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Article

Assessment of urban surface performance of open spaces with multi-criteria decision-making method

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ABSTRACT

The research presents a multi-criteria decision-making method that focuses on evaluating spatial performance by considering all areas without roads or structural elements as "urban surfaces". In this context, the Seyyid Ömer neighbourhood in Istanbul's Fatih district, as the study area, was discussed in detail in terms of physical, ecological, and social criteria and their sub-criteria. While the physical criteria include the size of each area and enclosure; the ecological criteria were studied with permeability rates and the normalised difference vegetation index (NDVI) value, which measures unit area through the amount of chlorophyll. In addition, the type of property and land use in the urban context, which are the main factors for citizens' interaction with open spaces, were included as sub-criteria under the main social criterion. The relationships between the identified criteria and the open space typologies in the neighbourhood were converted into an index using the analytical network process (ANP) to measure the urban surface performance. The developed index indicated that some urban voids stand out even more than the important ones and have greater potential than urban parks such as Çukur Bostan in terms of social and vegetation qualities. As a result of the research, a map of the importance level was created to illustrate the potential areas for improving the urban ecological performance. Then, various pocket parks such as Şelaleli Park and Skate Park and urban voids regarding their physical, ecological and social values were extracted as potential urban open spaces. With this structure, the research proposes a multi-criteria index that can be used to evaluate the potential of urban surfaces by putting them on a multi-dimensional and computable scale.

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INTRODUCTION

Cities are holistic structures of hybrid ecosystems that change and transform with human and environmental interaction. Although a limited part of the world consists of built surfaces, a significant proportion of the human population is concentrated in these areas (Alberti et al., 2003). The cumulative effect of human action and the built

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environment in the near future is predicted to increase the number of people living in metropolitan areas and account for 70% of the world's population (Lin & Grimm, 2015). This situation also corresponds to the land use and environmental problems that increase and intensify over time with the centralisation of population, production and movement. Therefore, cities leave a huge ecological footprint on the world (Alberti et al., 2003, p.1170). The increasing horizontal and vertical urban growth causes the open and green areas to decrease both in quality and quantity. The atmospheric temperature has increased by about 1°C since the Industrial Revolution, which is an important aspect in the destruction of natural areas and the formation of the greenhouse effect. The prediction is that should this trend continue in this way, the temperature difference will reach 1.5°C in 2040 (IPCC, 2018, 2021, p.1). However, today, increasing environmental awareness in the context of climate change, with the effect of fundamental environmental problems such as urban heat islands and drought, compels cities to focus on both problems and potentials. Therefore, research on the ecological qualities of urban surfaces and the importance of their use in urban life is gaining more importance (Kazmierczak & James, 2007; La Rosa, 2014; Niemelä, 2014; Dyson et al., 2019). In addition to ecological features such as the distribution and quality of green areas are the main factors that directly shape and determine the quality of life and stage of the world population (Reid et al., 2005, pp. 71–84).

In the current literature, importance is placed on studies focusing on various specialised subjects such as the ecological qualities of green spaces in the urban fabric through vegetation (Firozjaei et al., 2020), examining their potential according to property typologies (Dyson et al., 2019), and focusing on the urban accessibility relationship of open spaces (Liang et al., 2021). However, it can be said that there are still gaps in examining the interactions of people with urban open spaces and in revealing the property, usage typologies, and green space qualities provided by these surfaces from a holistic perspective. Therefore, the theoretical infrastructure of urban ecology can be applied in order to deepen the potential of urban surfaces to create physical space in terms of providing social benefits. Although urban open spaces have become the focus of ecology-based design approaches, it should not be ignored that urban ecology, an approach that integrates natural science and social sciences, and a frontier profession that has not yet been widely evaluated. In particular, the attitude of ecological studies that ignored built environments until the second half of the twentieth century played a significant role in the emergence of this situation (Grimm et al., 2008). Today, while considerable progress has been made on urban ecology (Mcdonnel, 2011, p.756), research on the use and environmental qualities of urban landscapes is still not at the same level as research on natural landscapes. At this point, many research topics have been suggested, aiming to link the theory and practice of urban ecology with its socio-demographic, ecological, and technological dimensions, and focusing on the benefits they provide to the citizens of the city (James et al., 2009; Niemelä, 2014; Verma et al., 2020).

The conceptual framework offered by urban ecology is based on socio-ecological systems which are put at the centre of ecosystem services. This framework is based on the integration of the social structure in which humans exist into the ecological structure (Niemelä et al., 2011, p. 1–4). As the keystone of urban ecological systems, urban areas come to the fore as urban spaces which have vegetation cover but no structure (Dunnet, et all., 2007, p. 8), that citizens benefit from directly or indirectly (Baycan-Levent et al., 2002), and that provides an environment for different activities and experiences depending on the spatial pattern of the urban fabric (Van Herzele and Wiedemann, 2003, p. 110). These spaces also typically include valuable landscape remains with respect to biodiversity carrying the traces of cultural life (Barthel et al., 2007) in terms of being a cumulative result of users, objects, or actions in and around them (Madanipour, 1996). In this situation, landscape elements form "Novel Ecosystems" (Hobbs et al., 2006, p. 2) reflecting both the social and ecological qualities of the city.

Another feature that has a key place in the formation of this originality and in the basis of urban life is that these spaces are physical stages that allow for the accidental intersections of social life. The systematic structure of these areas, which define the interaction area of the society and reveal the character of the settlement they built, is shaped by urban fiction (Erdönmez & Akı, 2005). It would be appropriate to focus on the smallest hierarchical unit, the urban space, where the ecological effects and social equivalents of this spatial limitation can be observed. The subject of examining the relations it establishes with its environmental context in terms of the fact that the neighbourhood scale hosts many different open space constructions and usage (Rouse & Bunster-Ossa, 2013) has been considered as a limiting factor within the scope of the research.

The objective of this study is to determine the performance of urban areas by examining their spatial qualities along with social and ecological dimensions. For this purpose, a selected urban district, suitable as a benchmark for the evaluation of socio-ecological characteristics, was analysed using weighted multi-criteria based on city plans. In this regard, the multi-criteria decision-making (MCDM) method (Triantaphyllou, 2000) was selected for its convenience in analysing the complex relationships of the open space typologies. To this end, the importance levels of the criteria were determined using the analytical network process (ANP), which stands out as a superior method for creating a cyclic and interactive network relationship among the criteria (Saaty, 2002). Spatial analysis and performance maps were then generated for the neighbourhood pattern based on the study area. As a result, an index for assessing the performance of the urban surface was developed.

METHOD

Various methods have been utilised in the literature in order to understand the complex structures of cities and ecological processes. The leading of these methods is numerical grading, in which indexes and indicators are used as comparison tools. While indicators represent the attributes and functions of a system (Gallopin, 2005), indexes represent more complex values consisting of weighted sub-elements of many different indexes or indicators (Wu & Wu, 2012). Therefore, indexes are important tools for analysing the multi-factor relational structures of dynamic urban systems and making self-evaluations about their current status (Huang et al., 2015). Although indexes have an important place in measuring sustainability, the accuracy of the results they provide cannot always be guaranteed. The value of an index rather than its conformity to reality can be measured by its explanatory-interpretive representation capacity and functionality (Machado, 2004, p. 100). The most common indicators used to measure the ecological qualities of urban open spaces are the size of green areas per capita, the ratio of green areas, and the extent of green areas. If taken on a larger scale, the next most common indicators are conceptual evaluation schemes from upper scales to lower scales approaches (Raymond et al., 2017) to evaluating ecosystem services with sustainable urban ecology (Olalla-Tárraga, 2006; Larondelle & Haase, 2013), and closer to residential areas, suitability analyses and evaluation indexes. These indexes include landscape metrics such as landscape structure indicators (Cook, 2002), landscape network connectivity indexes (Saura et al., 2011), open area indexes, habitable area indexes (Bölen et al., 2011) or vegetation surface width, distribution density (Liu et al., 2016), and weighted fractal indexes (Zhao et al., 2014). In addition to these, it is seen that indicators such as public space quality indexes (Siregar, 2014), visibility analyses, visual impact assessments (Saeidi et al., 2018), and urban landscape quality indexes (Gavrilidis et al., 2016) are used in examining the relations between public uses and their physical components. However, it can be said that these approaches focus on a singular main criterion and its sub-criteria clusters. From this point of view, the research aimed at a holistic analysis of the focus of three main, based on the fact that cities are unique ecosystems shaped by human influence. To highlight the problems and potentials of the physical, ecological, and social characteristics, the methodology of this study was built as a holistic evaluation

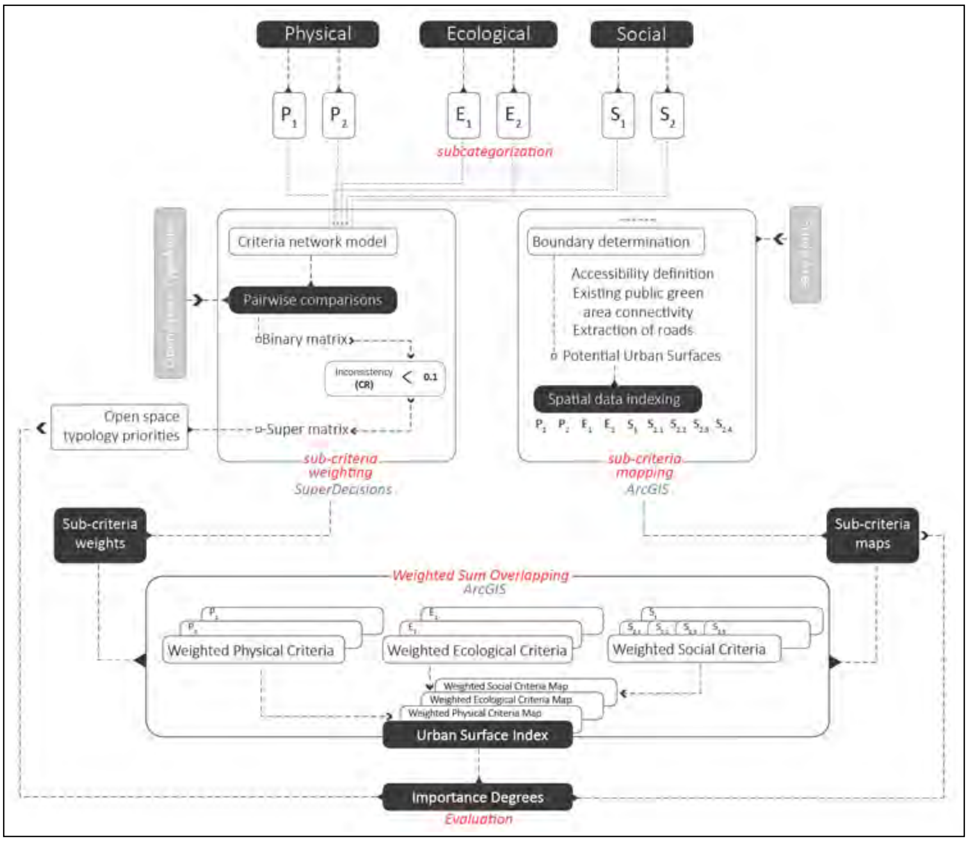

Figure 1. Methodology flow.

through sub-categorisation, sub-criteria mapping and weighting, overlapping of the maps' weighted sum, and evaluation (Figure 1). While the first step emerged from the literature review, the weighting of the selected sub-criteria was elaborated using the analytical network process (ANP) method in SuperDecisions Software (Saaty, 2002). With the aim of analysing the characteristics of the routers of each spatial unit under the mechanism of multi-criteria decision-making (MCDM), all criteria related to the urban open space typologies were weighted with binary and multiple comparisons to obtain the important values and criteria weights. Subsequently, the urban surface index was obtained by mapping each sub-criterion and combining it with each weight in ArcGIS (Esri, 2020). As a result, the urban surface performances of all open areas in the study area were measured and compared with the current situation.

Criteria and Weighting

Research on open space is diverse, as it is a component of visual perception (Cullen, 2012), the image of the city (Lynch, 1960), a social interaction environment, and the infrastructure system in relation to the impact of green space (Benedict & McMahon, 2012). The spatial functionality of the areas within the structured texture varies according to the characteristics, settlements, and typologies of environmental uses (Walzer, 1986, p. 470). Therefore, this functionality is directly related to the size and accessibility of urban surfaces. Also, vegetation quality and density are diminished in commercial functions such as squares with high levels of spatial movement and access, they improve as one descends toward the city park and private spaces. In order to evaluate urban surfaces quantitatively, unit areas were divided into two sub-criteria under the physical, ecological, and social main criteria, and their sub-criteria evaluations were shown in Table 1. The physical criteria were unfolded into the land size and enclosure values. Land dimensions reflect the value of all unit areas (A*i*) in m^2 in the neighbourhood, excluding roads, pavements, and structural elements. The enclosure value is the ratio of the accessible boundary length (Px*i*) to the entire boundary length (P*i*) of the area, where all open areas are not blocked by any structural element.

Ecological criteria expanded into permeability and vegetation quality based on orthographic photo information. Permeability of the surface is defined as the ratio of each unit area (A*i*) to its impermeable surfaces (Ax*i*). Vegetation quality was obtained with the normalised difference vegetation index (NDVI) which is calculated through orthographic photographs throughout the neighbourhood. NDVI is a numerical notation that measures the quality of green areas with the amount of chlorophyll and is a method used by many natural resource researchers for many years (Takács et al., 2014). Its value is measured by the difference and amount of radiation intensity reflected by plants between the near-infrared (NIR) and visible red (VIR) regions (Carlson & Ripley, 1997). Even though the index does not distinguish the typology of vegetation, such as trees, shrubs, or land cover, the value of the spectrum expresses the knowledge of the relative comparison between them. The index outputs values in the range of −1.0 to +1.0. Values between −1.0 and 0.0 indicate that there is no vegetation, while values between 0.0 and +0.5 indicate that there is very little vegetation like groundcovers, shrubs or small trees; and above +0.5 means rich vegetation like broad canopy tree-dominated areas (Bakay, 2012, p. 11).

The social criteria were defined as publicness types of zoning status and land-use characteristics. The parks, playgrounds, and neighbourhood gardens were considered as public spaces; parking lots were considered semi-public areas. Also, urban voids between building blocks were included in the study as private open spaces. Land-use types were examined as the accessibility of all residential,

Table 1. Criterion list with sub-criteria and their evaluation units

Main-criteria	Sub-criteria	Evaluation
Physical	Land size	A*i*
	Enclosure	PX*i*/P*i*
Ecological	Permeability	AX*i*/A*i*
	Vegetation index (NDVI)	(NIR – VIR) / (NIR + VIR)
Social	Property types	Public, semi-public, private
	Land use types	Residential, commercial, religious, education

Table 2. COpen space typologies

Open Space Typologies			
Urban squares	Pocket parks	Playgrounds	Neighbourhood parks
Market squares	Courtyards	Shortcuts	
Urban parks	Urban voids	Private gardens	Traffic islands

commercial, religious, and educational buildings within the boundaries of the neighbourhood within the 500 m walkable zone and were mapped for each. Within the scope of this research, the characteristics of the open space typologies at the neighbourhood scale in the context of the urban environment were taken into consideration in terms of evaluating the social relations of the citizens with their surroundings. These typologies are listed in Table 2. After establishing the criteria and open space typologies, the weighting stage was initiated. At this stage, the objective was to evaluate the open space typologies that could be included in the neighbourhood scale using the established criteria and to make numerical comparisons between them. Thus, the importance levels of the selected criteria were determined, as well as the importance levels of the open area typologies. The ecological, social, and physical characteristics of open spaces were developed using the multi-criteria decision-making (MCDM) model during this process. MCDM follows a flow in which multiple active criteria are considered and the most appropriate option is determined as a result (Yıldız, 2014).

Analytic Network Process

The analytical network process (ANP) stands out in an associative with analytic hierarchy process (AHP) which is one of the most commonly used mathematical methods and the most robust decision measurement theory in solving complex problems involving more than one variable (Kou & Ergu, 2016). The focus of both methods includes breaking down a complex problem into sub-problems and combining the solutions corresponding to each of them with expert opinions (Saaty, 2002). In this way, it serves as a tool that assists the designer make decisions by determining the relative importance of the given criteria in order to select the most appropriate outcome from the listed pool of alternatives. Through its hierarchical structure, the criteria integrated into the system are evaluated independently. At this point, the ANP method becomes prominent as a superior method because it establishes a cyclical and interactive network relationship between the criteria and the alternatives. Thanks to this reciprocal system, a holistic priority matrix is created by using the pairwise comparisons of each node for the goal with Saaty's importance scale of 1–9 (Table 3).

Therefore, within the holistic approach of this study, ANP was used as the main decision-making system, due to its compatibility with the analysis of not only quantitative but also implicit factors. From this point of view, the criteria identified from the literature were evaluated using the SuperDecisions Software (Saaty, 2002). SuperDecisions is a free educational software developed by Saaty and his team. Thanks to its strong link to theory, and suitability, it is widely used by decision-makers and academics (Mu & Pereyra-Rojas, 2016; Ruano, 2018; Mirzaei & Nowzari, 2021). The software works with a cyclical, systematic model to achieve the goal. Each criterion should be compared for all alternatives in terms of their priorities by specialists. In order to obtain the priority values of the criteria based on the selected open space typologies at the neighbourhood scale, each criterion was evaluated in pairs in a comparison model (Figure 2). This model consisted of three modules: the objective for determining priority values, the alternatives for the typologies, and the sub-criteria that included all the main physical, ecological, and social criteria. In this cyclical model, the pairwise comparisons of each sub-criterion were scored between 1 and 9 in relation to the alternatives (Figure 3). This resulted in the priority list (Table 4) for each sub-criterion and the values for the main criteria based on this list in a range between 0.0 and 1.0.

As a result, all priority distributions of open space typologies were obtained for each sub-criterion for relative criteria. Not only the ranking of priorities but also the weighting of sub-criteria for each alternative was elaborated. In this sense, urban parks, neighbourhood parks, private gardens, and courtyards are the most important open space types; social and ecological main criteria are more important rather than physical ones. As a total result of comparisons, all sub-criteria with respective weights were illustrated in Figure 4.

Table 3. Saaty's importance scale of 1–9 (Saaty, 2002)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

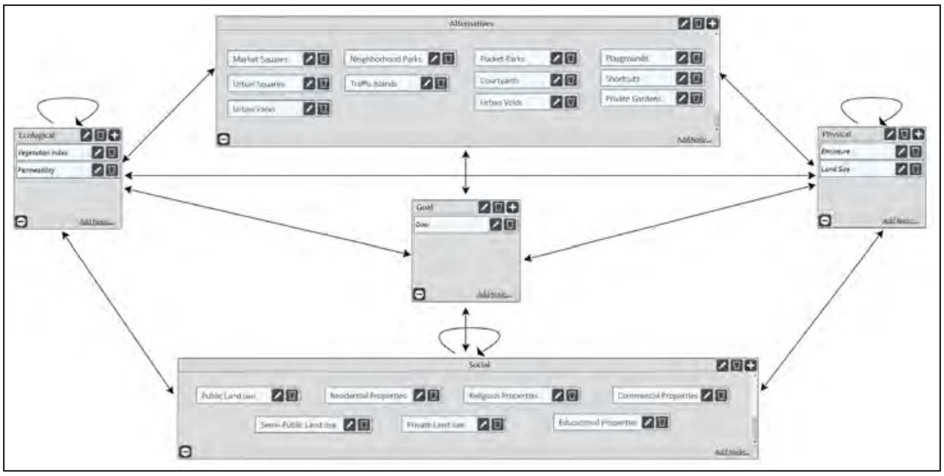

Figure 2. ANP network of relationships from SuperDecisions Software (Creative Decisions Foundation, 2021).

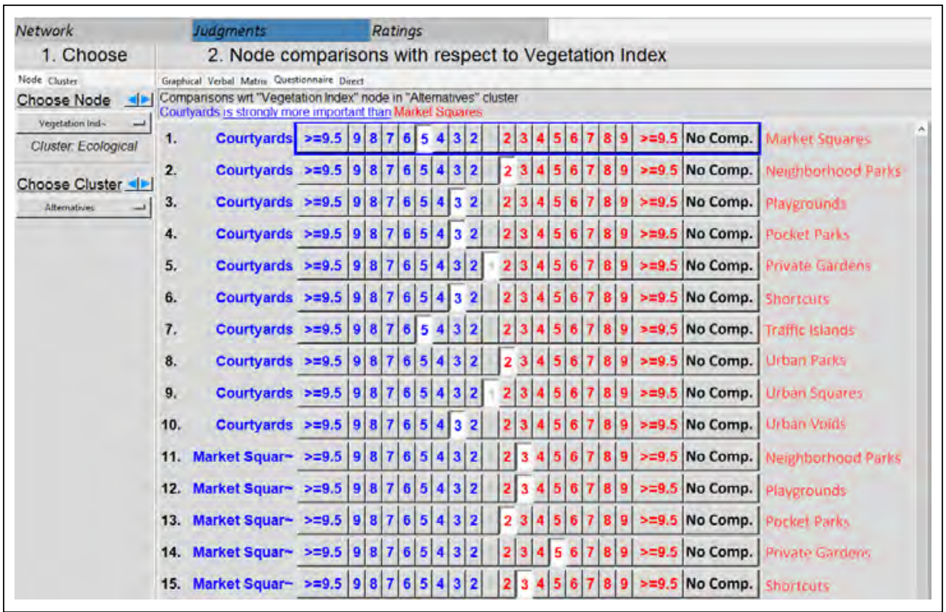

Figure 3. Pairwise comparison questionnaire for vegetation index from SuperDecisions program (Creative Decisions Foundation, 2021). Each criterion was compared for all alternatives as binary evaluation.

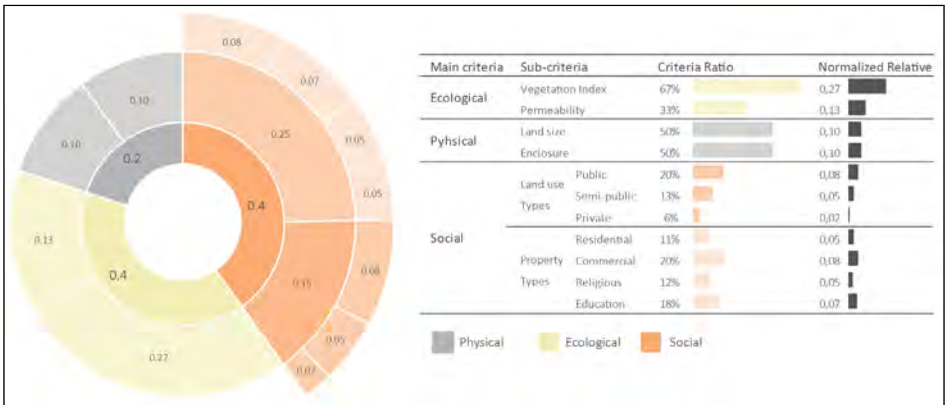

Figure 4. Sub-criteria weights and ratios for each criteria group.

Table 4. Priority table for each open space typology based on related sub-criteria weights

Priority	Open Space Typologies	Criteria Weight Distribution											Priority Values (Normalized by Cluster)
		Ecological		Physical		Social							
						Property Types			Land use Types				
		Vegetation Index	Permeability	Enclosure	Land size	Public	Semi-public	Private	Religious	Education	Residence	Commercial	
1	Urban parks	0.5	0.5	0.333	0.667	0.18	0.136	0.108	0.094	0.151	0.196	0.135	0.15456
2	Neigh-bourhood parks	0.667	0.333	0.667	0.333	0.177	0.134	0.107	0.124	0.184	0.13	0.144	0.13141
3	Private gardens	0.667	0.333	0.333	0.667	0.11	0.138	0.184	0.135	0.135	0.199	0.099	0.11488
4	Court-yards	0.5	0.5	0.25	0.75	0.185	0.138	0.11	0.154	0.113	0.188	0.113	0.10161
5	Play-grounds	0.667	0.333	0.25	0.75	0.169	0.139	0.114	0.098	0.213	0.149	0.119	0.08673
6	Urban squares	0.8	0.2	0.667	0.333	0.214	0.136	0.095	0.156	0.119	0.092	0.189	0.08131
7	Pocket parks	0.75	0.25	0.75	0.25	0.179	0.135	0.108	0.114	0.089	0.157	0.219	0.08078
8	Market squares	0.667	0.333	0.667	0.333	0.178	0.134	0.107	0.139	0.114	0.092	0.235	0.07229
9	Shortcuts	0.667	0.333	0.80	0.20	0.136	0.165	0.112	0.142	0.132	0.089	0.223	0.06869
10	Urban voids	0.667	0.333	0.667	0.333	0.178	0.134	0.107	0.086	0.171	0.126	0.199	0.05809
11	Traffic islands	0.5	0.5	0.333	0.667	0.169	0.135	0.124	0.148	0.097	0.118	0.21	0.04964

As shown in Figure 4, while the social and ecological criteria were equally rated at 0.4, the physical criteria achieved a value of 0.2. Accordingly, the ecological criterion of the vegetation index gained importance in its own group with a value of 0.67, surpassing the surface permeability (0.33). While this value represented the highest percentage of the total criteria pool at 0.27%, it was followed by surface permeability with a value of 0.13. Within the physical criteria, both land size (0.5) and enclosure (0.5) had equal weight as a 0.1 normalised relative value. Social criteria were divided into several sub-headings; property types (0.15) have 3, and land use types (0.25) have 4 sub-headings. While commercial had the highest value (0.2) among property typologies, public spaces (0.2) ranked first among land use typologies.

STUDY AREA

After weighing the criteria, the study area was selected considering the neighbourhood layout. The main selection parameters were specified as long-standing neighbourhoods, which have traditionally built textures to test existing ecological and social values regarding vitality and open space interactions. For this purpose, Seyyid Ömer neighbourhood, one of the oldest neighbourhoods of Istanbul, located in the historical peninsula of Fatih district, was selected as the study area. It is located within the coordinates 41°01'21, N°28'56 and is surrounded by the Byzantine walls, the Golden Horn and the Marmara coast.

Aside from its dissolved neighbourhood texture, an area that draws attention is Fındıkzade Çukur Bostan which gained the function of a garden by having vegetables and fruits planted by its fertile lands after the dysfunctionality of the open-air cisterns from the Byzantine period (istanbul.net.tr, n.d.). It can be argued that this type of function has an increasing effect on the vicinity, and creates a common memory of open space usage. Due to its fragmented but adequately preserved open space system and cultural background, the area promises a valuable neighbourhood pattern in the heart of the Historical Peninsula (Figure 5). The current map of the neighbourhood's orthophotos,

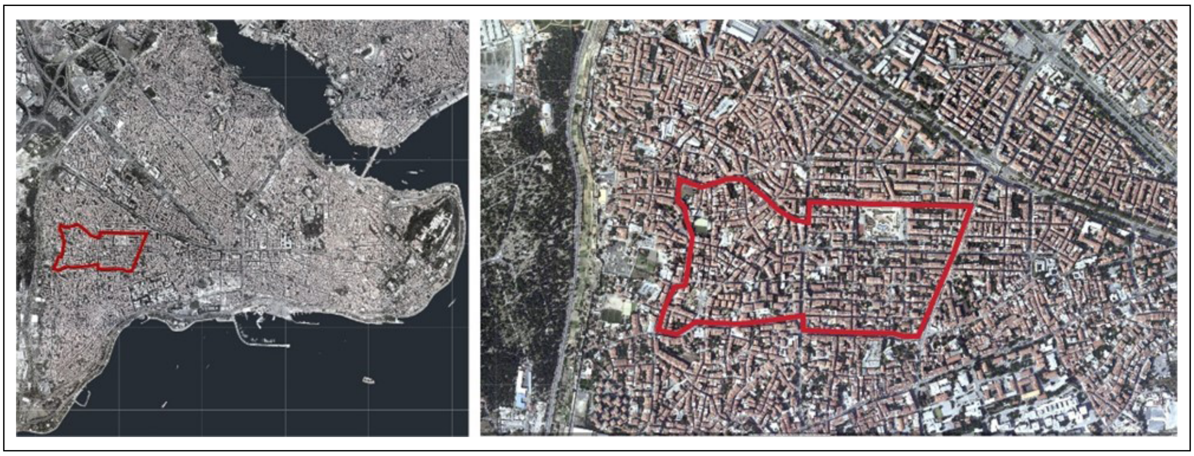

Figure 5. The location of Seyyid Ömer Neighbourhood in the Historical Peninsula and Istanbul Fatih District (Fatih Municipality, n.d.).

which are accessible online, and the 2012 development plan (Fatih Municipality) was used as the main data sources.

URBAN SURFACE INDEX EVALUATION

Based on the weights of the criteria and sub-criteria evaluations from ANP method, importance values were integrated into the index formula for urban surface performance measurement. The primary objective was to develop a measurement mechanism that enabled the identification of problems and potentials within the built texture by treating open spaces as holistic surfaces. From this point of view, the urban surface index was calculated by the weighted sums of the spatial values of the areas within the built texture per unit surface (Equation 1). Accordingly, when UX*i* is the urban surface index, α corresponds to the relative importance weight of the j criterion, and β*ij* corresponds to the scaled spatial value of all surfaces. When the number of all urban surfaces is expressed with n, the sum of the values of each area gives the UX*i*. In this direction, the outputs of the multiple decision-making model were combined with their spatial values using the ArcGIS program and the urban surface index values of alternative open spaces were revealed.

$$UXi = \sum_{j=1}^{n} \alpha j * \beta ij \qquad (1)$$

Evaluation of the urban surface index was conducted on the study area in four main steps: First, the boundary of the computable index area was extracted. Then, all sub-criteria maps were created and rescaled in ArcGIS, after that overlapped by their weights to create each main criteria map. Last but not least, all main criteria maps, ecological, physical, and physical criteria, were overlapped with weights to obtain the final urban surface index value (Figure 6). First, the spatial boundary of the open areas to be included in the calculation within the study area was determined. Considering accessibility and connectivity, a 150m convergence limit to existing public green spaces and main access lines was defined, based on the location of public green spaces within a maximum of 5 minutes walking distance from public buildings and commercial areas (Bayer & Bell, 1998). Issues such as the spatial bond of urban green surfaces with users and how environmental

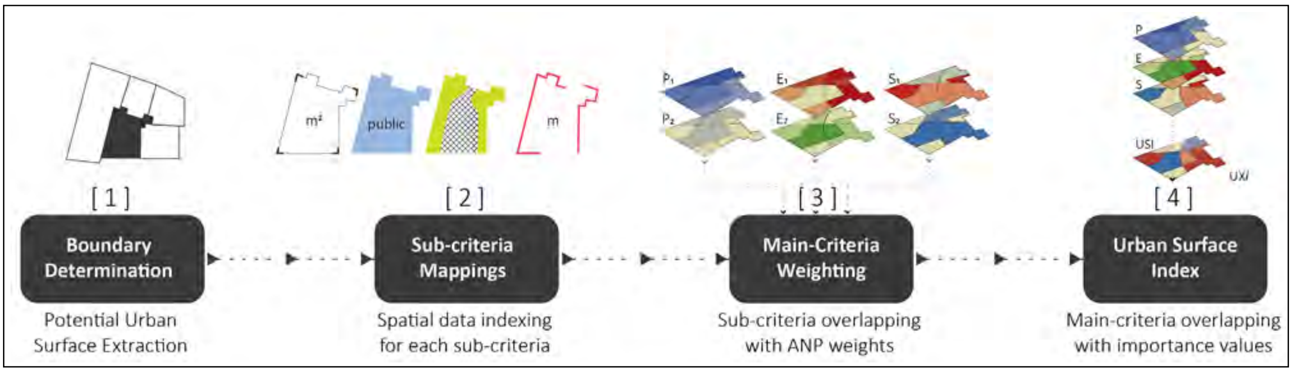

Figure 6. The flow diagram of computation of urban surface index.

functions support them diversify and strengthen the public use of that urban surface (Haq, 2015). In addition to these, the calculation area was determined by leaving roads and sidewalks outside the space boundary. All sub-criteria maps were generated based on this boundary determination. Since there are different sub-criteria and parameters, all maps were reclassified to bring all maps into the same unit based on Saaty's importance table (Saaty, 2002). With this classification, the aim was to combine the criteria consisting of different units (m^2, m, quality, etc.) into one raster data unit. Three distinct data sets were visualised while creating the criteria maps (Figure 7).

Quantitative values such as area dimensions, enclosure values, and surface permeability were converted into raster data by scaling from 1 to 9 by using the "reclassify" method. In addition, the values obtained from the analysis of raster data, such as vegetation quality, were also scaled on a scale of 1–9 with the same method. According to this value range, the analysis result with the lowest score is represented by 1, while the analysis result with the highest score is shown with 9. Since each of the produced maps displays different outputs, this unit of measure is shown in separate legends for the colours used in each map. The weights obtained from the decision support model were

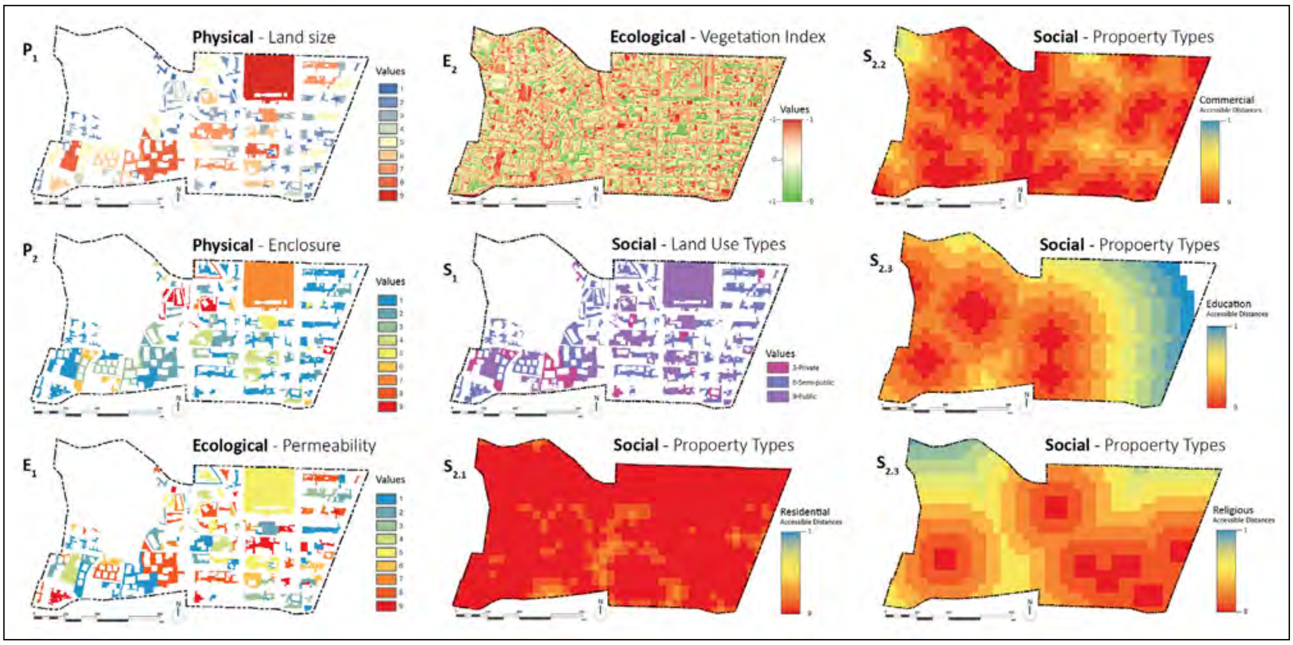

Figure 7. Sub-criteria maps for all main criteria groups.

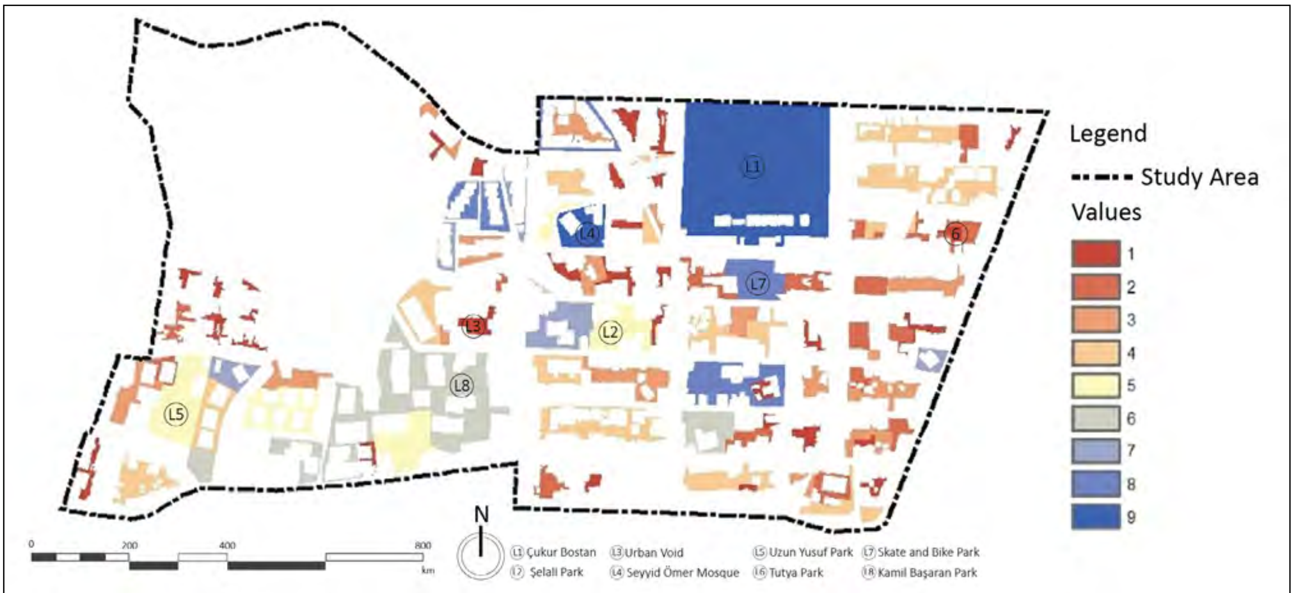

Figure 8. Weighted physical criteria map.

used in order to quantify the social characteristics of the areas and to compare them with other criteria. In the context of urban open spaces, the importance weights for public, semi-public, and private space types were 0.2, 0.13, and 0.06, respectively. The values were then converted to a scale of 1–9 for the land use type raster map, with public use assigned a value of 9, semi-public space 6, and private space 3. Also, property types were integrated into the mapping of impact areas within the research's accessible distances. After the sub-criteria maps were obtained, the "weighted sum" method was used in the ArcGIS program, which gave a superimposed result by evaluating the spatial attributes according to their importance. This method is used to calculate multiple functions in a multi-criteria decision-making process (Yang, 2014). By overlapping the spatial values of all criteria with weights, this method generates new spatial quantitative results.

The function of the urban surface index was calculated within the scope of the research by combining the sub-criteria from top to bottom. In order to obtain a weighted physical criteria map, land size, and enclosure maps were combined with their relative importance values according to the main criteria follows as evenly (Figure 8). By this method, the surface permeability and NDVI maps were combined with 0.33 and 0.67 weights for the ecological criteria map (Figure 9). And the land-use and property type

Figure 9. Weighted ecological criteria map.

Figure 10. Weighted social criteria map.

Figure 11. Urban surface index.

mappings were superimposed according to the 0.61 and 0.39 values for the social criteria map (Figure 10). Then, the maps indicating the weights between each of the three main criteria, the social and the ecological values share both 0.4 and physical 0.2, were once again calculated with the "weighted sum" method. At the end of this process, the urban surface index values of the study area were obtained (Figure 11).

RESULTS

The map of weighted physical criteria (Figure 8) shows that Çukur Bostan (L1) receives the highest rating. Other highly rated areas are some urban voids between blocks of buildings, the Skate and Bike Park (L7) and the Seyyid Ömer Mosque (L4). It can be inferred that these areas were rated based on their enclosure values rather than land size. The other moderately evaluated areas are mostly small pocket parks such as Uzun Yusuf Park (L5) and Şelaleli Park (L2) in terms of their land sizes. In the elaboration of the map with the weighted ecological criteria (Figure 9), the highest rated areas are mainly non-functional urban voids (L3) and some neighbourhood parks such as Tutya Park (L6) and Kamil Başaran Park (L8) with their surroundings. On the other hand, Çukur Bostan (L1) and Şelaleli Park (L2) were rated moderately despite their physical importance. These contradictions become clear by comparing the maps with the main criteria. However, the weighted social map (Figure 10) shows some parallel results for both main criteria. While Çukur Bostan (L1) receives the highest value similar to other criteria groups, some areas that receive a high value from physical or ecological criteria stand out, such as Skate and Bike Park (L7) and Kamil Başaran Park (L8). Also, some areas such as Uzun Yusuf Park (L5) and Şelaleli Park (L2) distinguished despite their low physical and ecological values.

When all maps are evaluated together, building blocks with different zoning types and wide openings stand out in terms of supporting urban ecological values. In fact, it is seen that the ecological criteria of Çukur Bostan (L1) district park, which has the largest surface area in the neighbourhood, is lower than the values of the private or public areas between some building blocks. However, open spaces in the immediate vicinity of the main streets, where commercial use is concentrated, have the potential to establish a spatial relationship to form a network system. When compared with the current zoning status, it can be said that increasing the ecological values of urban surfaces such as schoolyards or parking lots, which have semi-public use characteristics, has an important potential to increase the quality of life. It can be deduced that the open areas in the neighbourhood are predominantly used areas with different zoning typologies under 4 Ha. The areas that stand out with the greatest potential are Çukur Bostan (L1), which is currently used as a public space, and the surrounding educational and religious buildings. In addition to these, it is seen that large building blocks containing some residential buildings have physical potential. On the other hand, the physical qualities of the blocks, which were completely surrounded by structures, received a low response.

As can be seen, Çukur Bostan (L1), whose green features draw the most attention in terms of structural texture, has an average score in terms of ecological criteria, while it increases the urban surface index with its social and physical values. On the other hand, Tutya Park (L6) and Kamil Başaran Park (L8) also receive a high overall index score despite their lower scores on some criteria. Therefore,

Figure 12. Importance degrees of the surfaces.

inferences can be made about expanding the size or usage patterns of existing surfaces or improving their potential within their existing borders. At this point, it would be useful to evaluate the alternative open space typologies obtained during the determination of the criterion weights together with the index results. This would be important in terms of developing the existing areas and revealing the potential surfaces that can be brought to the city. As mentioned above, the limit of open areas, which have the highest weights in terms of ecological, social, and physical criteria, can be considered to be 6 points. Thus, the ecological, social, and physical characteristics of surfaces are classified into three categories according to the benefits they provide to cities (Figure 12). A degree of "Very Important" describes the surfaces on the 8–9 scale, "Important" represents the 6–8 scale, and "Least Important" is the 1–6 scale. The purpose of a triple classification is to establish a framework for designing strategies. By defining the action range on a 6–9 scale, it is possible to develop strategies for improvement and/or renewal in these areas, as well as strategies for transformation and/or re-functioning.

DISCUSSION AND CONCLUSIONS

The study of urban ecology has resulted in the development of a paradigm that places a calculable premium on the sustainability of cities (Wu, 2014). Computable criteria can be viewed as indicators and indexes used in quantitative evaluations in the literature. In this respect, it can be said that this research will contribute to the reflection of the theoretical studies and modelling approaches, especially at the landscape scale, into practice, based on the context of urban ecology, which still has gaps in the literature. With this structure, the "Urban surface index", developed within the scope of this research, provides outputs that can direct planning and design by placing the qualities of open spaces on a calculable scale. By considering cities with a complex and multi-dimensional systems approach, this index can examine the ecological, social, and physical indicators of open space in a multi-dimensional way. Nevertheless, most of the literature examines the indicators in a homogeneous and uni-dimensional way. As such, the majority of this research assesses cities as a whole using large-scale remote sensing methods (Patel & Mukherjee, 2015; Mourya et al., 2021). Some urban ecology studies focus on more specific areas; however, their objectives are usually about on one or a few indicators such as biodiversity (Deslauriers et al., 2018), climate comfort (Gómez et al., 2018) or rarely on socio-ecological interactions like population density and vegetation cover (Grove et al., 2014). As can be seen, research that focuses on indices or indexes based on urban ecology usually overlooks the interdependent and complex relationships through uniform indicators.

In this study, the Seyyid Ömer neighbourhood in Istanbul's Fatih district was analysed in terms of physical, ecological, and social criteria and their sub-criteria. By applying a multi-criteria decision-making method, ANP was used to determine an index for elaborating urban open space performances. The index indicated that some urban voids stand out even more than the important ones and have greater potential than urban parks in terms of social and vegetation qualities. As a result of the research, a map of the importance level (Figure 12) was created to illustrate the potential areas for improving the urban ecological performance. In summary, neighbourhood and urban parks such as Çukur Bostan (L1), Kamil Başaran Park (L8) and pocket parks like Tutya Park (L6) with some urban voids nearby the religious buildings gained the highest importance. On the other hand, various functional open spaces with some neighbourhood parks such as Şelaleli Park (L2), Skate and Bike Park (L7) and Uzun Yusuf Park (L5) show potential through the urban surface index. Using this index, these areas were identified as open spaces that need improvement and can contribute to the urban ecological value of the neighbourhood. In this respect, research represents a point that combines theory and practice. Research shows detailed comparisons based on neighbourhood scale by considering the existing qualities of urban open spaces under sub-categories. In addition, it also reveals under which main criteria the existing urban surfaces should be improved. The research is unique in that it focuses on both the scale of a neighbourhood and a multi-dimensional analysis perspective of urban structure. Given the emphasis of contemporary urban ecology theory on socio-ecological relationships, the research has great potential to provide a guide for the redesign of urban open spaces in densely built cities, particularly in Istanbul.

In the present study, the primary criteria relationships were highlighted by limiting the criteria (e.g., land size, enclosure) for the characteristics of urban surfaces. For this reason, it can be said that the measurement units are few in number. For future studies, the sub-criteria for site-specific assessments such as air, water, or sound pollution can be. In particular, in an approach that aims to study the city in different dimensions, the relationship of social life to space should be addressed through field observations. Considering these conclusions, it can be said that the index revealed by this particular research will provide important data for the analysis of the factors that determine the performance of the urban surface and spatial design.

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