions of parks to various population characteristics (e.g. income, race/ethnicity, and age) for spatial equity maps of parks (Talen 1998) in different cities (e.g. Barbosa et al. 2007; Dai 2011; Heckert 2013; Ibes 2015; Lara-Valencia and García-Pérez 2015; Mavoa et al. 2014; Nicholls 2001; Wolch, Wilson, and Fehrenbach 2005). At their analysis, these studies measure spatial proximities to parks (e.g. with travel cost and minimum distance), number and size of park areas in an area (i.e. container approach), or population-weighted distances to parks (i.e. gravity model) and use hot spot analysis, network analyst, and buffer analysis (e.g. Javed et al. 2013; Lindsey, Maraj, and Kuan 2001; Wolch, Wilson, and Fehrenbach 2005). With the two-step floating catchment area method based on gravity-based models, new studies consider multiple transportation modes for park accessibility (e.g. Xing et al. 2018).

Research at the neighbourhood scale expects that the diversity and density of some land uses and population characteristics at the neighbourhood level encourage park accessibility. For instance, the availability of retail-commercial and recreational land uses and transportation facilities around park areas attract distant and older visitors to those parks (Liu, Chen, and Dong 2017). In contrast, various neighbourhood problems (including crime, traffic problems, and noxious land uses) around parks discourage park accessibility (Weiss et al. 2011). The research considers the neighbourhood level of parks with a buffer or service catchment areas determined with 5 min to 20 min walking distances to parks. Some studies produce maps of "park pressure levels" concerning population densities and other configurations of park service areas (e.g. Sister, Wolch, and Wilson 2010), street networks (e.g. Koohsari et al. 2013), and neighbourhood facilities (such as sports fields and courts and recreation services) (e.g. Weiss et al. 2011; Liu, Chen, and Dong 2017) within certain distances to parks.

At the park scale, the research considers various physical characteristics of parks, including park facilities (e.g. Thawaba 2014), conditions of landscape features and safety, and playgrounds in terms of age, state of repair, and safety (e.g. Smoyer-tomic, Hewko, and John Hodgson 2004). Kaczynski, Potwarka, and Saelens (2008) examine the availability of the settings for physical activities (including trails, paths, open spaces, playgrounds, courts, and pools) and the amenities supporting physical activities (like a drinking fountain, picnic area, and parking lot). Paquet et al. (2013) emphasise that of the parks within 1000-meter-distance to dwellings, not the number but the qualities (e.g. size, greenness, and type) influence their users' cardio-metabolic health. For their assessment of the attractiveness of accessible green spaces, some researchers develop parameters with a ranking scale of "bad," "neutral," and "good" (e.g. Herzele and Wiedemann 2003). Others deploy data from volunteered geographic information platforms and map the use density at park trails (e.g. Norman and Pickering 2017).

Data and its sources

Whereas the selection of spatial scales informs the kind of study data, the literature uses various data sources. A group of studies at the city and the neighbourhood scales uses publicly accessible official data, such as census data and open space categories (e.g. Higgs, Fry, and Langford 2012; Lara-Valencia and García-Pérez 2015; Martori, Apparicio, and Séguin 2020; Mavoa et al. 2014). Ibes (2015) deploys census data, multiple online sources, and satellite images of parks in Phoenix (United States). A study about six cities in Illinois (Zhou and Kim 2013) has the data of tree canopy area derived from the colour infrared imagery classified by remote sensing methods. Another study develops a real-time navigation route approach for collecting multi-source big data about green space, socioeconomic status, and housing prices (Chen, Yue, and La Rosa 2020). Norman and Pickering (2017) convert data from three volunteered geographic information platforms into route data in the GIS. Some studies gather data on-site by deploying the user surveys and interviews (Thawaba 2014; Koohsari et al. 2013) or observation-sheets about parks' socio-spatial characteristics, such as park entrances (Koohsari et al. 2013; Nicholls and Scott Shafer 2001) and park "attractiveness" with the themes like "space", "nature", "culture and history", "quietness" and "facilities" (Herzele and Wiedemann 2003).

Study approach

Of the GIS-based research about park accessibility with the concern of social needs, the majority examines the socio-spatial features of park accessibility at a single socio-spatial scale. Research at one spatial scale has the risk of ignoring the nature of park accessibility as part of totalised socio-spatial experiences and inequities. This paper aims to contribute to the research with a multi-scalar focus on park accessibility. It takes neighbourhood parks as the public green spaces significant with their supposedly quick and easier access to local dwellers. Traditionally, urban planning and GIS-based analysis of urban space measure dwellers' access to neighbourhood parks with walking distances in 5–10 or 20 min (Boone et al. 2009; Cetin 2015; Heckert 2013). These distances correspond to park service area, or a buffer area with a radius of 400 m to 800 m from park centres (Nicholls 2001; Wolch, Wilson, and Fehrenbach 2005; Boone et al. 2009).

A few studies at the neighbourhood and park scales develop data about safety, aesthetics, walkability, and incivilities (e.g. Kaczynski, Potwarka, and Saelens 2008; Richardson et al. 2020). Next to Zhang, Lu, and Holt (2011) with the measurements of park accessibility at the national and local level, Oh and Jeong (2007) use land use maps at the city scale with the network analysis of pedestrian roads, crosswalks, overpasses, and underpasses around park areas. Kimpton (2017) deploys data about types of green spaces (e.g. amenity-rich and – poor) and social characteristics of neighbourhoods (e.g. child and population density, residential stability, and concentrated immigration). In the context of Turkey with limited data, our investigation about (neighbourhood) park accessibility aims to add to this small body of research across multiple spatial scales.

Study site and methodology

This paper uses our case study in Izmir and in its three central neighbourhood areas (Figure 1). With a population of 4.5 million, Izmir is the third biggest city of Turkey. It is appropriate for this study because its metropolitan area has wide green spaces but fewer shares in the central districts with higher population sizes.

The study has three research stages corresponding to three spatial scales (Figure 2). At the city scale, the first stage produces Izmir's "spatial equity mapping" of parks (Talen 1998; Talen and Anselin 1998). This mapping needs detailed data about the characteristics of the population (e.g. income level, race/ethnicity, and car ownership) and parks (including kind, location, and size).

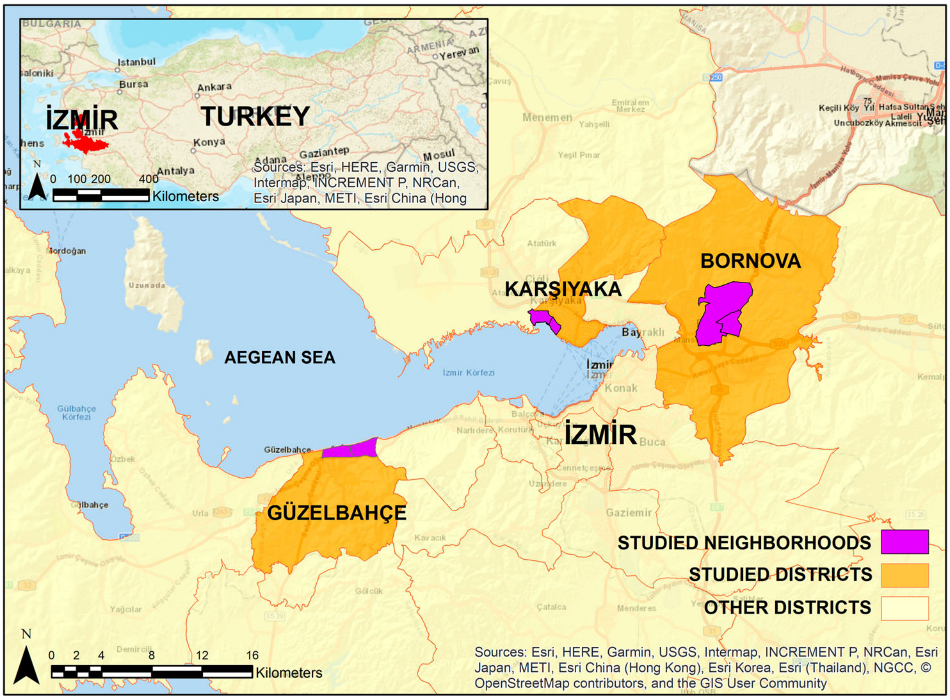

Figure 1. Izmir and selected six neighbourhoods in three districts (prepared by authors on Esri basemaps).

In Turkey, however, the data with such detailed features and geographic references are limited. Availability of data about public parks depends on local municipalities' efforts and intends for recording and sharing this data publicly. We gathered data about public greens from all 30 local municipalities and the Metropolitan Municipality of Izmir. To join this data from textual into vector format (point and polygon) (Figure 2), we related the address information of public green areas to ESRI base-maps, the City Map of the Metropolitan Municipality, and Google Earth and the satellite views[2] dated 2016–2017. The resulted data set with vector data includes neighbourhood parks, city parks, sports areas, front and backyards of public buildings, public squares, cemeteries, forestation

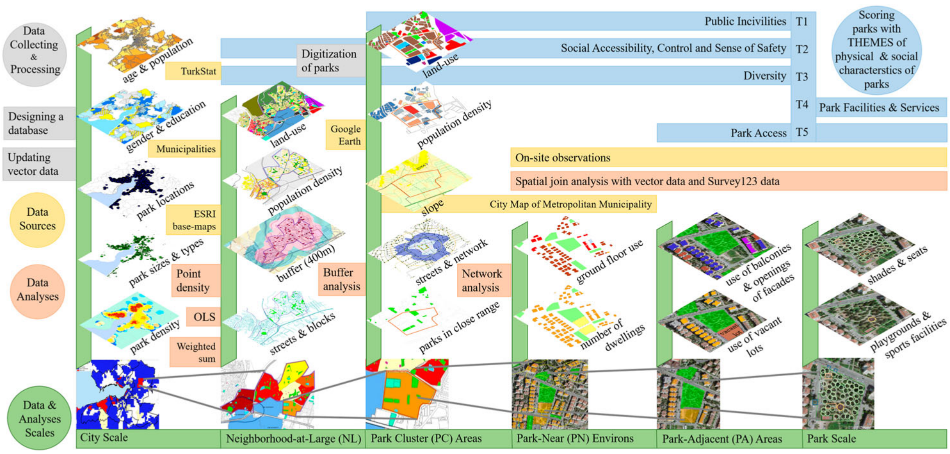

Figure 2. Types and sources of data at relevant spatial scales.

zones, pedestrian areas, and traffic islands. This study focuses on "neighbourhood parks" because ideally, they are public greens within walking distances to and designed with facilities for children, the elderly, and those with daily life bounded to home environments. At the larger data set of green areas, we selected the entries whose name includes "park". Our selection considered a size threshold. Different from other studies (for a review, Le Texier, Schiel, and Caruso 2018), it took the parks smaller than 30.000 m^2, rather than bigger parks attracting users by car from other districts.

Official census data are provided annually by the Turkish Statistical Institute. However, it does not cover the information about income level, racial/ethnic origin, religious affiliation, and other characteristics often used by the GIS-based mappings of park accessibility in the United States (e.g. Zhang, Lu, and Holt 2011; Zhou and Kim 2013), Western Europe (e.g. Comber, Brunsdon, and Green 2008; Martori, Apparicio, and Séguin 2020), and Australia (e.g. Kimpton 2017; Koohsari et al. 2013). Moreover, the geographical unit to list the census data in Turkey, the neighbourhoods have irregular shapes and sizes larger than the comparable geocoded units in the US, UK, or New Zealand. We reorganised the official census data available only for age, gender, education level, and household size, in multiple forms and sometimes with inconsistent contents. This reorganisation aims to reflect data about multiple age groups and groups with different education levels.

To develop a spatial equity mapping of Izmir, the study run a regression and overlay analysis with both final data about parks and population, detailed in the Result section.

The second stage develops at the neighbourhood scale and in three neighbourhoods (with differences in education level) selected at the spatial equity mapping of Izmir. For gathering socio-spatial data in these sites, the study identifies four different neighbourhood environments of each park (see Figure 2). The Neighbourhood-at-Large (NL) is the largest neighbourhood area of parks. To have a comprehensive dataset even about neighbourhood parts without park access, the NL is determined with a buffer of 400 m radius from each park point, rather than the network analysis that defines the areas with park access. To consider differences in walking capacities among social groups due to their physical and social characteristics (Kent and Thompson 2014), we identified three other park environments in each NL. With different distances from each park, these park environments have multiple socio-spatial features affecting walk experiences, including alternative parks nearby, physical thresholds, safety concerns, landscape and climate, and "attractiveness", and "comfort" of parks (see Table 1) (Herzele and Wiedemann 2003).

The Park-Clusters (PCs) are the areas with parks in close range to each other and divided by physical thresholds (e.g. major roads and hills) from other PCs. We determined the boundaries of PCs through our site experiences by walking, as an alternative to network analysis (Higgs, Fry, and Langford 2012; Oh and Jeong 2007) and cluster analysis in GIS (Talen and Anselin 1998; Thawaba 2014). Two other neighbourhood scales are the Park-Near (PN) and the Park-Adjacent (PA) that include respectively building blocks and buildings/lots adjacent to each park (Figure 2).

For NLs and PCs, the data about streets, land uses and building blocks is gathered (if available) in vector format from the district municipalities and updated with the help of Google Earth and ESRI base maps. From the City Map of the Metropolitan Municipality (an open-access platform with textual data at the building scale), we gathered data about the dwelling numbers and land uses of the ground, first and second floors to calculate the approximate population size and density at building blocks. Moreover, with multiple trips to the study sites, we recorded data about the socio-spatial attributes of the buildings/ lots in PN and PA (Table 1). For fieldwork, we trained 12 undergraduate and graduate students in urban planning. Data collection by trained evaluators is a valid method (e.g. Mckenzie et al. 2013; Richardson et al. 2020). When recording the field data, these student-evaluators used the Survey123 on their mobile phones. Like its alternatives, this application by ESRI uses geographic coordinates and transfers the field data to the attributes in the GIS database.

At the park scale, the third stage developed with on-site observations about socio-spatial features in total 112 parks. Student evaluators visited each park and surroundings for 30 min and four times separately for one week. On site, they filled a checklist about the characteristics of park-close vicinity

Table 1. The checklist for data gathering at the neighbourhood and park scales.

Category	Variable	Protocol
PARK ATTRIBUTES		
Park - close vicinity relationship	Park entry	Code 'yes' if there are more than four park entries
	Sidewalk access	Code 'yes' if park entrances are linked to sidewalks
	Fence/ wall	Code 'yes' if there is no fence or wall surrounding the park
	Traffic	Code 'yes' if there is no heavy vehicle traffic around the park
	Visual access	Code 'yes' if it is possible to see the buildings/ street from inside the park
Park services and facilities	Bench	Code 'yes' if park has benches
	Picnic table	Code 'yes' if park has picnic tables
	Shading	Code 'yes' if park has any shades
	Shading elements	Code 'yes' if park has (natural or artificial) elements designed for shading
	Rain-proof area	Code 'yes' if park has any rain proof area
	Water elements	Code 'yes' if park has water elements
	Lighting	Code 'yes' if park has lighting
	Playgrounds	Code 'yes' if park has playgrounds
	Sport equipment	Code 'yes' if park has outdoor sport equipment
	Sport field	Code 'yes' if park has any sport fields
	Walkway	Code 'yes' if park has walkways
	Bicycle way	Code 'yes' if park has a bicycle path
	Eatery/ kiosk	Code 'yes' if park has eateries or kiosk
	WC	Code 'yes' if park has WC
	Parking lot	Code 'yes' if there is a car parking lot adjacent
	Bicycle rack	Code 'yes' if there is a bicycle rack in or next to park
Park vegetation	Shade by vegetation	Code 'yes' if vegetations in the park make shade
	"Stepable" green	Code 'yes' if the green surface is with stepables
	View blocking vegetation	Code 'yes' if park vegetations do not block the view
	Green coverage	Code 'yes' if more than half of the park surface is soft
Park maintenance	Well-kept facilities	Code 'yes' if park's benches or sport facilities are well-kept
	Garbage	Code 'yes' if park has no garbage around
	Graffiti	Code 'yes' if park has no graffiti on walls or floors
	"Feeling safe"	Specify the reason (physical or social attributes)
	"Feeling not safe"	Specify the reason
	Security camera	Code 'yes' if park has security cameras
	Security guard	Code 'yes' if park has security guards
ATTRIBUTES OF LOTS/BUILDINGS ADJACENT TO PARKS (FOR PN and PA)		
Adjacent lot	Vacant/occupied	Code "no" if the lot is vacant
	Lot boundary	Code "yes" if any physical elements (wall, fences, natural) surround the lot
	Building number	Number of total independent units in the lot
Vacant lot	Use of vacant lot	(Choose: green but unmaintained, with litter/garbage, car parking, play area, maintained green, others—specify)
Buildings	Number of stories	Specify
	Yard	Code "yes" if the building has a yard
	Use of the yard	Specify (with trees and sitting areas, without sitting area, car parking, unmaintained, others—specify)
Ground level (Repeat the questions for the 1st and 2nd floor)	Number of units	Specify
	Land use	Specify
	Openings	Code "yes" if the façade has any openings (door, balcony, window)
	Size of openings	Specify
	Conditions of balconies	Code "yes" if the balconies are well-maintained and/or used
	Conditions of facades	Code "yes" if the facades are maintained (or not discomforting)
PARK CLUSTER (PC) ATTRIBUTES		
Park cluster	Number of parks	Number of parks in each park cluster (PC)
	Park coverage	Total park coverage (m2) in each PC
	Population size	Total population size (number of residents) in each PC
	Residential density	Gross density in each PC
	Non-residential uses	Code 'yes' (i.e., '1') if specified PC has major land uses for commercial, educational, or public administration purposes

relationships, park services, facilities, vegetation and maintenance, and sense of safety in each park (see Table 1 and Figure 3).

To interrelate the data at the neighbourhood and park scales for each park, we proposed a list of themes (Table 2) concerning "accessibility" and "diversity" (Herzele and Wiedemann 2003; Vaughan et al. 2013). Each theme has different attributes of data across spatial scales. Table 2 can include *others*, or additional socio-spatial attributes if researchers have data. Similarly, local concerns (for instance, gathered by community surveys) can identify the characteristics of "unwanted" or "pedestrian-friendly" uses, acts, or events. Of the Public Incivilities (T1), "unwanted" land uses can include liquor stores and auto repair shops respectively at PC and PN, and vacant and unmaintained buildings/lots at PA (Herzele and Wiedemann 2003; Vaughan et al. 2013; Richardson et al. 2020). At T2 and T3, "pedestrian-friendly" uses can be schools, worship areas and certain workplaces and stores.

About "accessibility", the study has two themes: The Park Access (T5) with the presence, quantity, and quality of physical characteristics at park boundaries, and the Social Accessibility (T2) concerning population sizes and land use characteristics in PC, PN and PA, and the building features affecting visual access from PA to parks. Similar building façade features contribute also to the Sense of Safety and partially to Public Incivilities in PA (Vaughan et al. 2013). Table 2 considers the "diversity" through land-use diversity and social diversity at the neighbourhood scales. Measuring the latter is a difficult task in Turkey because census data does not include information about income level, race/ethnicity, or religious affiliations. At best, the study calculates the approximate population sizes and densities in each block with the data about dwelling number per building and the average household size.

For "diversity" at the park scale, the field data about park attributes (Table 1) are grouped in four sub-clusters of the Park Facilities and Services (T4, Table 2): Physical attributes providing basic needs (e.g. seats, walkways) and some "comfort" (e.g. shade, café, water elements), attractive for some groups (e.g. playgrounds, sports fields) (Le Texier, Schiel, and Caruso 2018; Sister, Wolch, and Wilson 2010), and maintaining the sense of safety (e.g. cleanliness, security guard, landscape elements).

The study analysis at the neighbourhood and park scales considers the park (polygon) as the unit of analysis. All parks receive a numerical value for each theme of the relevant spatial scales at Table 2. The calculation of these values follows different steps. The data for T1, T5, and all sub-clusters of T4 is gathered at the fieldwork with "yes" or "no" statements (Table 1) and scored with "1" or "−1", alternative to a scoring, for instance, from 1 to 5 by Lotfi and Koohsari (2009). The summation of scores for each themes makes the park's final scores at Park, PA, PN and PC. About the population sizes and densities in PC, PN, and PA and number and sizes of alternative parks in PC at T1 and T2, the study uses the resulted figures. Differently, for T1 and T2 with building/ lot attributes in PNs and PAs, we calculate the percentage of buildings/ lots with the specified characteristics (see Tables 1 and 2) and take the average percentages as the thematic final scores of the park. To get the

Figure 3. Examples of parks with plenty and scarce features for T4-basics.

Table 2. Themes interrelating socio-spatial attributes at the neighbourhood and park scales.

Code	Name	Socio-spatial attributes and relevant spatial scales
T1	Public Incivilities	(PC, PN)-"Unwanted" land uses, and *others (e.g., "heavy" vehicular traffic, or "annoying" events)* (PA, Park)-"Unwanted" land uses or facilities, litter, neglected areas (lots, balconies, walls, gardens, etc.), graffiti, annoying smells, blind walls, and *others (e.g., "unwanted" park users, acts, and events)*
T2	Social Accessibility, Control and Sense of Safety	(PC, PN, PA)-Population size (number of dwellings x household size), residential density, and *others (e.g., characteristics with income level, race/ethnicity, and age)* (PC, PN)-Land uses (kind, "pedestrian-friendly," density), and *others (e.g., vehicular and pedestrian circulation)* (PA)-Use of lot/ ground floor, "pedestrian-friendly" uses, orientation of building entrances, window sizes, use of balconies, landscape elements not closing scenes, and *others (e.g., density and duration of pedestrian circulation)*
T3	Diversity	(PC, PN, PA)-Population size (number of dwellings, household size), residential density, and *others (e.g., characteristics with income level, race/ethnicity, and age)* (PC)- Alternative parks (number, size, facilities) (PN, PA)-Land uses (kind, "pedestrian-friendly," density)
T4	Park Facilities and Services	(Park) **Basics:** seats, green areas, shade, walkways, illumination, and *others (e.g., signs, easy circulation by disabled people)* **Comfort:** toilet, cafes/ eating and drinking areas, shade, water elements, and *others* **Attractive for some:** playgrounds, sport facilities, and *others (e.g., public events)* **Sense of safety:** illumination, landscape, cleanliness, security guard, cameras
T5	Park Access	(PA, Park) Vehicle accessibility, parking lot nearby, number of park entrances, orientation to sidewalks, access for disabled people, presence of park fences/ walls, and *others (e.g., signs, information boards)*

scores about T3 for the land-use diversity in PN and PA, we developed a scale for ranking the ratios of buildings with similar land uses at the street level at each PN and PA. These ratios are scaled from 1% to 30% and 31–59% ("heterogeneous" and "half-heterogeneous") to 60–74% and 75–100% ("half-homogeneous" and "homogenous"). The minimum level of heterogeneity is 30% because we considered a maximum of three land uses (namely, residential, commercial, and educational uses) common in neighbourhoods. Depending on the research context, the kinds of land uses and the ratios can be elaborated.

Results

The city scale with a spatial equity mapping of parks

About the park accessibility at the city scale, the spatial equity mapping (see Talen 1998; Talen and Anselin 1998) relates the spatial distribution of park areas per dweller to the population characteristics (e.g. age, income, and race/ethnicity) at census tract level (e.g. Wolch, Wilson, and Fehrenbach 2005; Weiss et al. 2011). For this purpose, we run a regression analysis with the ordinary least squares (OLS) with an equation developed for this study:

$$\text{parkarea per capita}_i = \alpha + \beta_1 \text{populationdensity}_i + \beta_2 \text{agegroups}_i + \beta_3 \text{educationgroups}_i + \beta_4 \text{women\_educationgroups}_i + e_i$$

In equation, the subscript "i" represents the neighbourhoods. The dependent variable is the neighbourhood park area per dweller in each neighbourhood. Independent variables include the population density and the neighbourhood percentages of the age groups and the groups with different education levels. With the intervals of 0–5, 6–13, 14–22, 23–55, 56–64, 55+ and 65+, the age groups reflect multiple groups of children, and young, middle age, and older people and thus, people at different stages of their lifecycles in Turkey. For all and female dwellers, the data about education levels is reorganised as "low" (education degree up to secondary school), "medium" (high school degree), and "high" (for university and above graduates).

We run the equation by taking into account possible multi-collinearity problems.[3] To avoid such a problem, we included age or education groups in the regression alternatively one-by-one. Moreover, the analysis is performed separately for Izmir's central and peripheral districts because the latter have lesser population densities, park area per dweller but an extending rural landscape. According to OLS results for the central districts of Izmir, the park coverage per dweller decreases in the neighbourhoods with higher percentages of 0–2 and 3–5 age groups and women with low education level Table 3.

To develop a spatial equity mapping, we deployed an overlay analysis with the weighted sum method considering the regression results (Greco et al. 2019). Rather than LISA (Local Indicators of Spatial Associations) used by the research with data at the census tract level (Talen 1998; Talen and Anselin 1998), we chose the overlay analysis to identify spatial units smaller than the neighbourhood. Overlay analysis requires data in raster format. This study has its raster images by converting vector data, rather than using the sources for raster data that might constrain the results (Le Texier, Schiel, and Caruso 2018). It deployed park cluster maps and the map of neighbourhood polygons with census data significant at the regression analysis. We produced park cluster maps in a raster format by deploying a point density analysis with the data about park locations and sizes, and 1600 m as the maximum walking distance (as Euclidian distance) to parks. With the tool "feature to raster", the maps of neighbourhood polygons are converted into a raster format. Of parks and neighbourhoods, we reclassified all the raster values into three legend categories. By considering the correlation coefficient of the regression analysis, the data is weighted in the raster maps. The

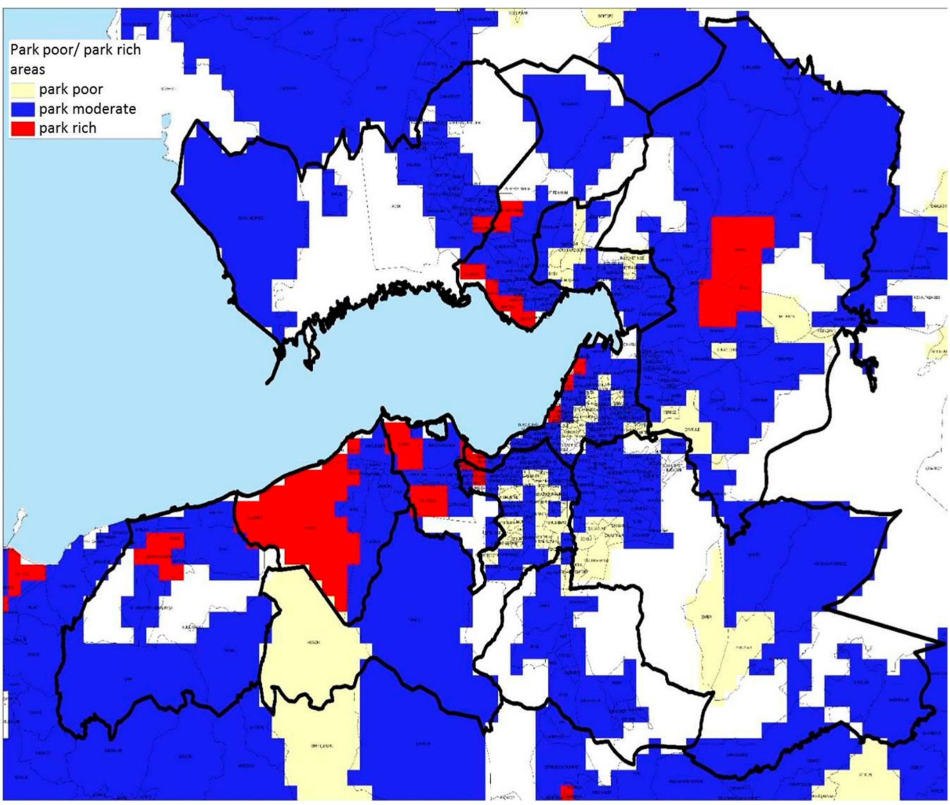

Figure 4. "Park-poor", "park-moderate" and "park-rich" areas in Izmir's central districts in 2018.

Table 3. The results of the models for regression analysis.

	Central districts: Park Coverage per dweller (dependent variable)											
Independent Variables	model 1	model 2	model 3	model 4	model 5	model 6	model 7	model 8	model 9	model 10	model 11	model 12
Constant	4.77*	4.86*	4.18*	4.16*	3.94*	2.79*	2.85*	7.58*	9.17*	1.52	2.86*	5.70*
Age 0_2	−47.88*											
Age 3_5		−52.09*										
Age 6_13			−14.23									
Age 14_22				−9.41								
Age 23_55					−3.17							
Age 55_64						2.17						
Age 65+							1.65					
low education_wom								−10.30*				
low education_all									−6.63*			
medium education_all										18.24*		
high education_wom											−0.34	
high education_all												20.69*
N=386												

*shows the statistical significance with minimum 10%.

produced maps identified the spatial equity mapping of Izmir with "park-poor", "park-moderate", and "park-rich" areas and independent from official neighbourhood boundaries (Figure 4).

"Park-poor" areas are the city parts with low park coverage per dweller and high neighbourhood ratios of the 0–5 age group and women with low education level. "Park-rich" areas have high park coverage per dweller and low neighbourhood percentages of these population groups. Most park-rich areas extend along the urban waterfront or at the city parts with new residential areas. In contrast, park-poor areas are either at older parts of central neighbourhoods or at the hilly city parts.

Multiple neighbourhood scales and the park scale

For its research at the neighbourhood and park scales, the study focused on three park-rich areas to have a high number and, thus, variety of parks and socio-spatial attributes affecting park accessibility. Among the top park-rich areas, three areas are selected due to their relatively low, average, and high ratios of women with low education levels. Each area has a high percentage of elderly (65+ ages) (*Karşıyaka*) or children (0–13 ages) (*Bornova*) or both groups (*Güzelbahçe*) (see Figure 1).

The paper presents the study results with the help of the Bornova case because compared to Karşıyaka and Güzelbahçe cases, Bornova has more neighbourhood parks and higher diversity of land uses, street patterns, topographical slopes, and population density (A, B and C in Figure 5).

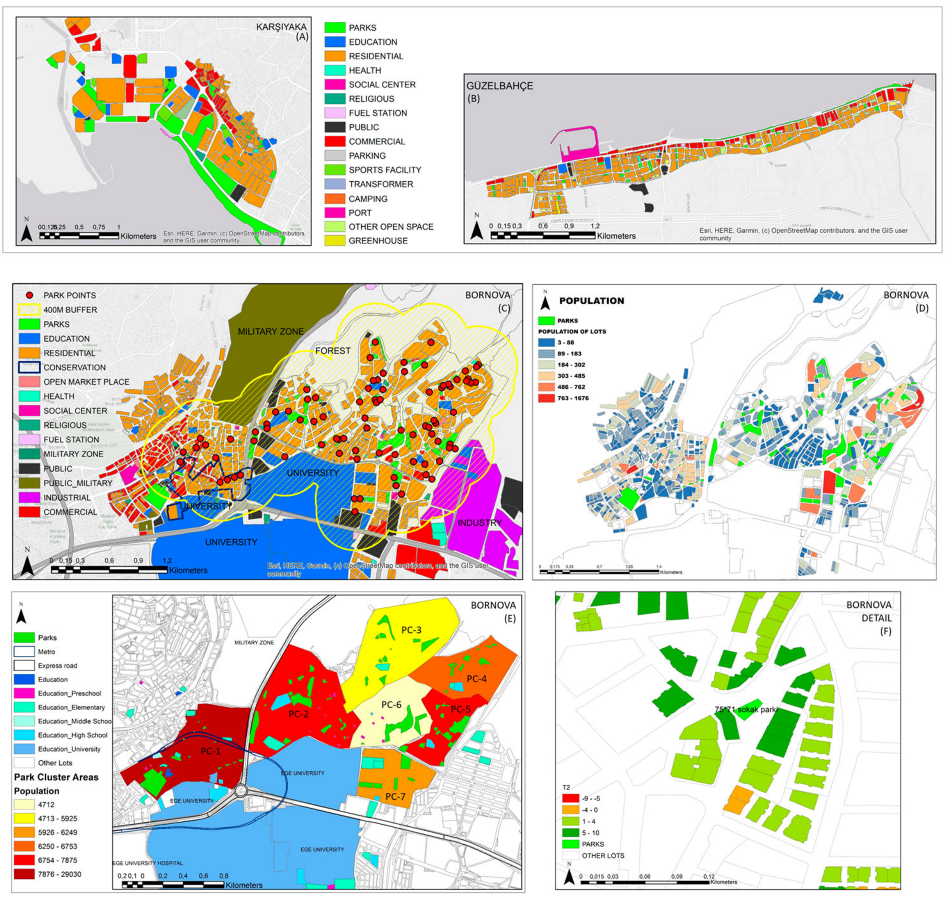

Figure 5. Selected maps in case studies: Land uses in the Neighbourhood-at-Large (NL) of Karşıyaka (A), Güzelbahçe (B), and Bornova (C); population distribution in Bornova (D), population sizes, schools and neighbourhood parks in six PCs of Bornova (E), and an example for a PN and a PA with T2 (F).

The Neighbourhood-at-Large (NL) is the largest neighbourhood area of parks and identified by the union of park buffers with 400 m radius. Produced maps of NL in Bornova with 67 parks identify many dwelling blocks separated from each other by large land uses (e.g. military zone, forest area, university campus, hospital site, and industrial area) as well as the topography (C and D in Figure 5). With the legend values grouped according to Natural Breaks (Jenks), the map D shows a heterogeneous distribution of population size and density in this NL. That is, dwelling blocks in a same park-rich area differ with their socio-spatial features that can shape differences in park accessibility.

To measure park accessibility among dwelling blocks in the same NL, we considered smaller park environments, namely Park-Cluster (PC), Park-Near (PN), and Park-Adjacent (PA). Through our site experiences on foot in Bornova, we identified seven PCs with parks in close range to each other and divided by major roads and high slope levels from other PCs (E in Figure 5). For each PC, we calculated the population size as the daily population creating park pressure, or the number of potential demands for parks nearby (Sister, Wolch, and Wilson 2010).

In Bornova, a total of seven Park Cluster areas range from 28 to 75 hectares and vary with their park demand pressures. For instance, PC-1 and PC-5 have more (total 11) parks with the highest total park area (respectively, 47176 and 41785 m^2). However, with 29.030 dwellers, PC-1 has a population higher than 7875 dwellers of PC-5. Thus, PC-1 and PC-5 have respectively 1.6 and 5.3 m^2 park coverage per dweller. PC-1 also has significant number of daily visitors due to its commercial and administrative activities and schools with the highest number of students. Meanwhile, the total park coverage in each PC is resulted by the different number of parks that affects maximum walking distances to parks. For instance, PC-3 has a high park coverage (40506 m^2) with only three parks.

In PNs and PAs, the data about land-uses, number of dwelling units and building/ lot attributes is coded respectively for the building blocks and the buildings/ lots next to park polygons (F in Figure 5). When PN areas overlap, we coded data for each relevant park. We used the spatial join analysis that matched the field data coded in the polygons with geographical coordinates. This analysis appended the data attributes to the related target features by transforming the data from point to polygon format and was finalised as the image F of Figure 5.

At the maps with the calculated scores (Figure 6), the red colour shows the lowest score for the "positive" themes (e.g. T2, Social Accessibility and Sense of Safety) and the highest score for the Public Incivilities (T1) with negative affect on park accessibility.

Public Incivilities (T1) have the features (i.e. "unwanted" land uses or facilities, litter, neglected or unmaintained areas including lots, balconies, walls, and gardens, graffiti, annoying smells, and blind walls) in PAs and the Park scale (Figure 7). In the Bornova case at Figure 6, the Public Incivilities are more at the PA level than the Park scale. Interestingly, except the residential areas at a northern hill and along a major road, the PAs with low scores of Public Incivilities are next to the parks without any problems.

At PAs, the Social Accessibility, Control and Sense of Safety (T2) is about the use of lot/ ground floor, "pedestrian-friendly" uses, the orientation of building entrances to the park, large window sizes, use of balconies, and the landscape elements not closing the park view. The resulted map points to three building clusters with problems. Two of these clusters are at the northeast hills. Another one is at the north border of the campus area. Reflected at the park level, the average scores are low at two of these three clusters. That is, a high percentage of buildings in these PAs have the problems of T2.

A consideration of T1 and T2 together suggests that the same PAs at the northeast hills and some building blocks to the east need improvements. At the map of T3 with the homogeneity ratios of land uses at the street level in PAs, the parks in these northeast hills and at the north border of campus are surrounded only by residential uses. Of the site, more parks have "half-homogeneous" uses at PAs, that is, with more of a land use (here, residential, commercial, and educational) supported by others. A large cluster of parks to the east and another cluster (with smaller parks) to the northwest have a heterogeneous mix of land uses in their surroundings.

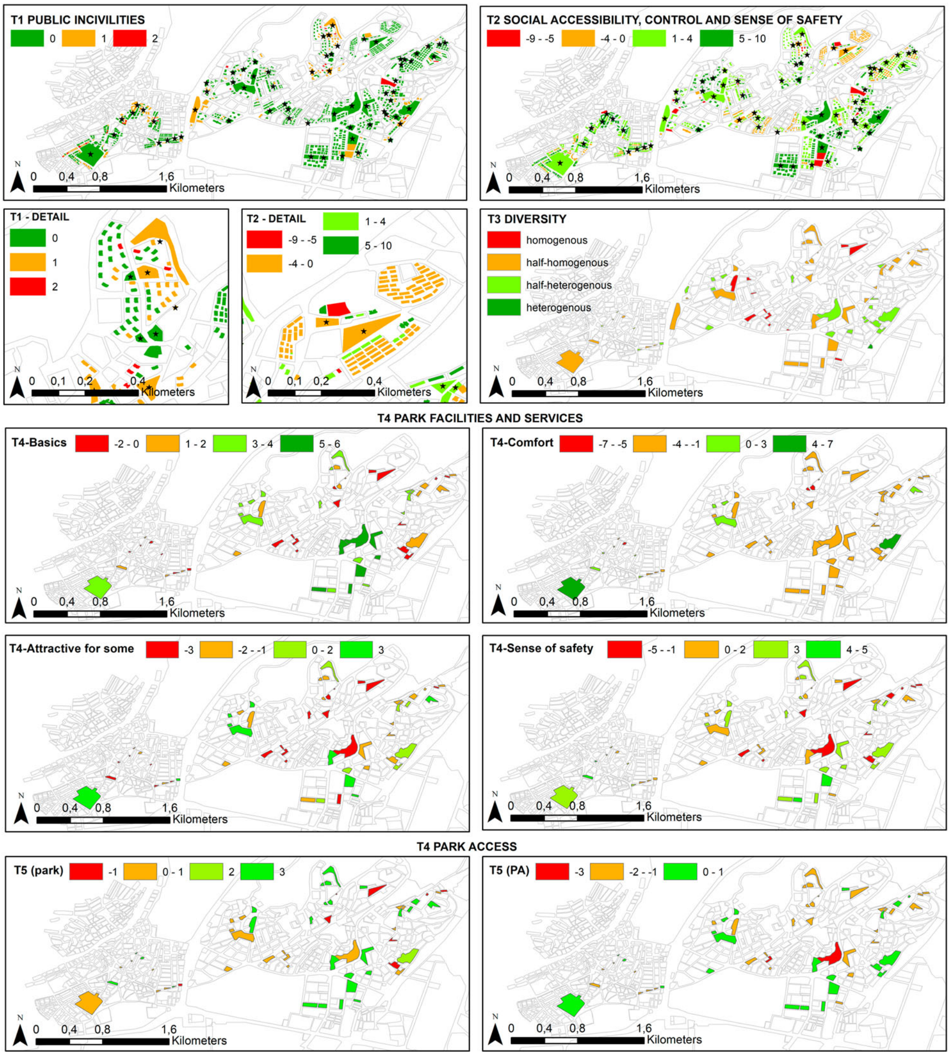

Figure 6. Thematic maps for socio-spatial attributes at relevant spatial scales (T1, T2, T3, T4, T5).

Figure 7. Field examples of public incivilities in parks with (A) technical infrastructure and graffiti, and (B) stray horses.

At the park scale, thematic maps have results for T4's subgroups (Basics: seats, green surfaces, shade, walkways, and illumination; Comfort: toilet, cafes/ eating and drinking areas, shade, water elements; Attractiveness for Some Groups: playgrounds and sports equipment and areas; and Sense of safety: lighting, landscape, cleanliness, security guard and cameras) and T5 (Park Access). The map for T5 shows the park access with park entry points and fences/ walls and with the parking lot, bicycle racks, and traffic load at the PA. Same parks in the northern hills and at the north border of the campus and some small parks to the east have the lowest scores for all the T4s (except for Comfort) and T5-Park. For T4-Attractiveness, T4-Sense of Safety, and T5-PA, a large park just in the middle of the site appears with the problems.

Discussion

This study underlined the need for research at multiple spatial scales to detect and evaluate socio-spatial features shaping park accessibility. At the city scale in central Izmir, the study developed a spatial equity mapping of neighbourhood parks (Talen and Anselin 1998) despite Turkey's limited census data (especially about income level) used commonly by the research in data-rich contexts (e.g. Barbosa et al. 2007; Dai 2011; Heckert 2013). It considers that in Turkey, education level has a positive correlation with income level (Akça and Ela 2012). Thus, similar to the literature (Talen and Anselin 1998; Boone et al. 2009; Wolch, Wilson, and Fehrenbach 2005), the resulted map of central Izmir displays that the poor neighbourhoods with higher ratios of the 0–5 age group tend to have less park coverage per person.

In contrast, the park-rich areas have high park coverage and ratios of high education level and lower ratios of the 0–5 age group. The research at the city scale tends to consider such park-rich areas with better park accessibility (Cetin 2015; Heckert 2013). However, our examination of the neighbourhood and park scales at selected park-rich districts underlined that in these districts, some housing blocks and parks have socio-spatial features that can limit park accessibility for various social groups. In the Bornova case, PCs determined by walking distances have distinct park coverages per dweller. Commercial and educational land uses add to the daily demand for parks in central areas like PC-1. The PCs with low population sizes and high park coverages have problems reified at the other neighbourhood and park scales. For instance, to the north, PC-3 has the third-largest park coverage. Yet the maps for T1 and T2 point more housing blocks (PNs) and buildings (PAs) in PC-3 with problems. Moreover, surrounded by these PN and PAs with low scores of T1 and T2, the parks get low scores for some sub-groups of T4 and T5 significant for park accessibility (see, Güngör and Tuğrul Polat 2017).

The results at multiple scales also enable a better comparison for selected themes of park accessibility. For instance, two parks in PC-6 have high scores for the Sense of Safety at the neighbourhood scales (T2) with features about pedestrian-friendly uses, landscape elements, and facades of adjacent buildings. However, with T4-Sense of Safety at the park scale about the availability of illumination, cleanliness, and cameras, these parks have low scores. Such multiple-scale mappings would facilitate the local decision-makers to determine the nature and spatial scale of the hindrances for park accessibility.

With its deployment of different sources and kinds of data, the study aimed to overcome the limited availability of vector and raster data about green areas and population characteristics in Turkey. Moreover, different data sources can provide the research with the ability to control the analytical quality of data (see Le Texier, Schiel, and Caruso 2018). As part of this effort, we developed field observations and gathered data about local socio-spatial characteristics (e.g, Mckenzie et al. 2013; Richardson et al. 2020). Fieldwork enabled to elaborate with the data according to distinct social needs for park accessibility. The prepared data considered different walking distances, land uses, variety of park facilities (Kent and Thompson 2014), and the researchers' place-based senses about, for instance, any smell, garbage, and perception of safety in parks. Further fieldwork can include observations about park users' physical, demographic, and behavioural characteristics (Lindsey, Maraj, and Kuan

2001; Vaughan et al. 2013) and surveys and interviews with dwellers about their perceptions, concerns, and expectations for park accessibility (e.g. Thawaba 2014; Koohsari et al. 2013).

Another context-based limitation relates to the "neighbourhood" as the smallest geographical unit with census data in Turkey. Without the census tracts as the geographical units with coded data, Turkish studies about park accessibility need to elaborate with GIS tools to develop, for instance, spatial equity mapping of parks. Rather than LISA with census tracts (e.g. Wolch, Wilson, and Fehrenbach 2005; Weiss et al. 2011), this study deployed an overlay analysis with point density analysis of parks and neighbourhood-based distribution of particular population characteristics. Further studies can collect and analyse data about green areas' coverage by using remote sensing techniques and alternative tools like grid squares (e.g. Barbosa et al. 2007).

The study identified multiple neighbourhood scales as the park environments sensitive to distinct walking distances by social groups (Kent and Thompson 2014). For data preparation and analysis at the neighbourhood and park scales, it developed a list of themes related to physical and social accessibility and diversity. According to research purposes and needs, further studies can extend their field data and analysis by re-formulating these themes at Table 2 and by others (see Herzele and Wiedemann 2003; Vaughan et al. 2013). For instance, Table 2 can include the observation-based data about the physical and behavioural characteristics of pedestrians in parks and nearby streets (Lindsey, Maraj, and Kuan 2001; Vaughan et al. 2013). Similarly, the flexibility with the choice of scoring systems in this study is both a strength and a weakness for assessing the attributes for park accessibility at any spatial scale. A context-based scoring system developed by the opinion of local groups can provide more justifiable evaluations of the park environs (e.g. Chen, Xu, and Devereux 2016; Güngör and Tuğrul Polat 2017).

This study supports the critique by Kimpton (2017) about the studies (e.g. Ibes 2015) considering the amenities with their presence or absence. Similar to Smoyer-tomic, Hewko, and John Hodgson (2004), it urges to consider the qualities and characteristics of the amenities, besides counting them. Meanwhile, among a few studies evaluating parks at multiple scales, Kimpton (2017) with a park typology uses the percentages of some spatial attributes relevant either to the neighbourhood or park scales. This study in İzmir calculates multiple thematic scores for all local scales and a final score separately for each park. This method can help the decision-makers to determine which attributes at which spatial scale needs improvement and provision.

Local policymakers, researchers, and community organisations in public safety and health can benefit from the research stages of this study in many ways. Similar thematic maps can provide easy recognition of the nature and location of problematic areas (Louis and Magpili 2002) and the kind and place of socio-spatial investments needed. With more statistical analysis, researchers can interrelate thematic maps' values with people's preferences about park features and their socio-economic characteristics (e.g. Chen, Xu, and Devereux 2016). Or civil society organisations can train children, elderly, youth, women, and other groups with similar themes at Table 2 to gather and monitor data via mobile phones at park environs. More data can include the dwellers' (dis)likes or (dis)comfort about social and physical characteristics concerning park accessibility.

Conclusion

This study presents a research framework for gathering, preparing, and analysing data with the help of GIS-based and other research tools at the city, neighbourhood, and park scales. Its details for deploying this framework for its case study can guide similar efforts in other contexts with limited data. Case study results confirm that the park accessibility is not bounded to a spatial scale but has versatile socio-spatial features at multiple spatial scales. Despite their high park coverages per person and a high-income level, the Bornova case as a park-rich area is not a homogenous space. It includes neighbourhood parts (PCs), housing blocks (PN), park adjacent buildings (PA) and parks with the socio-spatial features that can limit the park accessibility among local groups with different walking capacities and needs.

Limitations of this study include the context-based difficulties in data collection and appropriation. Especially the data about the distribution of social groups (even only in terms of age and education level) in housing block level would improve the discussions of the socio-spatial differences of park accessibility at local scales. Local surveys at the household level could have provided some information about this concern. Also, the data for some themes can be a temporary state of physical condition, such as bad smells local areas. Similarly, the deployment of data about temporal variables (e.g. weather conditions and events in parks) would enrich the results.

Notes

1. These stages are part of a funded research project we completed in 2019 (see Acknowledgements).
2. Satellite views were part of a project we run and funded by the Municipality of Greater City of Izmir and the University of *X*.
3. Histogram normality tests were applied to test whether residuals have desired normality property (Jarque and Bera 1980). Although we did not apply the heteroscedasticity tests, we assumed the residuals that provided the normality to have constant and homoscedastic error distribution. Spatial autocorrelation was not tested but can be examined in further studies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Turkiye Bilimsel ve Teknolojik Arastirma Kurumu [grant number 215K239].

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