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Assessing and Quantitative Evaluating the Locations of Schools Based on Multiple Environmental Criteria (Case Study: Zone 4 of District 5, Tehran)

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ABSTRACT

Crowded or contaminated areas are not proper places for schools because they have a direct impact on the comfort of families who have to commute to schools. In this study, environmental, physical, and residential satisfaction aspects of Primary schools in District 5 of Tehran (Zone 4) were analyzed using GIS joined with a multi-criteria decision-making technique. In this research, nine indicators in two categories, quantitative and qualitative, have been considered as criteria. Quantitative criteria include noise pollution, air pollution, school's green space, slope around the school, proximity to sports and parks, and educational per capita ratios of schools, and quantitative criteria include accessibility to school and school educational quality which was measured by a questionnaire. In total, 467 parents of students were surveyed in this study. The selected criteria were chosen to measure the spatial superiority and all the spatial criteria were used in the form of criteria maps. The sources of spatial data are satellite imagery, existing maps, and statistical data for both governmental and non-governmental primary schools in the study area. The rational importance of criteria maps was determined using the AHP method, while the inconsistency ratio of pairwise comparisons was 0.03. Each criterion was multiplied by the estimated weight and the final scores of the schools were calculated. The results indicated that the majority of the surveyed schools are within walking distance in terms of proximity to parks and sports facilities. Thus, high-quality education needs to be done in proper locations for education. For future research, it is recommended that the compatibility of schools with other urban land uses be examined.

KEYWORDS

Primary School,
GIS,
Qualitative Analysis,
Environmental Factors

1. Introduction

Because a significant portion of students' lives is spent in the school environment, school environmental conditions can help individuals improve learning. The increasing growth of urbanization and the lack of comprehensive planning in the urban system has caused educational applications such as other urban services, for reasons such as lack of optimal location and lack of provision of appropriate spaces, to face many problems. Spatial factors are factors that can affect the quality of places. The location of educational applications is of special importance in terms of various environmental and spatial factors and has a direct impact on the comfort of families (Mohammadi & Hosseinali, 2019). Analysis of the convenience of educational applications is a GIS-based process. The suitability of a place for a particular

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use can be examined from different aspects (Javadian et al., 2011). Determining this suitability is a Multi-criteria Decision Analysis (Moisa et al., 2022). This analysis is a process of finding the best decision or finding the best alternatives based on the criteria which may be conflicted (Malczewski, 2018). Decision- making is a common process in many issues such as site selection, ranking, selection, etc. (Bali et al., 2022; Kahnt, 2024; Trillo et al., 2022).

Information obtained from the use of GIS can be used to investigate the impact of environmental factors on the quality of places and assess the importance of these factors (Antunes et al., 2001). A review of previous research indicates that the issue of land-use location has been studied in many types of research, but limited studies have been conducted to evaluate and compare environmental conditions and factors affecting the quality of primary school locations, some of which are briefly reviewed below. Samad et al. (2012) used the indicators of school accessibility, slope, population density, and river network to evaluate the desirability of school locations using GIS. They used the AHP weighting method to weigh the indicators. Amanpour et al. (2014) evaluated the spatial location of educational spaces in Dehdasht city and as a result of research found that due to non-compliance with location standards in educational uses, these centers are in a good position in terms of proximity to other uses. Murata et al. (2015) measured the performance quality of five secondary schools in Istanbul, Turkey using PROMETHEE outranking method. However, the applied criteria were non-spatial. Shahraki et al. (2016) examined the distribution of educational centers in Piranshahr to analyze the spatial distribution pattern of schools and introduce the optimal model for school redistribution. Meiboudi et al. (2016) created an integrative system for assessing green schools in Iran. They applied fuzzy multi-criteria decision-making methods and found the levels of schools in their study area from the aspect of greenness. Panahi et al. (2019) examined the geographical suitability of schools in two areas of Tehran in terms of access to urban facilities, access to the urban road network, population density, and access to urban services and cultural centers. For this purpose, they used the SWARA method to determine the importance of each factor. Finally, five maps were prepared for the studied factors. Their results showed that the situation of schools located in District 12 was better than District 6. Ayyildiz et al. (2022) implemented a hierarchical cluster-based Interval Valued Neutrosophic Analytic Hierarchy Process (IVN-AHP) integrated VIKOR methodology that includes two stages, clustering, and ranking, to evaluate universities based on student perspective in Turkey. That study employs just subjective criteria (from the perspective of students) without any objective criteria or spatial ones.

In reviewing the studies, there is little information in the field of examining the position of educational uses in terms of environmental conditions in the country, and among these studies, primary schools are less evaluated, as well as studies on the status of environmental indicators. No research has been observed on the environmental situation of primary schools located in District 5 of Tehran. Accordingly, the present study was conducted to assess the environmental and spatial conditions of schools and compare their desirability in primary schools located in Zone 4, District 5 of Tehran. The criteria used in this study cover both objective and subjective aspects of the problem. In this study, in addition to revealing the situation of schools in the study area, research methods and especially methods for evaluating indicators can effectively be used to assess the situation of schools in other parts of the country and provide valuable information for administrators and planners in this area.

2. Method and Materials

2.1. Study Area

District 5 of Tehran has been one of the most populated areas of Tehran, but there is little information about the condition and spatial and environmental desirability of schools in this area. Therefore, in this study, public and non-profit primary schools located in Zone 4, District 5 of Tehran, have been selected for this study. These schools are located in the Parvaz, Southern Sazman Barnameh, and Eram neighborhoods. According to the 2016 census, Tehran's District 5, with a population of 858,346, is home to about 10 percent of Tehran's population. The study areas have a population of 79,606 people and an area of 302 hectares. Figure 1 shows the selected schools located within the study area.

2.2. Research Method

To assess the desirability of the location of schools, many indicators can be effective, which include several aspects. For example, Shahraki et al. (2016), applied indicators from environmental aspects including air pollution, noise, and physical pollution including proximity to green space, the radius of access to school, distance from school to residential areas, acceptable distance from cultural centers, health, commercial, transportation, and urban infrastructure. (Mohammadi & Hosseinali, 2019) used the indicators of greenness, air pollution, noise pollution, access to urban facilities, and compatibility with surrounding land uses. In reviewing the conducted studies, no study has been observed that wants to examine a combination of quantitative and qualitative indicators of environmental and physical factors along with residents' satisfaction in primary schools. Therefore, in this study, the criteria used for the desirability of school location in terms of environmental factors, physical factors, and parental satisfaction of students with access and the educational quality of the school have been investigated. The environmental indicators studied in this paper are noise pollution, air pollution, the slope of areas, and greenery (Mohammadi & Hosseinali, 2019; Shahraki et al., 2016). Physical factors include proximity to sports centers, proximity to the park, per capita proportion of school educational space (Mohammadi & Hosseinali, 2019; Samad et al., 2012) and parental satisfaction including questions about satisfaction with access to school and satisfaction with the educational quality of schools is in the range of 5 Likert options (from very low to very high) that have been measured through a questionnaire. The studied indicators are different according to the type of application, but all of them are aligned to measure spatial superiority (Garcia-Diaz et al., 2016).

After identifying the indicators, they were categorized quantitatively and qualitatively. For the quantitative indicators, the factor maps were prepared. Because satisfaction was measured at the level of 5 options, the average satisfaction of access and educational quality of the school for each school was calculated. Each of the quantitative indicators has its measurement scale, which makes it impossible to compare their values with each other. Thus, each of the indicators should be normalized in such a way as to be comparable together. In the next step, it is necessary to estimate the importance of each of the indicators. The indicators may be evaluated through several methods. The methods can be classified in two groups of data-driven and knowledge-driven, which the former uses the data itself for evaluate the importance of indicators and the latter employs the ideas of the experts (Basile et al., 2022; Dorfeshan et al., 2021). In this study, the Analytical Hierarchy Process (AHP) as a knowledge-driven method was used to weigh the indicators. The AHP method is one of the most efficient multi-criteria decision-making methods, first proposed by Thomas L. Saaty in 1977 (Saaty, 1977). This method has been developed based on pairwise comparisons of indicators. AHP is a simple computational method based on the main operations on the matrix. In AHP the weights of the criteria or alternatives are calculated by creating a suitable hierarchy and constructing adaptive matrices at each level of the hierarchy. Parallel comparison is done by evaluating the row element relative to the column element, and a distance scale from 1 to 9 is used for evaluation. Then, from each matrix at any level of the hierarchy, the weights of that level are obtained.

If the value given is higher, indicates the greater importance and preference of the row element than the column element. So that the value of nine indicates extremely preferred or extremely more important, and the value of one indicates the same priority and importance (Table 1). The inconsistency ratio is used to validate the results of the pairwise comparison of indicators. The inconsistency ratio is a mechanism that determines how reasonable the respondents' response to the comparison of sub-criteria with alternatives is (Saaty, 2006). In this study, the importance of indicators has been used by the AHP method and Expert choice software.

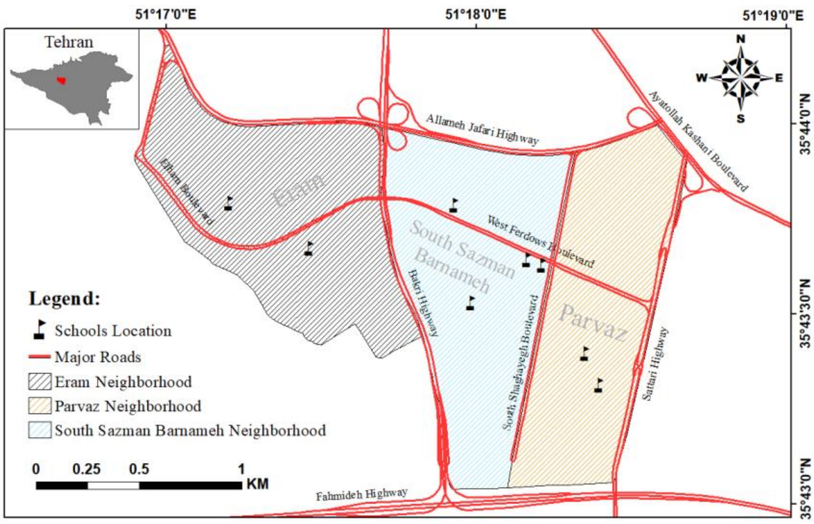

Figure 1. Study area and public and private primary schools.

Table 1. Preference values for couple comparisons (Saaty, 2006).

Definition	Intensity of Importance
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate values	2,4,6,8

The method of estimating each of the study indicators includes air pollution, noise pollution, green areas, the slope of areas, proximity to sports centers and proximity to parks, per capita educational space, satisfaction with school access, and satisfaction with school educational quality as follows:

2.2.1. Air Pollution

Air pollution is one of the most important problems in lots of cities. It is always a constant and serious threat to the health of society and the environment. Air pollution measuring stations in Tehran, which are operated by Tehran Municipality and the Environmental Protection Organization, is the reference for measuring air pollution in Tehran. The value of the air quality index (AQI) can be calculated through the concentration of pollutants. In this study, an air quality index map has been produced using the Kriging interpolation method (Liu et al., 2017). Interpolation is a method of estimating the value of variables in unknown sampling locations using known values in neighborhoods. The number, spatial distribution of sampling points, and the ability of the interpolation model are factors that play an effective role in the accuracy of the zoning map (Praene et al., 2019). The kriging method uses autocorrelation and statistical relationships between the measured points and according to the weight assigned to the sample values, unknown values are calculated. The ordinary kriging method is a linear estimator, and a noteworthy point in using linear kriging methods is that the desired variable has a normal distribution (Ahmad et al., 2021).

2.2.2. Noise Pollution

Noise pollution is one of the main problems in the world today and is one of the most important environmental pollutants in urban areas. Noise pollution and its effects on people's health is one of the obvious environmental problems in Tehran. In general, noise pollution can be produced by stationary and mobile sources. Stationary sources of noise pollution are industrial and commercial places and so on. The most important mobile sources of noise pollution are cars, motorcycles, airplanes, and trains. One of the active centers in Tehran in the field of reducing and controlling noise pollution is the Air Quality Control Company affiliated with Tehran Municipality. The modeled map of noise pollution caused by traffic in Tehran is prepared by this center and published on the relevant website. Normally, the maximum acceptable noise level for classrooms is 45 decibels, and if it is more than 80 decibels, students will face major problems (Shahraki et al., 2016).

2.2.3. Green Areas

Urban vegetation land cover as one of the major land-use/cover classes has an important impact on the quality of urban areas. Vegetation can be measured using vegetation indices such as the Normalized Differential Vegetation Index (NDVI)(Mohammadi & Hosseinali, 2019; Samad et al., 2012). In this research, to obtain images with high spatial resolution, Sentinel-2 satellite images have been used. These images in the visible and infrared bands have a resolution of 10 meters and currently have the best resolution among free satellite images. The NDVI calculation relationship is given in Equation (1):

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

Where, NIR indicates the near-infrared band (band 8 in Sentinel-2 images), and R represents the red band (band 4 in Sentinel-2 images). The NDVI index has a range of +1 to -1, which indicates dense vegetation as it increases to +1. More precisely in Sentinel-2 satellite imagery, negative NDVI values (values close to -1) correspond to water. Low and positive values (approximately 0.2 to 0.4) indicate shrubs and pastures, and high values (approximately 1) indicate forest areas.

2.2.4. Slope

The slope of the area is a major factor that can affect the ease of pedestrian access to the school. In this study, the average slope of the areas in the range of 500 meters of walking for each school has been calculated. In this way, first, with the help of network analysis, a 500-meter walking area is created for each school, and then the average slope of the areas is calculated. It is worth saying that to prepare the slope map of the regions, the digital elevation model (DEM) obtained from ALOS satellite images has been used. The prepared digital model has a resolution of 12.5 meters and is freely available to the public.

2.2.5. Proximity to sports places

In the deployment of utility services, one of the important issues is its compatibility with adjacent uses. According to its performance, sports land use is one of the uses compatible with educational units (Moussa et al., 2017). To evaluate the access to sports centers located in the areas of impact distance, from 300 to 800 meters has been considered (Hosseini Abbas abadi & Taleai, 2017). Thus, schools that are less than 300 meters away from sports centers are in very good condition and schools that are more than 800 meters away from sports centers are not in a good location. In this research, network analysis has been used to prepare the distance map of schools with the nearest sports use.

2.2.6. Proximity to the Park

Also, parks are compatible with educational units (Moussa et al., 2017). In assessing access to the park located in neighborhoods, the distance of impact is considered from 300 to 1000 meters (Reklaitiene et al., 2014). Thus, schools that are less than 300 meters from the park are in very good condition and schools that are more than 1000 meters from the park are not in desirable locations.

2.2.7. Per capita Educational Space

The per capita educational space indicates the proportion of the capacity of the educational space with the number of students, which is defined as the share of each student in the infrastructure space of the educational environment (Shammaei & Askari, 2009). Per capita educational space varies among countries according to the population of cities. For this purpose, through the statistics and information obtained from the Department of Education, the characteristics of the number of students in the 2018-2019 academic year for each school were extracted and the area of the schools in the study area was calculated through the maps.

2.2.8. Satisfaction with Access to School

Measuring families' satisfaction with easy access to school is a mental indicator that is typically done through survey or interview tools, and respondents' assessments will be based on their experiences. Mental indicators provide valuable feedback to planners and policymakers and can be more relevant for planning and policy purposes (Lee, 2008). Mental characteristics can be measured in different ways. One of the most important methods can be the cumulative level of satisfaction in different domains (Pacione, 2003).

In this study, families' satisfaction with the ease of access to school was measured in a range of 5 Likert options (from very low to very high) through questionnaires that were asked of students' parents with the permission of the Department of Education, and for comparison. The values from very high to very low are returned to the numbers 1 to 5 and are calculated from the average of the answers given in each school.

2.2.9. Satisfaction with the educational quality of the school

Also, the index of families' satisfaction with the quality of school's education in the range of 5 Likert options (from very low to very high) was asked from students' parents through a questionnaire, and as before, to compare the level of satisfaction, returned the values to 1 to 5 and the average answers were calculated in each school.

3. Results

In this study, criteria (factor) maps were generated in the GIS software environment, and then they were normalized. To prepare the air pollution map layer, the mean values of the air quality index (AQI) from 2017.3 to 2019.3 (for 24 months) were obtained from the air pollution measuring stations of the municipality and the Environment Organization. To enter data into the kriging interpolation method, we need to ensure that the data distribution is normal. For this purpose, with the help of the Kolmogorov-Smirnov test in SPSS software, the normality of 31 stations was checked and the significance of the test was calculated to be 0.2, which indicates the normality of data distribution. Therefore, linear methods such as ordinary kriging are allowed for interpolation. Finally, with the help of ArcGIS software, the zoning map of the Tehran air quality index was prepared. The greenness map was prepared using the NDVI index using Sentinel-2 satellite images, and the slope map was prepared using the digital altitude model of the ALOS sensor. Then, the average slope of schools in the 500-meter walking area around the school was calculated using network analysis and spatial analysis. Also, to prepare maps of the distance between schools and sports centers, and parks, the distance to the nearest sport place/park was calculated using network analysis and then normalized based on the effect intervals. Figure 2 shows the generated maps.

In the next step, using GIS analysis for each of the quantitative indicators, the average pixel values of the raster images of the indicators located within the school block were calculated. The per capita educational space index for each school was calculated and normalized through school statistics and school area data extracted from the land-use map. Also, the indicators of school access and school educational quality were measured through a questionnaire for each school. Questionnaires were distributed in all schools and 467 parents of students contributed to completing the questionnaire. Finally, the average response of parents in each school was calculated and normalized. The estimated values of all the indicators for schools are compared in Figure 3. It should be noted that the indices were normalized by the maximum-minimum method through Equation (2):

$$x_{norm} = (b - a)\frac{x - \min(x)}{\max(x) - \min(x)} + a \quad (2)$$

where x_{norm} is the final normalized value, x is the input value, b is the maximum value in the normal range and a is the minimum value in the normal range. For this purpose, the normalization range was set between 0 and 1 and the maximum-minimum normalization range was considered based on the desirability of the indicators so that for indicators such as air pollution, the maximum value was 0 and the minimum was 1.

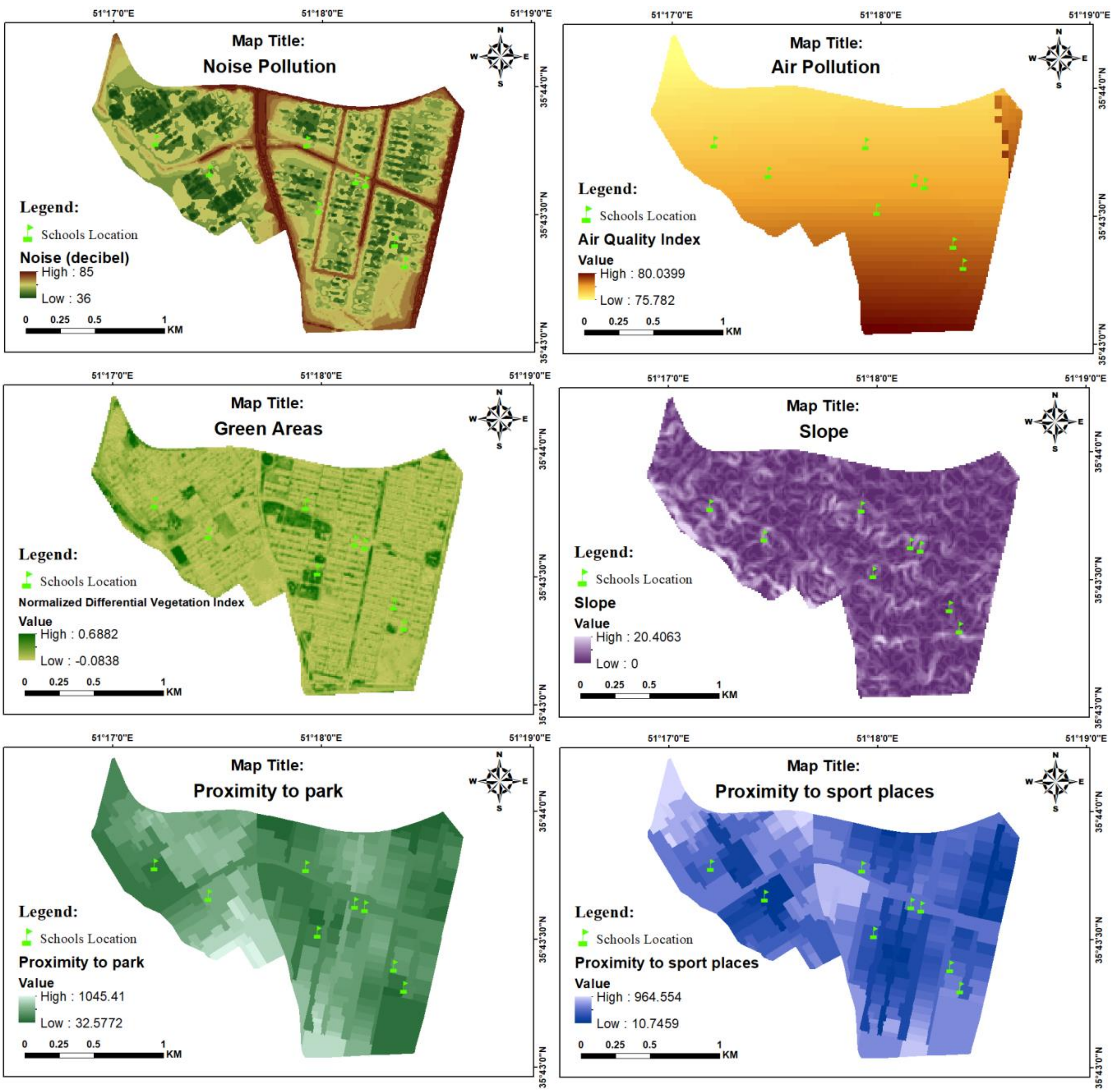

Figure 2. Criteria maps generated from quantitative indicators in the GIS environment

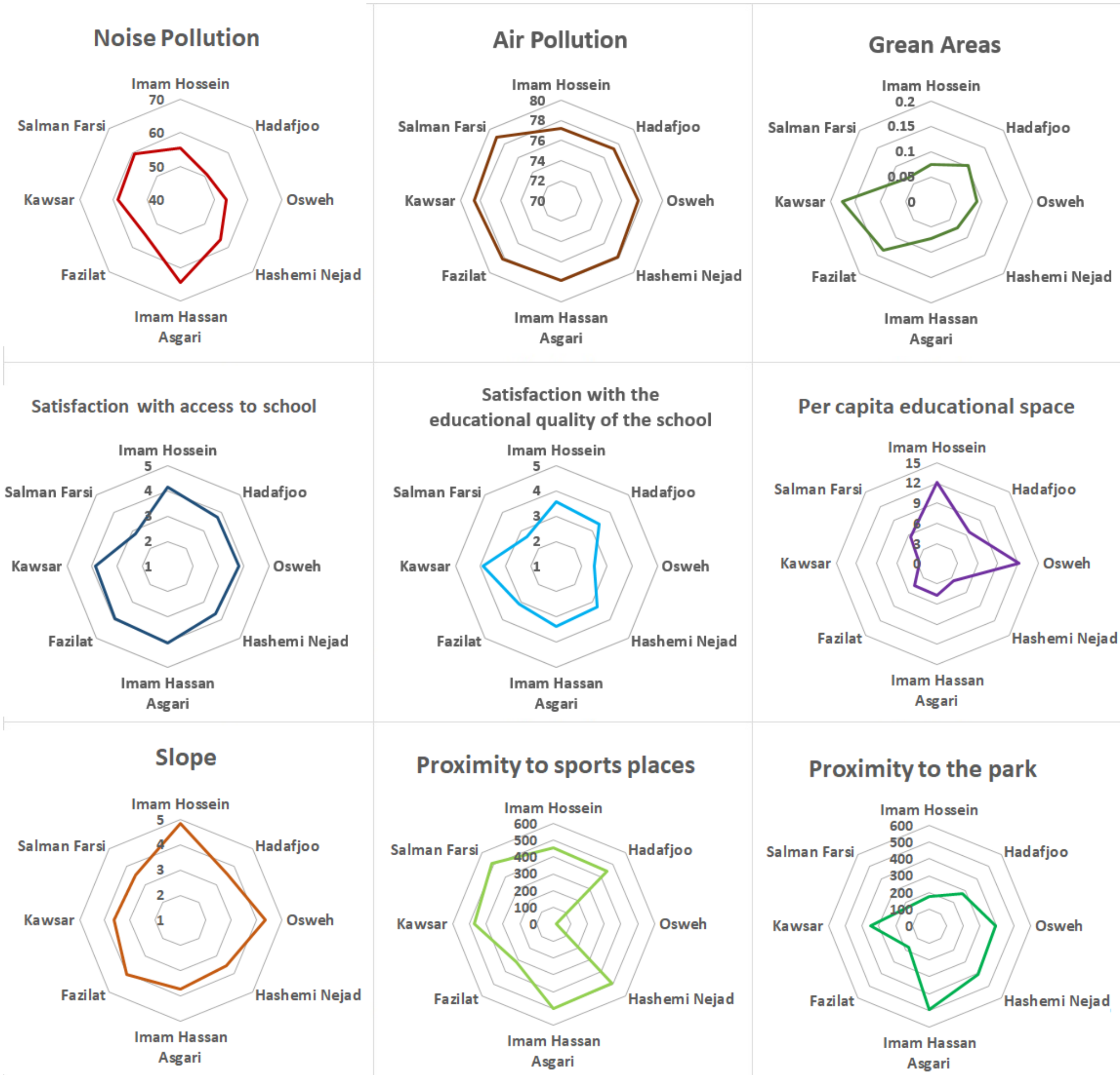

Figure 3. Comparison of schools by research indicators

To determine the weight of the indicators, the AHP method was used. The comparison matrix of AHP is shown in Table 2. To evaluate the decisions, the inconsistency ratio was calculated. If the calculated inconsistency is less than 0.1, the results will be acceptable. In this study, the inconsistency ratio was calculated to be 0.03, which shows an acceptable level in pairwise comparisons of indicators. Finally, the weight of the indicators is specified in Table 3.

To compare the schools in terms of the studied indicators, the normal values of the indicators are multiplied by the weight estimated by the AHP method and they are summed up together to calculate the score of each school. Thus, the ideal school in terms of total points is a school that has less air pollution, noise pollution, and slope of the surrounding area, has more green space and per capita educational space, and has the best access to the parks and to the sports venues. Also, the ideal school must achieve the highest average satisfaction of the student's parents to its accessibility and its educational quality. The normalized values for schools of each of the indicators are shown in Table 4 and the final scores of the schools are shown in Figure 4.

Table 2. Pair comparison of indicators with the AHP method.

Indicator	Noise Pollution	Air Pollution	Green Areas	Satisfaction with access to school	Per capita educational space	Satisfaction with the educational quality of the school	Slope	Proximity to sport places	Proximity to sport places
Noise Pollution	1	1	1	2	2	2	3	2	3
Air Pollution	1	1	1	1	1	2	2	2	2
Green Areas	1	1	1	1	1	1	2	2	2
Satisfaction with access to school	0.5	1	1	1	1	1	2	2	2
Per capita educational space	0.5	1	1	1	1	1	1	2	3
Satisfaction with the educational quality of the school	0.5	0.5	1	1	1	1	1	1	2
Slope	0.33	0.5	0.5	0.5	1	1	1	1	1
Proximity to sport places	0.5	0.5	0.5	0.5	0.5	1	1	1	1
Proximity to sport places	0.33	0.5	0.5	0.5	0.33	0.5	1	1	1

Table 3. The estimated weights of indicators by AHP method.

Number	Indicator	Weight
1	Noise Pollution	0.182
2	Air Pollution	0.142
3	Green Areas	0.131
4	Satisfaction with access to school	0.107
5	Per capita educational space	0.118
6	Satisfaction with the educational quality of the school	0.097
7	Slope	0.091
8	Proximity to sport places	0.071
9	Proximity to parks	0.061

Table 4. The score obtained by each school from the indicators studied.

School Name	Noise Pollution	Air Pollustion	Grean Areas	Satisfaction with access to school	Per capita educational space	Satisfaction with the educational quality of the	Slope	Proximity to sports places	Proximity to the park	Total Score
Imam Hossein	0.6	0.738	0.074	0.785	1	0.638	0.917	0.688	1	0.681
Hadafjoo	0.697	0.735	0.102	0.686	0.666	0.593	0.938	0.701	1	0.65
Osweh	0.644	0.725	0.09	0.699	1	0.371	0.925	1	0.867	0.669
Hashemi Nejad	0.576	0.72	0.072	0.66	0.349	0.566	0.939	0.617	0.846	0.564
Imam Hassan Asgari	0.419	0.718	0.072	0.758	0.464	0.588	0.936	0.6	0.719	0.552
Fazilat	0.619	0.71	0.134	0.736	0.467	0.519	0.931	0.97	1	0.63
Kawsar	0.538	0.697	0.175	0.717	0.263	0.725	0.937	0.659	0.928	0.587
Salman Farsi	0.523	0.686	0.066	0.457	0.56	0.414	0.939	0.57	1	0.543

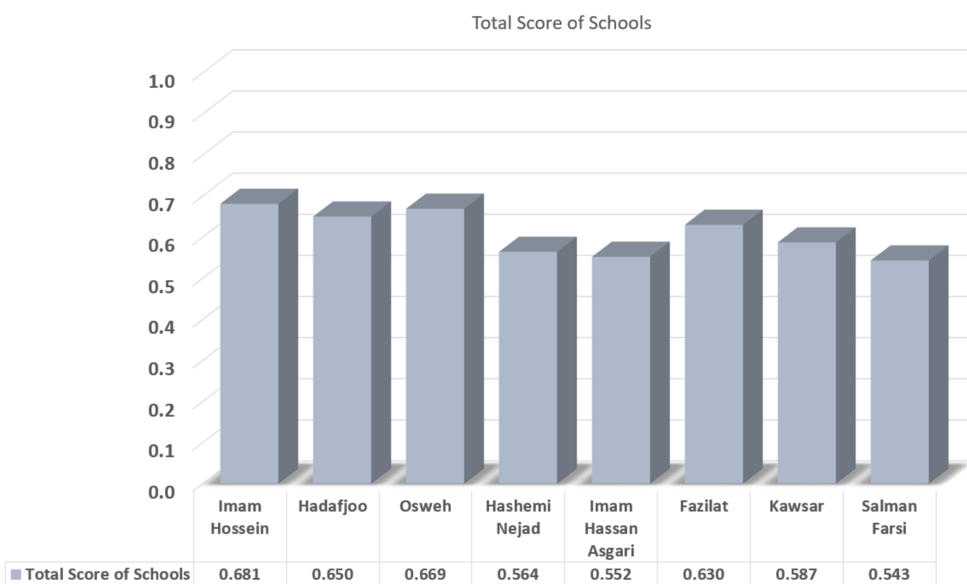

Figure 4. The final score of schools from the studied indicators

4. Discussion and conclusion

The location of schools in a convenient location provides comfort for students in the classroom, and crowded or polluted areas are not the proper place for schools. In the present study, the primary schools located in the study area were analyzed and evaluated in terms of environmental, physical, and residents satisfaction using GIS and AHP weighting methods. From the mentioned aspects, the indicators of noise pollution, air pollution, school green space, slope around the school, as well as proximity to sports uses and parks, which are compatible with schools and contribute to the well-being of students, were measured. On the other hand, in this study, the ratio of per capita educational space in schools was considered as an effective indicator of school ranking. Indicators of families' access to school as well as the educational quality of the school were measured through a questionnaire from 467 parents of students in schools.

The pair-wise comparisons between criteria revealed that none of the criteria has achieved extreme importance. The weights calculated for the criteria (Table 3) prove this fact. A review of the calculated weights of criteria indicates that most of the parents believe that locating the school in a place with the lowest pollution (noise/air) is of the highest importance. On the other hand, proximity to the especial places (park and sport) achieved the lowest attention of the parents. It is so exciting that the quality of education of the school achieved a lower score in comparison to the environmental factors (air/noise pollutions and accessibility of school). One of the strongest points of AHP is calculating the inconsistency index. In this study, this index obtained equal to 0.03 which shows the convergence of the ideas. It means that the diffraction of the idea is too low.

The results show that the majority of the surveyed schools are within walking distance in terms of proximity to parks and sports facilities. Noise pollution in the schools of Imam Hassan Asgari, Salman Farsi, and Kowsar was estimated at more than 55 decibels, and it is suggested that arrangements be made for these schools. The slope of the areas within the 500-meter distance of the schools is approximately in the range of 4 to 5 degrees, and there is a slight difference between the schools, and this situation indicates that the area around the schools is favorable in terms of students' walking. The air quality index in schools is slightly different and in the two-year average (2018 and 2019), all schools are in the healthy range (51 to 100). Regarding the satisfaction of families with access to schools, except Salman Farsi School (with a score of 2.83 out of 5), the rest of the schools are in a better and almost equal condition. In terms of satisfaction with the educational quality, Osweh and Salman Farsi schools have the lowest score and Kowsar school has the highest score. In terms of per capita educational space, there are many differences in schools, and Osweh and Imam Hassan Asgari schools have the highest per capita educational space by a large margin, which may be due to the lower population density in Eram neighborhood than in other neighborhoods. Finally, from the comparison of the total score, Imam Hossein school is in the best condition and Salman Farsi and Imam Hassan Asgari schools have the lowest score (see Figure 4). According to the research results, the importance of school spaces and their location in a suitable place can be evaluated from different aspects based on various criteria. In this study, 9 indicators of environmental, physical, and family satisfaction aspects were examined. This research has focused more on environmental and physical aspects. From the aspects of proximity to urban services, two types of sports land-use and parks have been considered. For future research, it is recommended that the compatibility of schools with another urban land uses be examined.

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