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Research Article

Environmental Urbanization Assessment Using GIS and Multicriteria Decision Analysis: A Case Study for Denizli (Turkey) Municipal Area

Erdal Akyol ,[1] Mutlu Alkan,[2] Ali Kaya ,[1] Suat Tasdelen,[1] and Ali Aydin[1]

[1]*Engineering Faculty, Pamukkale University, 20070 Denizli, Turkey*
[2]*Denizli Municipality, DESKI, Izmir Blv., 20010 Denizli, Turkey*

Correspondence should be addressed to Ali Kaya; alikaya@pau.edu.tr

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In recent years, life quality of the urban areas is a growing interest of civil engineering. Environmental quality is essential to display the position of sustainable development and asserts the corresponding countermeasures to the protection of environment. Urban environmental quality involves multidisciplinary parameters and difficulties to be analyzed. The problem is not only complex but also involves many uncertainties, and decision-making on these issues is a challenging problem which contains many parameters and alternatives inherently. Multicriteria decision analysis (MCDA) is a very prepotent technique to solve that sort of problems, and it guides the users confidence by synthesizing that information. Environmental concerns frequently contain spatial information. Spatial multicriteria decision analysis (SMCDA) that includes Geographic Information System (GIS) is efficient to tackle that type of problems. This study has employed some geographic and urbanization parameters to assess the environmental urbanization quality used by those methods. The study area has been described in five categories: very favorable, favorable, moderate, unfavorable, and very unfavorable. The results are momentous to see the current situation, and they could help to mitigate the related concerns. The study proves that the SMCDA descriptions match the environmental quality perception in the city.

1. Introduction

There has been a growing interest on life quality of the urban areas due to many reasons in recent years. The matter holds many components like buildings, physical environment, health, security, and community. The environmental issues of urbanization are the major portion of the physical environment difficulties. The quality of urban environment involves multidisciplinary parameters, and they are interconnected parameters containing the distribution of green zones, the urban heat island, air quality, and building density and geometry [1]. These parameters, vital for densely populated cities, can be monitored easily [2]. A large number of studies enlighten the problems, their sources, and mitigation measures [3–6]. This complex problem also contains many uncertainties and subjective judgements. Therefore, decision-making on these problems is tough and encloses many parameters and alternatives inherently.

Multicriteria decision analysis (MCDA) comes forward to handle that type of problem-solving; it is because the objective and subjective parameters can be defined and evaluated. Multicriteria decision-making takes accounts of several choices or behavior patterns when there exist a number of alternatives which disaccord to a major extent [7]. A set of systematic procedures to analyze multifaceted problems is employed in decision analysis. The problem is allocated into small logical parts each of which is analyzed, and the parts are integrated in a rational manner to form a meaningful solution [8]. MCDA is a very effective method to handle such problems, and it leads the decision makers confidence by combining that information. This practice may be intuitive or analytical [9]. Hence, experience as well as data is vital because the parameters have comparative significance. The criteria may be both qualitative and quantitative [10].

MCDA supports users in analyzing potential engagements or options based on multiple unmeasurable factors/criteria, using decision rules [8]. There are two approaches to classify the MCDA methods, namely, multiobjective decision-making (MODM) and multiattribute decision-making (MADM). The main difference between them is the number of evaluated options. The first one is more suitable to tackle the multiobjective planning, while the latter is designed for selecting discrete alternatives [11]. In this sense, the MCDA methods are classified into three groups: value measurement models, goal, aspiration, or reference level models, and outranking models [7]. The values of alternatives reflect a preference order in the first group. The second group leads methods for "situations in which users may consider it very difficult to express trade-offs or importance weights but may be able to describe outcome scenarios, expressed in terms of satisfying aspirations or goals for each criterion." The outranking models focus on "pairwise evaluation of alternatives, identifying incomparabilities as well as assessing preferences and indifferences" [11].

The analytic hierarchy process (AHP) as a type of MCDA was developed by Saaty [12]. This method consists of three distinct phases: the principle of "building hierarchies," the principle of "setting up priorities," and the principle of "logical consistency" [13]. The first principle is based on findings and detects relations between them. People cannot recognize and analyze the effective factors of a whole structure without dividing it into small parts. It is being performed by a logical process, which aims at building proper hierarchies. "A hierarchy is a specific system type, which is grounded on the assumption that the user assigned entities, can be grouped into separate sets, with the assets of one group impressing the assets of only one other group, and being impressed by the assets of only one group" [14]. The simplest model of hierarchy contains three levels: the first one is the aim of the decision-making problem and the other two comprise criteria and options. Pairwise comparisons in the AHP are engaged for setting up weights among components of the same hierarchical level. All the components of the level are paralleled in pairs with respect to the logical components in the next higher level, obtaining a pairwise comparisons' matrix. In order to represent the relative importance of one component over another, a pairwise comparison scale is announced. Its values range from 1 to 9, and they are assigned to judgement in comparing component pairs in each level [15]. It compares criteria pairwise on a fuzzy-linguistic ratio scale and calculates the overall relative weights based on cumulative computations of all pairwise ratios [9]. AHP also offers a contributive, hierarchical accumulation of criteria [16]. The method was engaged in numerous studies like engineering, nature, and social sciences [17–19]. It is also frequently used in environmental studies [20, 21].

The function of Geographical Information System (GIS) in early times was only storage, displaying geographic data. Presently, GIS has become a significant technology by the inclusion of end users in navigation devices, GPS- (global positioning system-) enabled smartphones, and so on. Moreover, its engagement in spatial analysis by collecting and evaluating geographical and nongeographical data widens the employment of the method. GIS can promote making decisions by integrating some geographical skills like GPS and remote sensing [22]. This capability of GIS made it a powerful tool in many branches of science and technology, namely, natural sciences, archeology, engineering, medical, and social sciences [23–25].

The combination of MCDA with GIS is an effective tool, and they take advantage of each other [26]. The automation, management, and evaluation of spatial data for end users have made GIS an essential player for examining MCDA issues. Nevertheless, increasing GIS applications are called as structures for assisting MCDA problems, and many of them lack the spatial analysis needed by decision makers. MCDA applications offer many skills and measures to help decision makers' preferences. Combination of these methods through a program enabling a user to communicate with a computer delivers the outline of the SMCDA support system. It helps to develop the efficiency of the decision-making by including end users' decisions. Normally, MCDA uses mean or overall data that are uniform in the whole area, which is unlikely in many studies [27]. Nevertheless, the geographical locations of alternatives and criterion values are needed in SMCDA [16, 28]. The GIS and MCDA synthetization began at early 90s. Carver [29] has described the basics and restrictions of merging them. For the comprehensive literature, some literature is available for interested readers [8, 15, 30]. Environmental quality is beneficial to determine the present position of sustainable development and asserts the corresponding countermeasures to the protection of environment.

This study deals with physical environmental quality of the Denizli (Turkey) municipal area as a part of urban environmental quality. The topography that designates particular natural hazard risks and some urbanization parameters is employed by using SMCDA and GIS. The results are momentous to assess the current status and to mitigate the related issues.

2. Site Characteristics

Denizli municipal area is one of the highly developed provinces and located at SW Turkey (inset of Figure 1). The area is in a graben area which is bounded by high mountains both in the north and in the south. The downtown is close to the northern part of the graben, and dominant slope direction is from north to south as illustrated in Figure 1.

Environmental assessment zoning maps of the municipal areas are based on the particular natural hazard risks and some urbanization parameters, namely, altitude, road density, green field density, and traffic noise. The altitude in the area controls both sediment size and flooding risk, and it is engaged as a natural hazard parameter. The sediment size distribution is controlled by slopes [31]. The larger sediments have higher strength than the smaller ones as seen in Figure 2 [32]. They cause less damage during an earthquake. Lower altitudes are also under the flooding risks inherently. The altitude values are obtained from the digital elevation

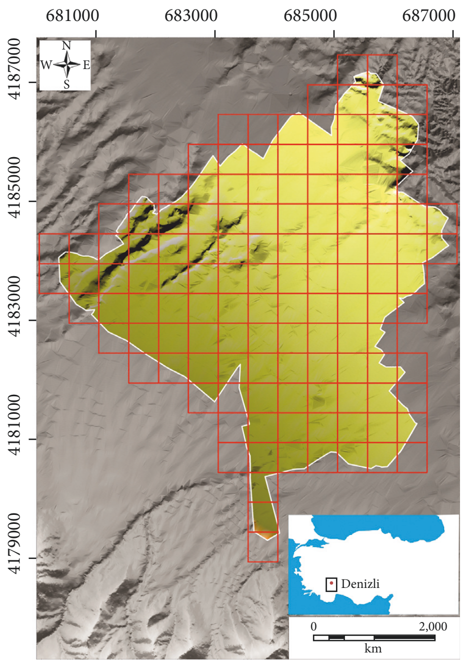

FIGURE 1: Elevation model of the study area.

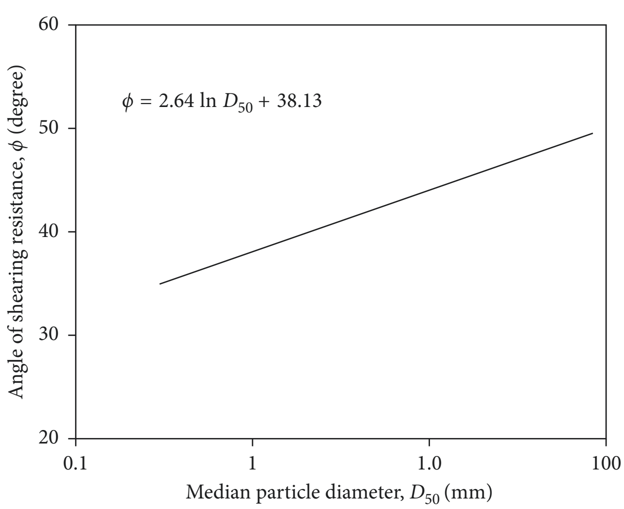

FIGURE 2: Correlation between the median particle diameter and the angle of shearing resistance [32].

model (DEM) of Denizli. The elevation and grain size of the sediments are getting smaller from south to north. Green field density and road density are employed to reflect the urbanization parameters. Because of the data location density, a square grid plan with 500 meters in size is established and every grid is considered for the calculation. The green fields are marked as blocks in the development plans. To find out the green field density, the area of green field blocks is proportioned to the area of building blocks in each grid. Similarly, the total road area in a grid cell is proportioned to the block area. The traffic noise is one of the major parameters for life quality [33], and it is the fourth parameter in this study. The traffic noise data are mainly based on the Cetin study [34].

TABLE 1: Considered parameters and grading.

Altitude (m)	Road density (%)	Green field density (%)	Traffic noise (dB)	Grade
250–275	60–63	0–4	20–25	1
275–300	63–66	4–8	25–30	2
300–325	66–69	8–12	30–35	3
325–350	69–72	12–16	35–40	4
350–375	72–75	16–20	40–45	5
375–400	75–78	20–24	45–50	6
400–425	78–81	24–28	50–55	7
425–450	81–84	28–32	55–60	8
450–475	84–87	32–36	60–65	9
>475	>87	>36	>65	10

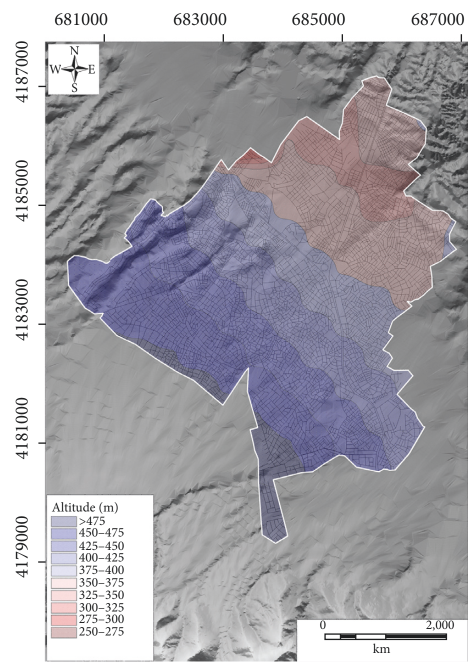

FIGURE 3: Altitude map.

It has not covered the whole study area, and the incomplete data were supplemented later.

This study has engaged the weighted grading as a MCDA. The criteria were compared with respect to their weights after identifying them. In order to implement it, a pairwise comparison matrix composed the relative weights. Then, the generated data were normalized, and the eigenvector associated with the maximum eigenvalue of the ratio matrix. MapInfo® was engaged to analyze and imagine the spatial data.

3. Analyses by MCDA

The employed parameters are, namely, altitude, road density, green field density, and traffic noise. These data are divided into ten groups and graded by using these groupings. The altitude, road density, green field density, and traffic noise values and grades are given in Table 1. The altitude varies from 250 meters to more than 475 meters (Figure 3). Higher altitudes have some advantages in terms of natural risks like flooding. Moreover, soil types at higher locations are coarser than that at the lower ones. It means coarser soils present better seismic characteristics than the fine soils. After all, higher altitudes are more preferable, reflect less natural hazard risk, and have higher grades. The road density is intensive at southern and northern parts of the area (Figure 4). Higher road density represents easy access and more parking spaces in the Turkish case, and it is desirable. Therefore, higher values have high grade points. Similarly, high green field density expresses better environmental conditions. The green field density of the area is illustrated in Figure 5. The vast majority of the municipal area has very low green fields, less than 10%. Limited areas at western and southern parts of the area have more than 20% green area density. Noise displays poor environmental settings. The lowest noise level measured in the area is 60 dB, while the highest one goes up to 90 dB (Figure 6). The central, southern, and northern fragments of the municipal area are noisier than the other parts. Especially, western and eastern districts are quieter, and they have noise level less than 70 dB.

The intensity scale submitted by Saaty [14] was employed in the study, and the measures were defined based on the professional knowledge of the authors. Table 2 lists the formed ratio matrix and the intensity importance values. Normalizing the weights was done by dividing the weights by the sum of the column (Table 3). Average of the cell in the rows gave the priority vector. The ratio matrix and priority vector were multiplied to find out D vector that was divided by the priority vector to get the eigenvector.

The validation of the consistency of the results is done by the "consistency ratio (CR)." The maximum value of the CR is 0.10. When it is higher than that value, the results are assumed to be consistent and should be revised. Randomness Index (RI) and the maximum eigenvalue ($\Lambda_{\max}$) were calculated to obtain the CR.

Randomness Index (RI) is the number of criterion-dependent values (n), and Saaty [12] has proposed it as 0.9. The ratio of Consistency Index (CI) to Randomness Index (RI) is called "consistency ratio (CR)," and it is equal to 0.04. Multiplying the eigenvector of each criterion to the designated points of this criterion in the alternatives gives the weighted value. The ultimate value at the localities was calculated by adding these values at each point, and the final thematic map of environmental assessment is accomplished by these data.

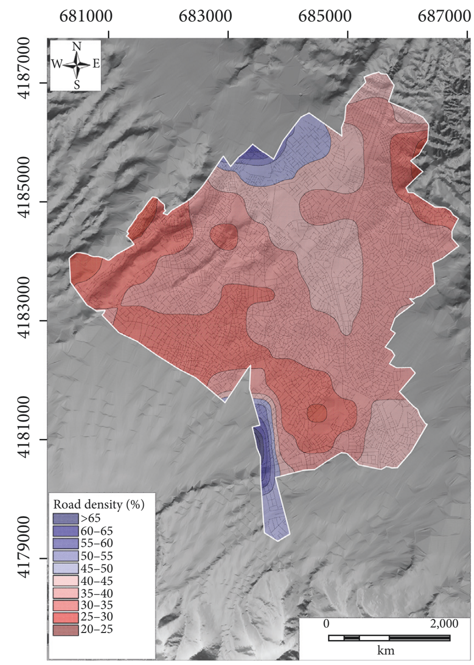

Figure 4: Road density map.

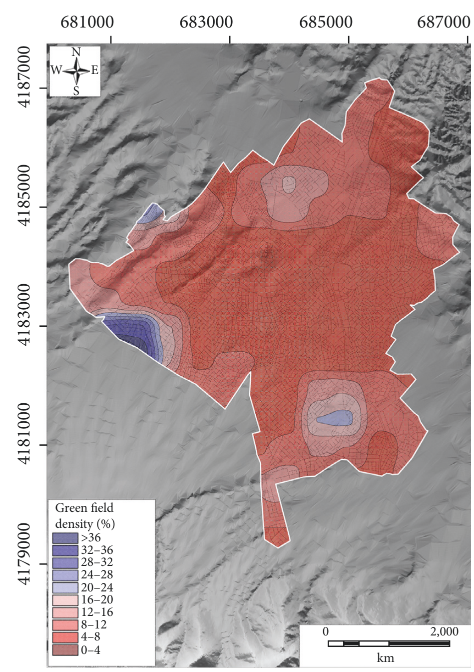

Figure 5: Green field density map.

4. Discussion and Conclusions

Several disciplines that have different approaches and methods deal with the environmental quality phenomenon. These branches vary from engineering to health, sociology, economy, and so on, and they have their own approaches and valuations. Furthermore, assessment of some criteria might be subjective when the perception of the people is concerned. Ironically, the models and/or evaluations should reflect the general perception.

Some problems became visible throughout the study. The first problem to tackle was the choice of the MCDA method. It is well known that MCDA procedures cause dissimilar results. This study has engaged AHP as it offers a structured, yet flexible method to decision-making. Additionally, AHP permits to control the inconsistency of the value judgements. Moreover, the observed data are being employed in a spatial manner. The second and the more critical one was minimizing the risks and cost of

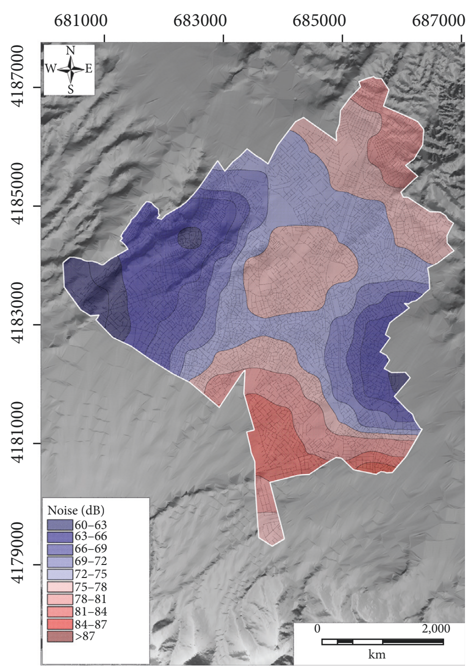

Figure 6: Traffic noise map.

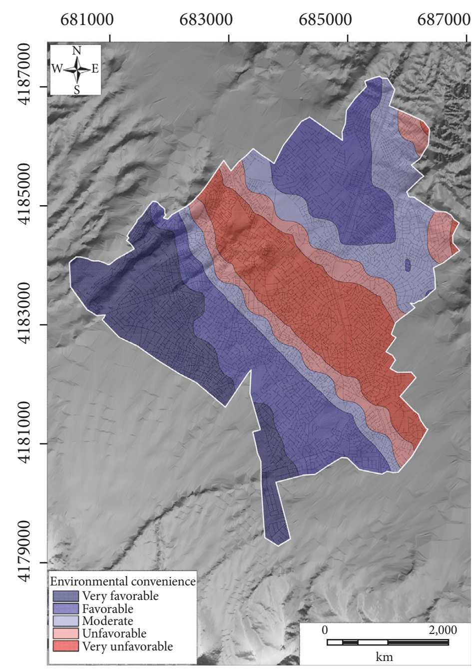

Figure 7: Thematic map of environmental urbanization.

Table 2: Relative importance of weightings.

	Altitude	Traffic noise	Green field density	Road density
Altitude	1	4	5	3
Traffic noise	0.25	1	0.5	0.33
Green field density	0.2	2	1	1
Road density	0.33	3	1	1
Sum of the column	1.783	10	7.5	5.33

Table 3: Normalization and priority vector values of the criteria.

	Altitude	Traffic noise	Green field density	Road density	Priority vector
Altitude	0.561	0.4	0.667	0.563	0.54757
Traffic noise	0.14	0.1	0.067	0.062	0.09219
Green field density	0.112	0.2	0.133	0.188	0.15828
Road density	0.187	0.3	0.133	0.188	0.20197
Sum of the column	1	1	1	1	1

environmental urbanization while maximizing the public acceptance or not. The results should be compatible with the general perception in the city.

The preferences for urbanization quality may be altered by virtue of social, economic, and technological level of the communities. However, globalization eliminates the physical dissimilarities between nations, and multinational companies dominate not only the economic systems but also the lifestyle and cities. This process leads to global hierarchy of cities, which results in increased living standards. Consequently, there are a large number of different criteria to evaluate the quality of the urban areas, and the attributes change in time. The studies show that the considered parameters are not the same. They are infrequently measured by the same units even if they are identical. In many cases, the names of social and political attributes may be misrepresentative [35].

The study has considered some certain natural hazard risks and life quality parameters. The altitude in the study controls the sediment size which is related to strength of the soil as foundation. Moreover, higher soil strength mitigates the earthquake damages. Altitude, naturally, governs the flooding risk of the municipal area. In this case, this criterion covers basic construction requirements. Traffic noise, road density, and green field density are the most common and problematic parameters in many urban areas like Denizli. Air quality has been added in many cases, but it is not a major problem in this example.

The classification techniques frequently use five clusters from "*very pro.*" to "*very con.*" Obviously, this description gives more detail than the three clusters (good, moderate, and bad). In this study, the weighted values have been divided into five equal parts, and the following five zone descriptions have been employed from higher to lower values:

(i) Very favorable
(ii) Favorable
(iii) Moderate
(iv) Unfavorable
(v) Very unfavorable

The distribution of the zones is illustrated in Figure 7. Generally speaking, most of the zones directed in NW-SE direction. "*Very favorable*" and "*favorable*" zones which have the highest calculated points are located at the south, southwest, and northern parts of the municipal area. These regions have higher altitude and partly lower road density. The green field density and noise level are at the average values. On the contrary, "*very unfavorable*" and "*unfavorable*" zones are mainly located around the central part of the study area. These two parts, except the northwestern parts, have low altitude, average road density and noise, and too low green field density values. These zones involve high flooding and soil amplification risks (high seismic risk), which are unacceptable for an environmental urbanization. The "*very unfavorable*" and "*unfavorable*" zones are mainly used for trading and light industrialized activities. The "*moderate*" areas lie between these two groups and cover widely in northwestern parts of the study area.

A comparison with multicriteria model results and the perception in the city might be valuable. Ozer et al. [36] has designated the same area on the basis of socioeconomic parameters. The definitions of the AHP model have meaningfully matched with those descriptions. The described zones reflect the general perception in the city, which is the main goal of the study. The central part of the municipal area is depicted as "*miserable,*" while southern and southwestern parts of the study are known as the best part of the living area parallel to the study.

The study proves that the SMCDA can be employed to assess the urban environmental quality perception in a city when the criteria are set well. The method is beneficial to see the present situation, and such a study may trigger the countermeasures to mitigate the related concerns in an administrative manner.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] J. Nichol and M. S. Wong, "Modeling urban environmental quality in a tropical city," *Landscape and Urban Planning*, vol. 73, no. 1, pp. 49–58, 2005.

[2] V. G. M. Annamdas, S. Bhalla, and C. K. Soh, "Applications of structural health monitoring technology in Asia," *Structural Health Monitoring*, vol. 16, no. 3, pp. 324–346, 2017.

[3] M. Cerreta and P. De Toro, "Urbanization suitability maps: a dynamic spatial decision support system for sustainable land use," *Earth System Dynamics*, vol. 3, no. 2, pp. 157–171, 2012.

[4] J. S. Yang, E. S. Chung, S. U. Kim, and T. W. Kim, "Prioritization of water management under climate change and urbanization using multi-criteria decision making methods," *Hydrology and Earth System Sciences*, vol. 16, no. 3, pp. 801–814, 2012.

[5] E. Borgogno-Mondino, G. Fabietti, and F. Ajmone-Marsan, "Soil quality and landscape metrics as driving factors in a multi-criteria GIS procedure for peri-urban land use planning," *Urban Forestry and Urban Greening*, vol. 14, no. 4, pp. 743–750, 2015.

[6] F. F. Dong, Y. Liu, H. Su, Z. Y. Liang, R. Zou, and H. C. Guo, "Uncertainty-based multi-objective decision making with hierarchical reliability analysis under water resources and environmental constraints," *Water Resources Management*, vol. 30, no. 2, pp. 805–822, 2016.

[7] S. Belton and T. S. Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*, Kluwer Academic Publishers, Norwell, MA, USA, 2002.

[8] J. Malczewski, *GIS and Multicriteria Decision Analysis*, Wiley & Sons, Toronto, ON, Canada, 1999.

[9] T. L. Saaty, *Fundamentals of Decision Making and Priority Theory*, RWS Publications, Pittsburgh, PA, USA, 2000.

[10] C. Kahraman, *Fuzzy Multi-Criteria Decision Making: Theory and Applications with Recent Developments*, Springer, New York, NY, USA, 2008.

[11] G. A. Mendoza and H. Martins, "Multi-criteria decision analysis in natural resource management: a critical review of methods and new modelling paradigms," *Forest Ecology and Management*, vol. 230, no. 1–3, pp. 1–22, 2006.

[12] T. L. Saaty, "A scaling method for priorities in hierarchical structures," *Journal of Mathematical Psychology*, vol. 15, no. 3, pp. 234–281, 1977.

[13] T. L. Saaty and J. M. Alexander, *Conflict Resolution-the Analytic Hierarchy Process*, Praeger, New York, NY, USA, 1989.

[14] T. L. Saaty, *Multicriteria Decision Making, the Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, RWS Publications, New York, NY, USA, 1990.

[15] A. Montis, P. Toro, B. D. Franke, I. Omann, and S. Stagl, "Assessing the quality of different MCDA methods," in *Alternatives for Environmental Evaluation*, M. Getzner, C. L. Spash, and S. Stagl, Eds., Taylor & Francis, New York, NY, USA, 2005.

[16] R. Greene, R. Devillers, J. E. Luther, and B. Eddy, "GIS-based multiple criteria decision analysis (MCDA)," *Geography Compass*, vol. 5, no. 6, pp. 412–432, 2011.

[17] T. L. Saaty, "Absolute and relative measurement with the AHP; the most livable cities in the United States," *Socio-Economic Planning Sciences*, vol. 20, no. 6, pp. 327–331, 1986.

[18] G. Dinardo, D. Levy, and B. Golden, "Using decision-analysis to manage Maryland river herring fishery—an application of AHP," *Journal of Environmental Management*, vol. 29, no. 2, pp. 193–213, 1989.

[19] G. Munda, ""Measuring sustainability": a multi-criterion framework," *Environment, Development and Sustainability*, vol. 7, no. 1, pp. 117–134, 2005.

[20] P. Klungboonkrong and M. A. P. Taylor, "A microcomputer-based-system for multi criteria environmental impacts evaluation of urban road networks," *Computers, Environment and Urban Systems*, vol. 22, no. 5, pp. 425–446, 1998.

[21] J. Solnes, "Environmental quality indexing of large industrial development alternatives using AHP," *Environmental Impact Assessment Review*, vol. 23, no. 3, pp. 283–303, 2003.

[22] S. K. Ghanem, "The relationship between population and the environment and its impact on sustainable development in Egypt using a multi-equation model," *Environment, Development and Sustainability*, vol. 20, no. 1, pp. 305–342, 2016.

[23] D. Cowen, "GIS versus CAD versus DBMS: what are the differences?," *Photogrammetric Engineering and Remote Sensing*, vol. 54, no. 11, pp. 1551–1555, 1988.

[24] M. F. Vine, D. Degnan, and C. Hanchette, "Geographic information systems: their use in environmental epidemiologic

research," *Environmental Health Perspectives*, vol. 105, no. 6, pp. 598–605, 1997.

[25] F. C. Dai, C. F. Lee, and X. H. Zhang, "GIS-based geo-environmental evaluation for urban land-use planning: a case study," *Engineering Geology*, vol. 61, no. 4, pp. 257–271, 2001.

[26] S. Sener, E. Sener, B. Nas, and R. Karaguzel, "Combining AHP with GIS for landfill site selection: a case study in the Lake Beysehir catchment area (Konya, Turkey)," *Waste Management*, vol. 30, no. 11, pp. 2037–2046, 2010.

[27] R. J. Tkach and S. P. Simonovic, "A new approach to multi-criteria decision making in water resources," *Journal of Geographic Information and Decision Analysis*, vol. 1, no. 1, pp. 25–43, 1997.

[28] F. Joerin, M. Theriault, and A. Musy, "Using GIS and outranking multicriteria analysis for land-use suitability assessment," *International Journal of Geographical Information Science*, vol. 15, no. 2, pp. 153–174, 2001.

[29] S. J. Carver, "Integrating multi-criteria evaluation with geographical information systems," *International Journal of Geographical Information systems*, vol. 5, no. 3, pp. 321–339, 1991.

[30] I. Linkov and E. Moberg, *Multi-Criteria Decision Analysis: Environmental Applications and Case Studies*, CRC Press, New York, NY, USA, 2012.

[31] W. E. Galloway and D. K. Hobday, *Terrigenous Clastic Depositional Systems: Applications to Fossil Fuel and Groundwater Resources*, Springer Verlag, Berlin, Germany, 2nd edition, 1996.

[32] J. J. Wang, H. P. Zhang, S. C. Tang, and Y. Liang, "Effects of particle size distribution on shear strength of accumulation soil," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 139, no. 11, pp. 1994–1997, 2013.

[33] D. Botteldooren, L. Dekoninck, and D. Gillis, "The influence of traffic noise on appreciation of the living quality of a neighborhood," *International Journal of Environmental Research and Public Health*, vol. 8, no. 3, pp. 777–798, 2011.

[34] F. Cetin, "Map of traffic noise in Denizli," M.S. thesis, Celal Bayar University, Manisa, Turkey, 2010, in Turkish.

[35] B. Ulengin, F. Ulengin, and U. Guvenc, "A multidimensional approach to urban quality of life: the case of Istanbul," *European Journal of Operational Research*, vol. 130, no. 2, pp. 361–374, 2001.

[36] I. Ozer, H. Kargi, and E. Akyol, *Crime Map and Analysis of Denizli City Center*, Project No: 105G090, (GIS Group), TUBITAK, EGM, Ankara, Turkey, 2009, in Turkish.