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Accessibility to urban parks: Comparing GIS based measures in the city of Padova (Italy)

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ABSTRACT

Accessibility to urban green spaces is essential for urban dwellers' health and well-being. For planning purposes different accessibility measures and indicators have been used. Some are only based on availability, others consider distance from residences, yet others rely on gravity-based methods that consider both supply and demand. Different indicators often provide diverse and sometimes contradictory results and many issues remain in developing a comprehensive measure of accessibility, and representativity problems remain in matching indices with reality. In this study different accessibility measures have been developed and applied to the urban parks of the city of Padova, in northeastern Italy. Effectiveness and reliability of ten indicators derived from these measures, in identifying needs, inadequacies and disparities in park access have been tested at the urban unit scale. The study confirmed that multiple indicators need to be used to provide a useful planning tool for the provision of adequate and equal opportunities for open space access to the citizens. The study has also shown which indicators can be replaced by each other without losing important information.

1. Introduction

In an increasingly urbanized society open spaces become an essential element for the quality of life in cities (Tzoulas et al., 2007). A growing body of scientific evidence indicates that green spaces in urban contexts (i.e. parks, forests and green belts) provide many environmental services, such as summer temperature mitigation (Gill et al., 2010), air and water purification (Escobedo et al., 2011; Livesley et al., 2016), rainwater runoff reduction (Zölch et al., 2017; Ruangpan et al., 2020); more importantly they provide opportunities for contact with nature, for leisure activities that promote emotional stability, for more active behavior and physical activity with positive impacts on health outcomes (Barton and Pretty, 2010; Bowler et al., 2010; Beyer et al., 2014; Nutsford et al., 2013; Richardson et al., 2013; Cohen-Cline et al., 2015; Halecki et al., 2023). These benefits are linked to the availability of parks and the ease of access for urban dwellers to such open spaces (Maroko et al., 2009; Coombes et al., 2010; Biernacka and Kronenberg, 2019; Cambria et al., 2021; Konijnendijk, 2022). Therefore, evaluating park accessibility is an important tool in urban planning, providing a basis to remediate insufficiencies and inequalities in open space presence and their spatial distribution in a city (Barbosa et al., 2007; Rishbeth, 2001; Wolch et al., 2014; Dinand Ekke and de Vries, 2017). The recent covid-19 pandemic, and the related movement restrictions, has further emphasized the necessity for close to home green space access (Slater et al., 2020; Larcher et al., 2021; Liu and Wang, 2021).

Many researchers have developed various methods and measures to evaluate access to parks and urban open spaces (Daniels, 2000; Nicholls, 2001; Van Herzele and Wiedemann, 2003; Oh and Jeong, 2007; Yin and Xu, 2009; Zhang et al., 2011). However, there are many issues in developing a comprehensive measure or index of accessibility and representativity problems remain in matching indices with reality. Although research on this topic has progressed over recent years, following the development of new techniques in spatial analysis, it still faces some methodological difficulties and shows significant lack of consistency between methods.

The simplest approach to measuring accessibility comprises the so-called "container-" or "area-" based methods (Table 1). These methods compare the number of parks, total park area, number of park accesses, within spatial units, such as census tracts, zip codes, or other administrative subunits at the urban scale. These measures are often used in

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Table 1
Summary of accessibility index types.

Method	Object of measures	Advantages	Problems
Container based	- Park number within spatial/ administrative unit; - Park area within spatial/ administrative unit and per capita; - Park accesses within spatial/ administrative unit.	- Simple to compute; - Based on easily available data.	- Considers mainly supply; - It i s subject to the modifiable area unit problem;
Distance based	- Population served within a predetermined distance from parks; - Service area of parks.	- Widely used indicator allows for easy comparison between cities; - Simple to obtain when calculated with Euclidean buffer distance.	- Considers mainly demand; - It requires GIS computation at various levels; - Data availability can be restricted due to privacy issues.
Gravity based	- Park number and population size, of the spatial unit and distance between population and park entrances.	- Consider both demand and supply using distance as a friction factor.	- Most complex to compute; - Data availability can be restricted due to privacy issues when distance between supply and demand is calculated for each resident.

association with population size and with the unit's total area. Indeed, these are the most commonly used in monitoring and comparing cities' progresses.

The main limitation of container-based methods is that they do not consider interactions between users and parks across administrative borders. For instance, they fail to consider park and green areas that are outside the unit, but close to its physical borders, and, therefore, easily reached by the population of that land unit. This problem is related to the size of the geographical unit and it is known as the "modifiable area unit problem" (MAUP; Zhang et al., 2011).

Another set of measures are based on distance between residences and parks (Table 1), assuming the distance, or the time necessary to reach the park by different means (e.g. walking), as the main determinant for accessibility. Distance-based methods are generally implemented using GIS technology. The most used approach applies indicators based on actual distances, calculating a service area for the park based on the distance, and counting the population in the serviced area. Distances mostly used are 300 m, corresponding approximately to a five-minute walk, or 800 m corresponding to a 15-minute walk; other studies, often in periurban areas or at the regional scale, use longer distances and various means of transportation. The main variation in the application of distance-based methods lies on the approach in calculating the service area. Firstly, the geographical position of the park needs to be defined. In some cases, the coordinates of the park's centroid are used. In other cases the park boundaries are considered. Other studies used the coordinates of park entrances for greater precision. Secondly, a method for measuring distance needs to be selected (Apparicio et al., 2008). Many studies considered a simple Euclidean buffer around the geographical coordinates of the parks (Nicholls, 2001). This is a very straightforward method that generally leads to an overestimation of the population served. Other studies used network analyses, considering the actual distance on the city's street, or pedestrian pathways network, to determine the service area. In this case the distance is generally calculated from the intersection of the street network with the park's access points.

Distance-based methods are effective in measuring accessibility accounting for the demand side (serviced population) but do not consider the supply side such as dimensions of the parks or other park features. For this reason, other studies that emulate spatial accessibility research in other sectors, such as healthcare services provision (Wang, 2012), employ gravity-based methods (Table 1). These methods generally use park number and size as a measure of supply, population of the spatial unit as a measure of demand and distance between population and park entrances as a friction factor, representing the reluctance or impedance of the population to visit the parks. This approach assumes that accessibility decreases with a longer travel distance between origins and destinations; accessibility increases with a greater demand at origins or with higher supply capacity and/or attractiveness at destinations (Zhang et al., 2011). An additional case of the gravity model, which is often used in accessibility studies, is the two-step floating catchment area method (2SFCA). The 2SFCA method, which considers supply and demand together, not only has most of the advantages of a gravity model, but is also intuitive to interpret, and easier to implement in GIS (Luo and Wang, 2003).

Indeed, there is a lack of studies comparing various indices of green space accessibility referring to different measurement methods (but see La Rosa, 2014; Wang et al., 2021). Furthermore, studies dealing with accessibility of green spaces rarely rely on their entrance position or on detailed data on population location. This would benefit both urban and green space planning as their comparison can provide crucial information on their use and variability (Halecki et al., 2023). Acknowledging whether indices provide similar information would help selecting only those that convey an array of information related to accessibility.

In our study the main objective is to apply and compare different accessibility measures, pertaining to the three categories (container-, distance- and gravity-based) to the urban parks using the case of the city of Padova, in northeastern Italy. The purpose is to test effectiveness and reliability of the indicators derived from these measures, in identifying needs, inadequacies and disparities in park access at the urban unit scale. Considering that some indicators are considerably simpler and faster to calculate and apply, the study also tested correlation between indicators, to point out their similarity and replaceability.

2. Materials and methods

2.1. Study areas and data sources

This study focuses on urban parks of Padova, a city in northern Italy in the Veneto region with around 208,000 inhabitants over 9303 ha. Green spaces cover 56% of the municipal territory (Costa and Degl'Innocenti, 2022). These spaces represent a large variety of types and features, including urban parks and gardens, agriculture land, small woodlots and urban social gardens (Sitzia et al., 2016). Indeed, urban parks (and gardens) managed by the municipal administration are important landscape elements for the provisioning of services to citizens and they cover an area of around 112 ha (Costa and Degl'Innocenti, 2022).

Considering the fragmented composition of the city's recreational green infrastructure, all parks exceeding 500 m^2 were included in the study, provided they contained a minimum set of fundamental features: shade trees, benches, lawns and a pedestrian path. Administrative units (Italian: *Consulte*) were selected as reference spatial units. The city of Padova comprises ten units (Fig. 1). Current data on park size and location were obtained from the city's geodatabase (Fig. 1). The geographical coordinates of all residential civic numbers were also obtained. Data on the unit's population and number of residents per civic number were obtained from the city's Demographic Services; these data were aggregated by municipal offices and treated anonymously. The location of all park entrances was recorded through aerial photo interpretation and field data collection and was recorded in a specific layer of the Quantum GIS vs. 3.20.3-Odense (QGIS Development Team, 2020). The street network, used in the distances calculations, was derived from

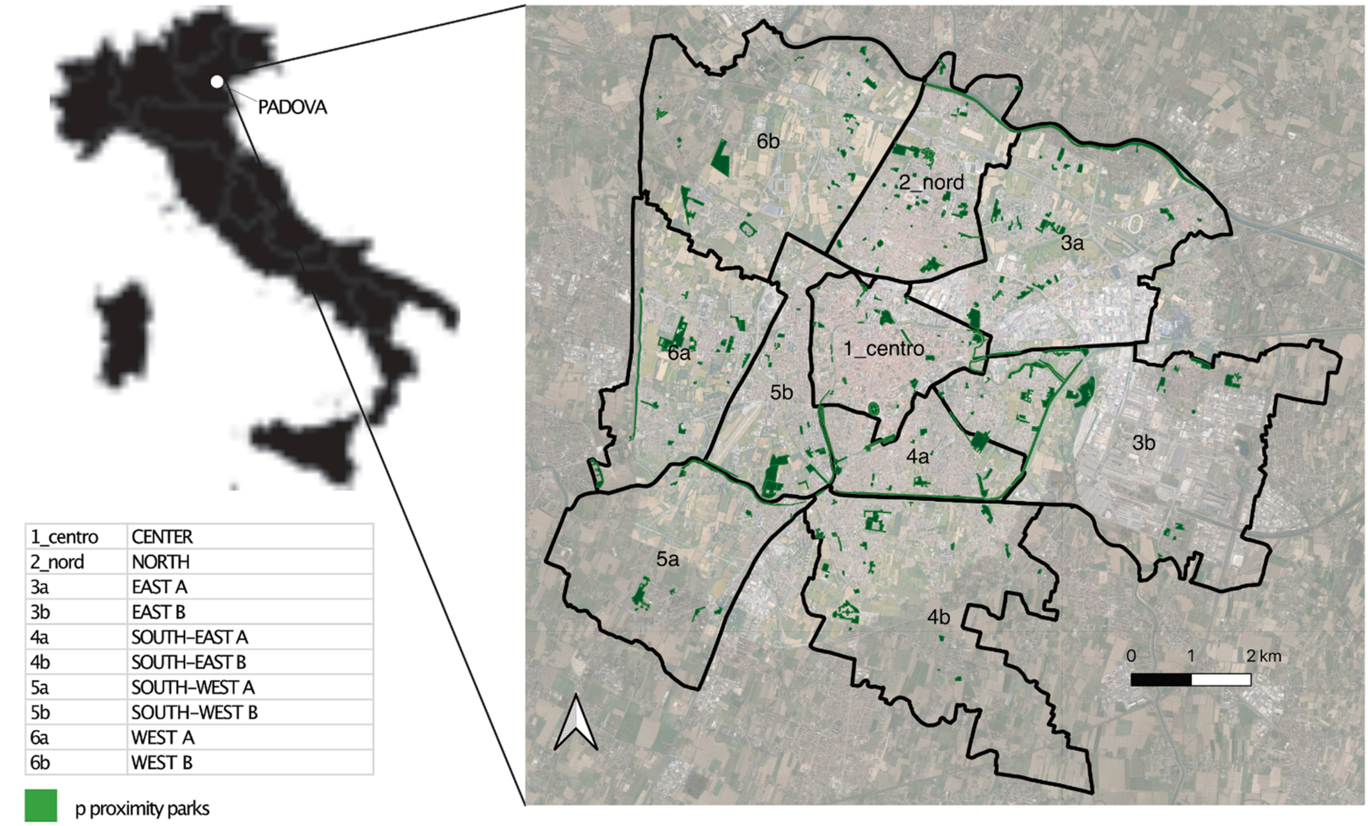

Fig. 1. Urban parks in the ten urban units of the city of Padova.

OpenStreetMap (OSM), and corrected for obstacles to pedestrian movement. A total of ten accessibility indicators were computed (Table 2).

2.2. Container-based indicators

For each urban unit the total cumulative park area was calculated (Indicator C1); to partially overcome the limitations of container-based indicators (MAUP effect; Zhang et al., 2011), parks located outside the unit, but with a 300-m service area extending into the unit were computed in the total area calculation. The methodology for the definition of the service area is explained in detail in the "Distance-based indicators" section.

From indicator C1 other measures were derived. Indicator C2 represents the park area per capita (C1/ total population of the unit), while indicator C3 is the ratio between C1 and the total area of the unit. Since the number of access points is also relevant, indicator C4 was calculated as the ratio between the number of access points in the unit and the total area of the unit.

Table 2
Summary of the applied accessibility indicators.

Type	Code	Indicator	Unit of measurement
Container based	C1	Total area of parks in urban unit	m^2
	C2	Park area per capita (C1/Population in urban unit)	m^2
	C3	Park area/Urban unit area ratio	%
	C4	Number of park accesses per ha in urban unit	number
Distance based	D1	Mean minimum distance to closest park for urban unit residents	m
	D2	Percentage of urban unit population living within 300 m from park	%
	D3	300 m service area/total area of urban unit	%
	D4	Park area per capita for residents living within 300 m from park	m^2
Gravity-based	G1	Gravity - considering park accesses distance from the urban unit centroid	
	G2	Gravity - considering park accesses mean distance from each resident in the urban unit	

2.3. Distance-based indicators

Two kinds of indicators based on the distance between parks and residents were calculated. The first one measures the average distance of residents to the closest park entry; the second defines the service area of the parks based on a predefined maximum distance. In both cases the distance considered is measured on the existing street network. All the calculations were performed using the open-source software QGIS and the plugin module QGIS Network Analysis Toolbox 3 (QNEAT3).

The first indicator D1 was calculated from a distance matrix between every park access and each civic number in the unit as the shortest path on the pedestrian street network. For each civic number the distance to the closest park was obtained and then averaged, after being weighted according to the number of residents for each civic number. The indicator shows the mean distance that a resident of the unit must cover to reach the closest urban park.

This study concentrated on urban parks that should be easily accessible daily. Hence, in the calculation of indicator D2, the maximum temporal distance, used to define the service area, was set at a 5-minute walk from the residence to the closest access point to a park, corresponding to a spatial distance of 300 m, within the range proposed by many authors (Harrison et al., 1995; Barbosa et al., 2007; Roo et al., 2011; WHO, 2016; Poelman, 2018; Konijnendijk, 2022). Distances are real distances, calculated on the street network from each park access point. Indicator D2 is calculated as the percentage of the unit's population living within the 300 m service area of a urban park. To define the total service area, the network analysis tools in QGIS were used. The population of the total service area was calculated summing up the residents of every civic number included in the area. Indicator D3 was calculated as the percentage of the total service area over the unit's area. Indicator D4 was the result of the ratio between the unit's total park area (C1) and the population in the unit's total service area, representing the *per capita* park area available to the serviced population.

2.4. Gravity-based indicators

Two gravity-based indicators were tested. Both assumed the park size as the measure of supply, and the unit's population as a measure of demand. Two different methods were used in the calculation of the distance between supply and demand. For the first, indicator G1, a traditional method was used, considering the distance between park's accesses and the geographical centroid of the unit, considered as the population center of the unit.

The formula used for the calculation of G1 is:

$$G1_i = \sum_{j=1}^{n} \frac{S_j * P_i}{d_{ij}^2}$$

Where n = number of parks in the unit i; S_j=area of park j; P_i=population of the unit i and d_{ij}= distance from the closest access of park j to the centroid of unit i.

Assuming that the use of fine-scale spatial units of origins to a park compared to a simplified centroid of a coarse spatial unit, would improve the accuracy of the indicator (Wang et al., 2021), civic numbers were used as origin points in the computation of the second gravity-based indicator. Therefore, for indicator G2 the distance between each resident of the unit and each access to a urban park was calculated and used in the formula. In both cases the distance was calculated as the shortest path on the pedestrian street network.

The formula used for the calculation of G2 is:

$$G2_i = \sum_{j=1}^{n} \frac{S_j * P_i}{\mu d_{ij}^2}$$

Where n = number of parks in the unit i; S_j=area of park j; P_i=population of the unit i and μd_{ij} = mean distance from the closest access of park j to the civic number of each resident in the unit i.

In both formulas the friction coefficient (distance exponent) is two as suggested by the literature, when considering walking as the means of transport (Zhang et al., 2011).

2.5. Comparing accessibility measures

The spatial distribution of the ten accessibility measures was mapped in QGIS for the ten urban units. Indicator values were classified in quintiles. For each quintile we used different shades of green from light green for the lowest accessibility to dark green for the highest accessibility.

To test replaceability of the measures in evaluating park accessibility a Spearman correlation (rho) analysis as well as the test for their statistical significance ($p < 0.05$) was carried out in R (R Development Core Team, 2021). Correlation analysis is commonly used to compare the performance of accessibility measures (e.g. Apparicio et al., 2008; de la Barrera et al., 2023; Higgs et al., 2012; La Rosa, 2014; Wang et al., 2021), and it is a robust test to understand whether two variables change consistently.

3. Results

The value of the ten indicators calculated for the ten urban units has shown a certain variability (Table 2). Urban Unit 3b ranked in first position for four indicators (C1, C2, D2, D4). Urban Unit 5a, instead, ranked in last position for six indicators (C1, C3, C4, D3, G1, G2). Except for indicator D1, for all other indicators higher values indicate higher accessibility.(Table 3).

The results are also visualized in Fig. 2, where the indicator's values, grouped in quintiles, are shown for each urban unit. The spatial pattern of accessibility measures in the study area showed a clear distinction between container-, distance- and gravity-based methods, with the exception of indicators C3 and D3, where the denominator (area of the unit) has a predominant effect on the value of the indicator.

According to container-based indicators (C1, C2, C3, C4) the southern units of the city present limited accessibility to urban parks compared to the center and northern units. This appears to be a consequence of a smaller park area both in absolute terms and as per capita availability. Distance-based methods yielded more heterogeneous results. Indicator D1 (average distance to the closest park) showed the lowest values in unit 5a and 5b, characterized by a concentration of parks in limited areas of the unit, while population is more evenly distributed. A relatively low accessibility was seen also in unit 1, where most parks are located at the periphery of the unit, while population density is highest in the center. Indicator D2 showed a similar spatial pattern, with some differences. The highest values were seen in the eastern units of the city (3b and 4a) where parks are located closer to the main residential nuclei within the units. The industrial area showed the lowest value, probably mainly due to a lower density of the pedestrian street network. A similar condition exists in unit 5b.

The two gravity-based indicators showed good overlapping. The differences are due to the distribution of the civic number around the unit's centroid, but in this case do not affect the hierarchy of accessibility between units, with the exception of unit 5b, where the unit's centroid coincides with the least populated area.

3.1. Correlation analysis

In general a high number of correlations were identified between the ten indicators (Fig. 3). Correlations were positive and negative (eleven cases each). Seven indicators, C2, C3, C4, G1, D3, D4, and G2, were correlated with other six indicators. Only C1 was not correlated with any other indicator. Among container-based indicators C2 and C3 were negatively correlated, while C4 was negatively and positively correlated with the two previous indicators, respectively. Among distance-based indicators, D1 and D2 were only negatively correlated with each other, as was also the case for D3 and D4. The two gravity-based indicators were strongly positively correlated with each other. C2 and D4, the two indicators with per capita values as denominator, had the highest number of negative correlations, with only one positive correlation between them.

4. Discussion

4.1. Accessibility indicators: an important tool for planning and monitoring

The spatial pattern of the ten accessibility measures confirm the assumption that the container based, distance based, and spatial interaction approaches generate distinctive types of indicators that might be suitable in different contexts. In general, none of the indicators can be used as a single and comprehensive measure of accessibility, but the use of multiple indicators can be a very useful tool in urban planning for the provision of adequate and equal opportunities for open space access to the citizens.

Container-based indicators are easy to obtain and rely on publicly available data. They provide a measure of the urban park area in each unit and point out deficiencies in the amount of green space per capita as compared to planning benchmarks or urban standards. Indeed,

Table 3
Computed values for the ten indicators in the ten urban units.

Urban Unit	*C1*	*C2*	*C3*	*C4*	*D1*	*D2*	*D3*	*D4*	*G1*	*G2*
1_centre	262,699.73	10.26	0.05	0.13	296.00	0.62	0.42	16.58	4771.30	2680.72
2_north	266,282.92	6.76	0.04	0.10	251.00	0.64	0.38	10.57	8197.48	4137.19
3a	286,709.43	13.29	0.02	0.05	294.00	0.43	0.17	30.81	1016.08	1025.64
3b	464,560.78	30.66	0.03	0.04	293.00	0.67	0.14	45.95	696.00	973.25
4a	206,705.71	9.62	0.05	0.12	287.00	0.65	0.45	14.77	3925.72	1325.89
4b	209,506.95	8.39	0.02	0.04	385.00	0.49	0.15	17.04	1414.86	974.47
5a	116,069.99	11.53	0.01	0.03	406.00	0.53	0.11	21.62	442.94	259.22
5b	234,589.83	13.38	0.05	0.08	438.00	0.47	0.23	28.19	1545.97	1035.98
6a	228,803.49	14.56	0.03	0.07	268.00	0.62	0.19	23.34	2864.69	969.57
6b	248,750.80	14.99	0.02	0.05	273.00	0.65	0.13	23.16	2311.01	612.23

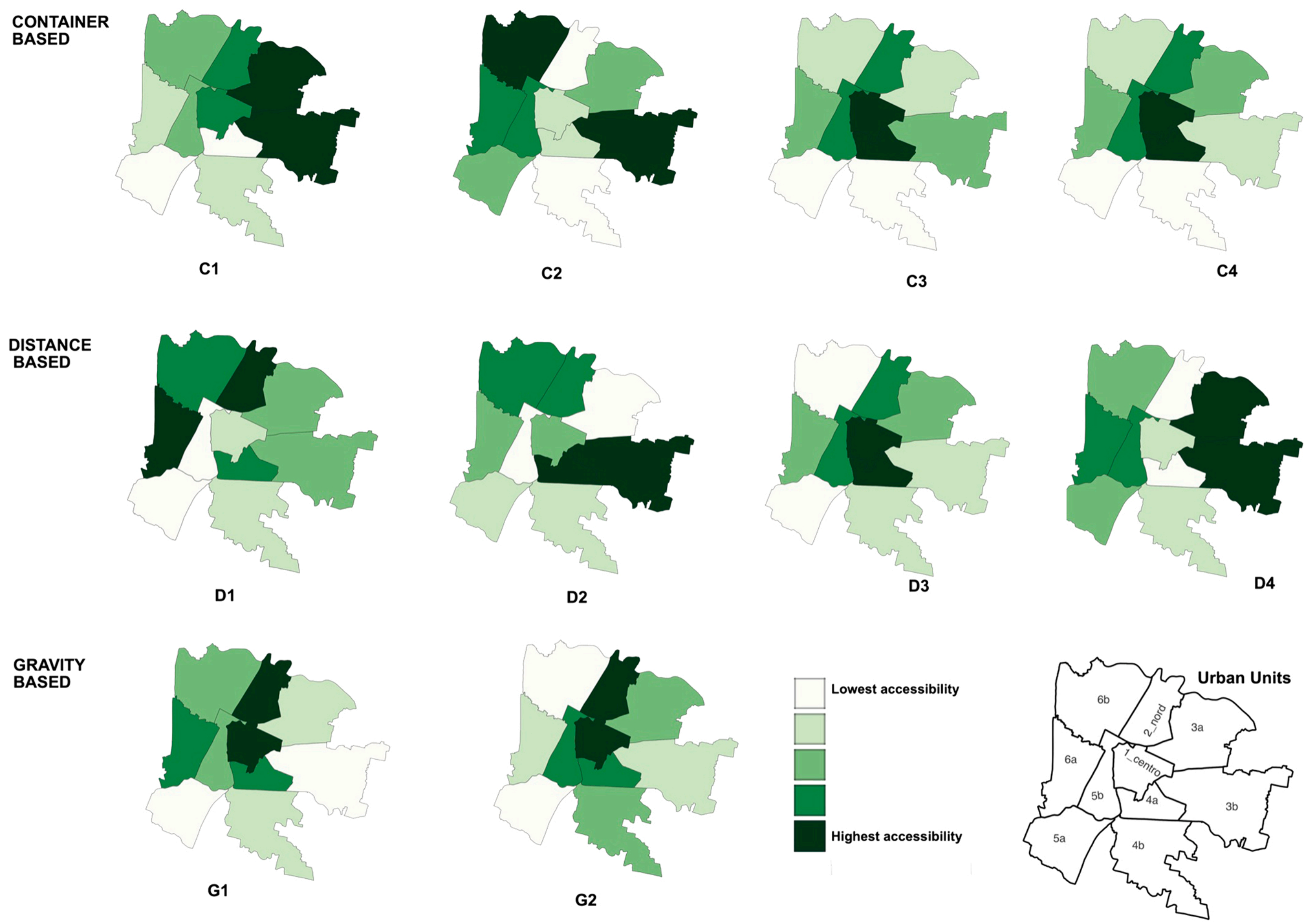

Fig. 2. Spatial pattern of the ten accessibility measures in the study area (urban units) classified according to a quintile distribution (first quintile = lowest accessibility; fifth quintile = highest accessibility).

considering the lack of correlations with other indicators, the total area of parks in an area would be an important indicator to be included in the monitoring of urban green spaces accessibility. We suggest using this measure when planning targets but also when conveying information on green space accessibility to the general public. The number of park accesses can be a useful indicator in conjunction with distance-based measures.

Distance-based indicators require more complex calculations and a relatively advanced mastering of GIS, but are particularly effective and useful at pointing out inequalities in the distribution of urban parks within and between spatial units. In units with low accessibility the different distance-based indicators can be used to better identify the main limiting factors also in conjunction with container-based indicators such as, for instance, the number of park accesses; increasing park accesses and locating them appropriately (e.g. connected to the pedestrian road network), can modify the extent of the serviced area without the need to plan new parks. In our case study this could be the case in unit 3a, which is characterized by a medium value for indicator C2 (per capita park area), but a low value for indicators C4 (park accesses per ha) and D2 (population served within 300 m). Furthermore, considering the correlation results, one between mean minimum distance to closest park for area residents (D1) and percentage of the area population living within 300 m from a park (D2) should be prioritized when assessing accessibility. Indeed, increasing values of one indicator would result in decreasing values of the other, as also expressed by the negative correlation. One of these two indicators should be assessed for monitoring urban planning as they did not correlate with other indicators, hence, they provide different information from the rest of the

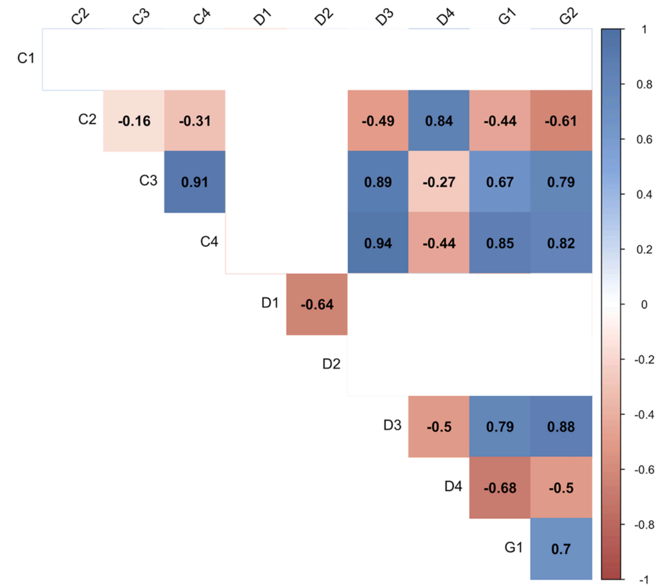

Fig. 3. Spearman (rho) correlation analysis between the ten indicators. Values are reported only for statistically significant correlations ($p < 0.05$). Positive and negative correlations are indicated both with mathematical symbols (+ or -) and different colors (blue or red).

indicators.

Spatial interaction indicators such as those obtained with gravity-based methods are the most complex and time consuming to calculate and require data, such as number of residents per civic number, which are not always publicly available and may be constrained by privacy issues. These indicators consider both demand and supply of green spaces and are useful to further refine planning strategies and scenarios developed using the previously described container- and distance-based indicators.

Gravity-based indicators are influenced by population size, available park area, and population distribution in the unit. Used in conjunction with indicator C1, C2 and D1 can help identify which is/are the limiting factors. For instance unit 5a has a very low value for indicator G2 compared to the other units; this is clearly due to the low value in indicator C1 and also a relatively higher average distance to the closest park for residents (indicator D1). The derived indication for urban planners is that this unit needs new parks, possibly located near the main residential areas. Indeed, it will be important to acknowledge the strong rural character of this unit, which could also be considered an indirect cause of the low values for several indicators. Unit 3b on the other hand shows relatively low values for G1 and G2 most likely due to the lower population size of the unit, as indicated by C1 and C2 and only to a lesser extent to distances between demand and supply. In this case a planning indication would be to provide new entrances or new pedestrian routes to better serve the residents but also, considering the high availability of green spaces in the unit, to better connect the existing parks to other units to increase urban park accessibility for these units. Furthermore, the results for this unit are, to a certain extent, influenced by the presence of a relatively large industrial site.

Based on our results one of the two gravity-base indicators should be selected to avoid using repetitive indicators. However, differences between indicators G1 and G2 are related to the spatial distribution of the population in the units. When the unit's population is evenly distributed around the centroid the indicator's values are similar, while when the unit's population is concentrated in areas away from the centroid, in general, G2 shows a lower value compared to G1. The dimension of the difference is related to the park distribution in relation to the centroid and to the main population nuclei. If G1 is used when data to compute G2 are not available, it is advisable to also consider distance-based indicators, to better analyze accessibility in the units when making planning decisions.

In general, the study also confirmed that many correlations exist between a number of indicators, but not all of them. Other studies have compared accessibility indicators, similarly, they have shown that they could provide different results in the same urban areas (La Rosa, 2014). Nevertheless, this is one of the few studies (Wang et al., 2021) that assessed the correlation between a large set of accessibility indicators. On the one hand, the study has shown which indicators can be interchangeable without losing important information. On the other hand, when selecting the indicators to be used, one should calculate and apply one among pairs of indicators showing high correlations; deciding which is the best based on the aim, on the main characteristics of the indicators and on data availability. In this specific case, the total area of parks in the urban unit (C1), mean minimum distance to closest park for urban unit residents (D1) and percentage of urban unit population living within 300 m from park (D2) showed the lowest replaceability. Whereas, the other seven indicators had an equally high number of correlations; therefore, based on our results, these may be the most likely to be dropped during the selection of indicators.

Interestingly, the two per capita indicators that are positively correlated between each other, show a high number of negative correlations with the other indicators. Similar consistent negative correlations were found in previous studies (Wang et al., 2021). The population size strongly influences the values obtained if compared to the other indicators. This may suggest misleading information when compared to gravity-based indicators.

4.2. Study limitations and research needs

With this study we provided the application of different methods for measuring park accessibility that can be applicable to other study areas in different geographical contexts and, to a certain extent, with different data availability. The main limitation in matching such indicators with reality remains the fact that they only consider spatial accessibility, while access to urban parks can be influenced by many other cultural, social and economic factors. Distance to origin and size are certainly not the only, nor necessarily the most important elements that attract users to parks. Park facilities and features, user preferences (Campagnaro et al., 2020; Sharifi et al., 2021), competition with other public or private open spaces or other leisure facilities, could have a greater effect than distance in determining park access. For these reasons further studies should also investigate other dimensions of accessibility, combining GIS spatial analysis techniques with methods to classify park features and attractiveness and social surveys to test users perception and preferences (Wang et al., 2021).

Indeed, the datasets used to calculate indices represent other main limits within which analyses can be conducted (La Rosa, 2014). For example, the applied indicators do not include or provide information on the type of potential users. However, this type of information, if available, could be used to assess possible social inequalities in the provisioning of urban parks, an important aspect in current urban planning. Another, however intrinsic, limitation is the lack of consideration of the quality of urban parks. In fact, not all urban parks are equal in terms of the ecosystem services they can provide. However, this would require specific attention to include relevant data or information in indices related to accessibility.

Considering the importance given to the route from origin to park, in many of the proposed indicators, it could also be interesting to consider factors other than distance, which could actually influence user willingness to walk to a park. In our study, when isolating the pedestrian road network from the overall street network, we were only concerned with the absence of obstacles and safety aspects. In further analyses, other factors such as, for instance, aesthetics (e.g. views, surrounding buildings), microclimate (e.g. tree cover, windbreaks) and traffic noise control (e.g. barriers, water features) could be considered in the definition of the pedestrian road network, thus introducing a route quality factor in the computation of the service area of the parks. Furthermore, other transport modes could be considered (Pinto et al., 2022) to account for recent trends in mobility and provide possible scenarios linked to favoring certain transportation modes (e.g. use of bicycles, scooters).

This study reported and compared data on a specific land unit. Indeed, when the unit of reference is changed (decreasing or increasing the spatial scales of analysis) different information will be provided. Therefore, modifying the spatial grain and extent of the assessment would allow a more in-depth comprehension of accessibility (e.g. comparing this study's results with the focus in Campagnaro et al., 2019).

5. Conclusions

Urban planning has been acknowledging the social importance of green spaces through an increasing focus on cities' necessities. Our study gives crucial information for identifying useful indicators of their accessibility. This study contributes to the literature concerning park accessibility in several ways: it identifies and applies a framework of methods transferable to other study areas with different geographic contexts and data availability; furthermore it proposes criteria to optimize measures of destination choices, and demand origin. The study has therefore highlighted similarity and replaceability for the applied accessibility indicators and included comments on their effectiveness and reliability for planning and monitoring urban green space in cities.

CRediT authorship contribution statement

Paolo Semenzato: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Anna Costa:** Investigation, Writing – review & editing. **Thomas Campagnaro:** Conceptualization, Methodology, Formal analysis, Visualization, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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