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AHP and GIS Based Multi-Criteria Site Suitibility Approach for Hospitals in Scope of Sustainable Environmental Planning–Aliağa, İzmir Case Study

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Sürdürülebilir Planlama Kapsamında Hastaneler İçin AHP VE CBS Tabanlı Çok Kriterli Yer Seçimi Yaklaşımı– Aliağa, İzmir

ABSTRACT:

Hospitals are one of the most important public amenities in cities. The location of hospitals is critical for residents' accessibility, as is the case with all other public amenities. However; most of the public amenities such as parks, and schools provide services at neighborhood scale, hospitals serve the entire city. Therefore, deciding where to locate a hospital is a complex issue that requires consideration of various criteria. The purpose of this study is to create a multi-criteria-spatial decision support model for selecting the optimal hospital sites, taking into account accesibility, environmental, and topographic aspects. Consequently, a fuzzy multi-criteria-spatial decision support model was created for the Aliağa district of İzmir province, by combining analytic hierarchy process and geographic information system.

KEYWORDS: Site Selection, Land Suitability, Hospital Siting, Multi-Criteria-Spatial Decision Support Systems, Analytic Hierarchy Process, Geographic Information System

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ÖZ:

Hastaneler, şehirlerdeki en önemli kamu olanaklarından biridir. Hastanelerin konumu, diğer tüm kamu tesislerinde olduğu gibi, sakinlerin erişilebilirliği için kritik öneme sahiptir. Parklar ve okullar gibi kamusal olanakların çoğu mahalle ölçeğinde hizmet vermekteyken hastaneler tüm şehre hizmet vermektedir. Bu nedenle, hastane alanlarının nereye yerleştirileceğine karar vermek, birçok farklı kriterin dikkate alınması gereken karmaşık bir konudur. Bu çalışmanın amacı, analitik hiyerarşi süreci ile coğrafi bilgi sistemini birleştirerek, İzmir ili Aliağa ilçesinde, erişilebilirlik, çevre ve topografya yönleri dikkate alınarak en uygun hastane yerlerini seçmek için çok kriterli-mekansal bir karar destek modeli oluşturmaktır.

ANAHTAR KELİMELER: Yer Seçimi, Arazi Uygunluğu, Çok Kriterli-Mekansal Karar Destek Sistemleri, Analitik Hiyerarşi Süreci, Coğrafi Bilgi Sistemi

INTRODUCTION:

Decision-making is a difficult process and a complex task because of the numerous issues to consider and there are various psychological traps that might induce our thinking to go wrong. The process of establishing the suitability of a certain piece of land for a specific purpose is known as site suitability analysis (Steiner et al., 2000). Selecting the location of social amenities in cities is a more challenging procedure, in order to assure social justice in their utilization, because it is dependent on numerous social, physical, spatial, and economic variables. To create better decisions, it's critical to identify criteria that can influence the decision problem, as well as all the many types of stakeholders who have an impact on it, and to determine if their involvement is direct or indirect (Dell'Ovo et al., 2018). First and foremost, the hospital site selection problem must be contextualized as a planning (Murad, 2007) issue that affects all people' access to healthcare services (Saaty, 1980). Appropriate hospital site selection, will serve to improve the distribution of medical resources, provide better health care to meet population demands, maintain aerial health service development, and aid improved social health development.

The technique of multi-criteria decision analysis (MCDA) is ideal for evaluating alternatives, and it has been utilized to solve site selection difficulties in the literature. Analytical Hierarchy Process (AHP), described by Saaty (1980), is one of the multi-criteria decision analysis method for picking optimum alternatives (Yakcinkaya, 2020). To attain more flexibility in judgement and decision-making, AHP might be paired with Zadeh's fuzzy set theory (1965). Many of the advantages of conventional AHP, such as the relative ease with which it handles many criteria and a mix of qualitative and quantitative data, are retained by fuzzy AHP (FAHP). It provides a hierarchical structure, eases breakdown and pairwise comparison, eliminates inconsistency, and generates priority vectors, just like AHP.

The AHP integrated with geographic information system (GIS) application has been used for various site selection processes (Yalcinkaya, 2020; Yalcinkaya et al., 2021; Yalcinkaya & Kirtiloglu, 2021; Sener et al., 2010; Bunruamkaew, & Murayama, 2011; Zabihi et al., 2015; Akinci et al., 2013; Bhausaheb Zolekar & Shivaji Bhagat, 2015; Donevska et al., 2012; Kar & Hodgson, 2008; Miller et al., 1998; Höke & Yalcinkaya, 2021). It involves pairwise comparison and weighted multi-criteria decision analysis of several selected socioeconomic, biophysical and physical criteria (Ahmed et al., 2016). As a multi-criteria decision support system, the AHP has been used widely for solving several site selection problems based on many parameters over many stages, and the interface among parameters has common characteristics.

Numerous studies have employed GIS to settle hospital or health care facility related difficulties (Eldemir & Onden, 2016). The characteristics of location distribution and hospital site selection should consider numerous criteria, such as the existing hospital, population density, main road availability, land use and land cover area, and socioeconomic factors. Eldemir and Onden used AHP-GIS integration for measuring the effectiveness of the alternative scenarios for hospital locations in Istanbul (Abdullahi et al., 2013). Dell'ovo and friends (2018) combined spatial analysis with MCDA for the siting of healthcare facilities (Dell'Ovo et al., 2018). Abdullahi et al., 2013 made a comparison between the results of AHP and the ordinary least square (OLS) evaluation model, based on various criteria, to select suitable sites for new hospitals in Qazvin city, Iran.

The study intends to create a GIS-based multi criteria decision support system for siting hospitals taking into account accessibility, topographic and environmental concerns. Because the decision problem is characterized by spatial factors, a combination of MCDA (FAHP) and GIS is suggested.

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MATERIALS AND METHODS:

1. Study Area

İzmir, Aliağa district was determined as the study area, since it has been learned that a new hospital will be built in Aliağa district. Aliağa, a district of İzmir, is located on the coast of the Aegean Sea. Aliağa is the most industrialized district of İzmir. It is adjacent to Manisa in the east, Bergama in the north, Menemen in the south, and Foça in the south-west (Figure 1). According to the first five-year development plan adopted in the 1960s, Aliağa was chosen as a good location for industrialization, and it has been gaining prominence with its industrial character since that date. Aliağa, which has many different potentials due to its historical riches, natural beauties and geographical features, has turned into an industrial city within 15-20 years with the establishment of the Petro Chemical industry. Rapid industrialization and rapid urbanization has led to out-migration and population concentration. Between 1960 and 1990, the population increased by 789.2 percent. According to the results of the address-based population registration system made in 2018, the population of Aliağa Center was determined as 95,392 (Turkish Statistical Institute, 2018). There is only one hospital in Aliaga which cannot serve the entire population in the district. In Figure 1, the location of Aliağa, current hospital of Aliağa, boundaries of the neighborhood, bus and metro stops and road network can be seen.

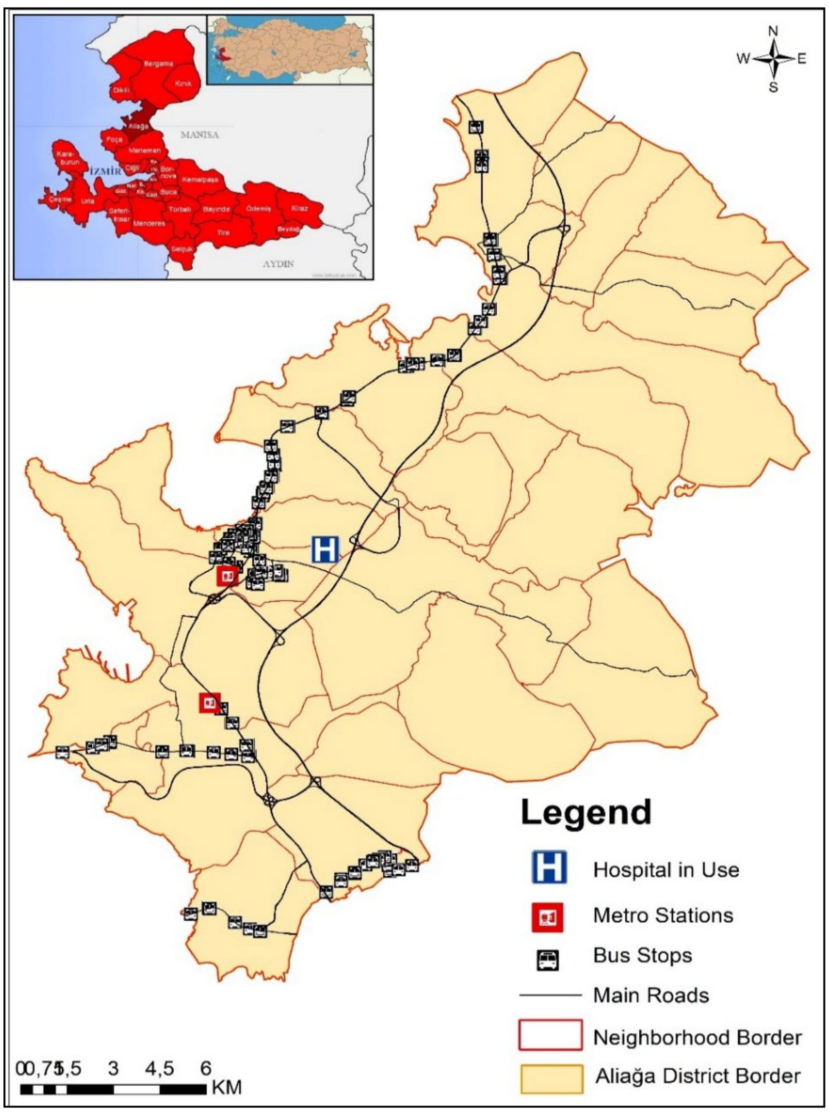

Figure 1: Location of the study area, and illustration of bus stops, metro stations and hospital in use.

2. Methodolgy:

Every method of decision-making begins with the definition of the problem. As a result, the process begins with the definition of the problem, its surroundings, and possible solutions (Abdullahi et al, 2013). The question set in this study: How can we prepare a GIS based multicriteria decision making model for siting and sizing a public hospital?

Because the most appropriate site analysis necessitates the consideration of a wide range of criteria, it's important to pick which Multi-Criteria Decision Analysis (MCDA) approach to use. For this study, the AHP approach was used as MCDA.

The methodology of this study is depicted in Figure 2, which comprises of 4 steps.

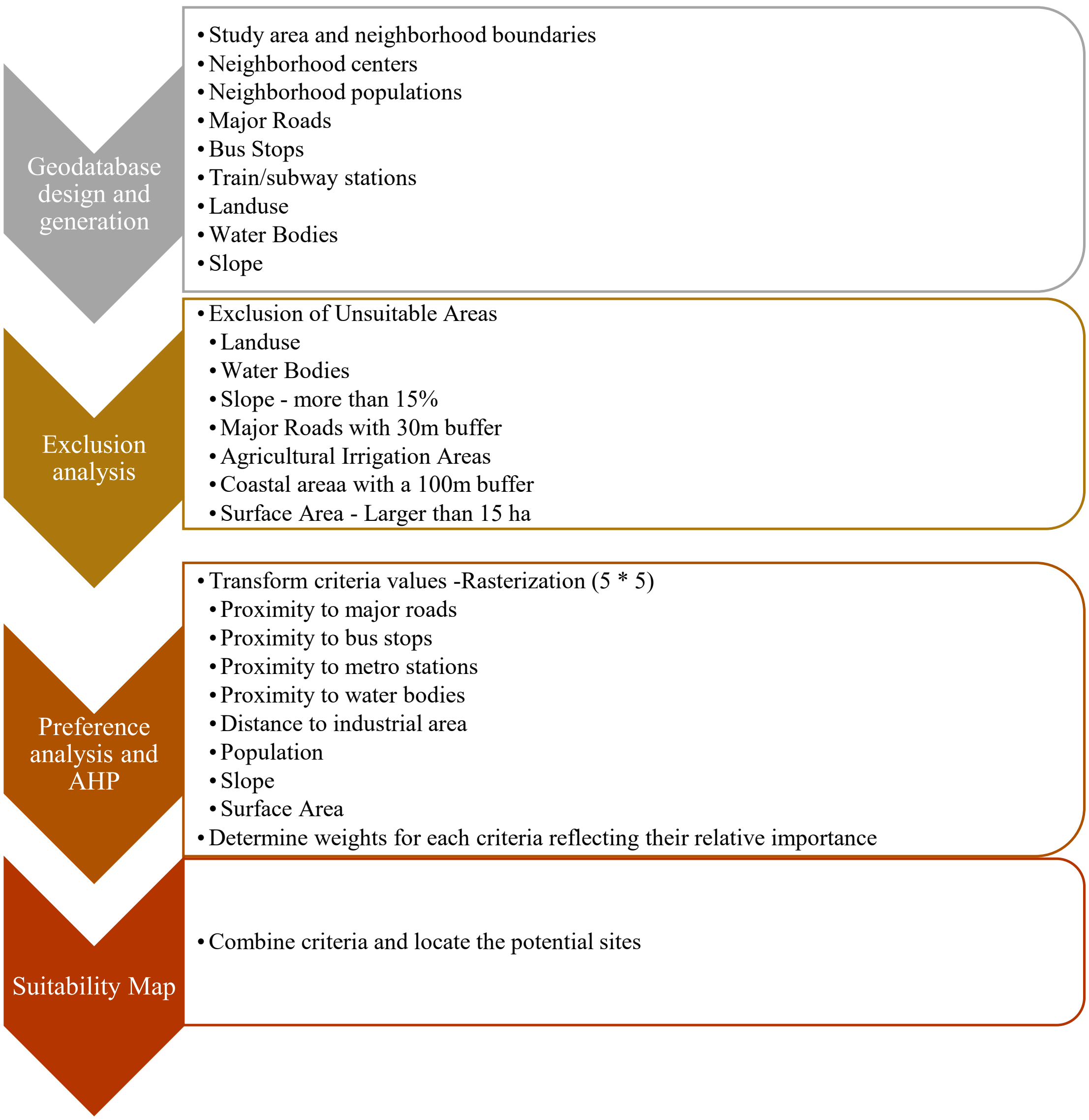

Figure 2: Methodology flowchart

The collecting of geographical and statistical data for the research for the Aliağa district, which was chosen as a case study, and the building of the geodatabase were accomplished in the first stage. Various variables are studied in order to discover ideal locations for new hospitals in literature, which have direct or indirect impacts on the desirability of hospital locations. According to Minimum Standards for Turkey's Health Structures in 2010 Guideline article 4.3 (Minimum Standards for Turkey's Health Structures, 2010):

"It is possible to collect the location selection criteria under the following headings.

— *Being close to settlements,*

— *Being less affected by traffic density,*

— *Low initial cost (purchase cost),*

— *Being at easily accessible points by public transport,*

— *Being away from negative environmental factors (noise, garbage, dust, insufficient lighting, etc.).),*

— *Availability of sufficient parking spaces,*

— *Being in a region with high potential for development in the near and medium term,*

— *Planning infrastructure such as electricity, natural gas, water, sewerage,*

— *Being close to other health facilities and populated areas"*

However, no distance or size information is included.

According to the studies reviewed, the criteria used for hospital site selection can be listed as at Table 1 (Halder et al, 2020; Kaveh et al, 2020, Dell'Ovo et al, 2018):

Table 1: Criteria used for hospital site selection in previous studies

Halder et al, 2020	**Kaveh et al, 2020**	**Dell'Ovo et al, 2018**
Distance from main roads	Distance from the existing hospitals	Existing hospitals
Distance from streets and sub-streets	Distance from fire stations	Areas of hydrological and hydraulic instability
Distance from railway	Distance from population centers	Centre of Urban redevelopment
Distance from highway	Distance from road and street network	Flexibility
Land use (Residential or not)	Distance from green spaces and parks	Building density
Distance from existing hospitals	Distance from strong power lines	Accessibility
Distance from an educational instutition	Distance from fault	Services
Agricultural land		Green area
Water body		Network infrastructures
Green area		Noise pollution
		Air pollution
		Unhealthy industries
		Value of the area
		Land ownership
		Land suitability

As a result of the literature and legal research, all of the criteria for hospital site selection were evaluated, but in this study, the criteria could be made on the data available. These data and their sources are listed in Table 2. Following this step, it was determined which data would be included in the research and which would be excluded.

Table 2: Obtained data and their sources

	Criteria	**Data Source**
Prerequisites	County and Neighburhood borders	Aliağa Municipality
	Existing hospitals	Aliağa Municipality
	Abondoned areas	İzmir- Manisa Environmental Arrangement Plan
	Landuse map	İzmir- Manisa Environmental Arrangement Plan
Accesibility	Highway	OSM
	Primary roads	OSM
	Subway stops	İzmir Metropolitan Municipality
	Bus stops	İzmir Metropolitan Municipality
	Population	Turkish Statistical Institute
Topography	Elevation	USGS
Environmental	Unhealty industries	İzmir- Manisa Environmental Arrangement Plan
	Water Bodies	İzmir- Manisa Environmental Arrangement Plan

Unsuitable areas for hospital building were identified from the land use data in the Exclusion Analysis section. (Table 3).

Table 3: Excluded areas from the land use map and suitable areas

Excluded Area	
Area to be afforested	Hazardous waste landfill
Water body	Themed park and fair area
Sewage treatment plant	Thermal reactor
Military zone	Shipyard
Dam	Tourism facility area
Regional park/large urban green area	Salt marsh
Regional/urban sport area	University campus
Storage area	Irrigation area
Energy investment area	Archaeological sites
Lake - pond	Natural sites
Airport	Urban sites area
Urban development area	Protection area
Urban residential area	Historical site area
Urban and regional green and sport area	Special environmental protection zone
Rural settlement area	Culture and tourism conservation and development region
Port/port back area	Wetland
Logistics	Culture and tourism conservation and development region
Organized industrial zone	Special environmental protection zone
Organized agriculture/livestock area	Nature park/nature protection area
Forest	Drinking water protection area

Beach	**Suitable Area**
Industrial	Public institution area requiring large area use
Industry and storage area	Pasture
Reeds - marsh area	Agricultural Area
Free zone	Preferred usage area

After eliminating the unsuitable areas from the land use data, areas within 100 meters of the sea are also eliminated, as defined in Article 4 of the Coastal Law: "*Coast Line: The area having a width of at least 100 meters horizontally in the direction of the land from the coastal edge line*" (Ministry of Environment and Urban Planning, 1990).

Although agricultural areas have been identified as suitable areas for the hospital, irrigated agricultural lands are also excluded, as stated in article 8.8.3 of the İzmir-Manisa Environmental Plan, "*It is essential to protect the irrigation areas for agricultural production purposes... they cannot be used for non-agricultural purposes*" (Ministry of Environment and Urban Planning, 2014). Additionally, locations within 30 meters of major roads and those with a slope of higher than 15% are excluded.

The regions that were not large enough for the hospital were eventually omitted after all of the removal processes were completed. Information about the required minimum space can be found in Annex 2 of the Spatial Plans Construction Regulation. According to this, settlements with a population between 75.000 and 150.000 should allocate 1.5 m2 of area per person (Ministry of Environment and Urban Planning, 2014). Since the 2020 population of Aliağa is 101.242, the minimum hospital area should be 15 hectar. Accordingly, areas smaller than 15 ha were also excluded.

The preference analysis step was initiated in order to categorize the sites detected via the pre-selection process based on their suitability and to identify potential hospital areas. For this analysis, first of all, main criteria and preference factors were determined in line with the data available. As shown in Figure 3, these factors are split into three primary objectives.

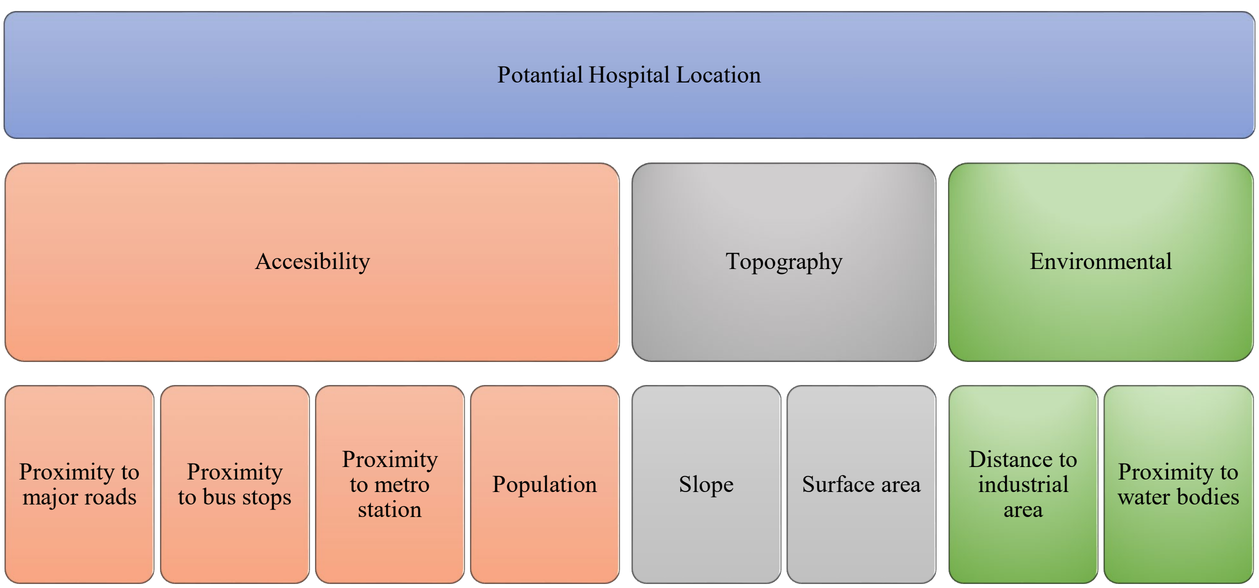

Figure 3: Criteria and Preference Factors

Fuzzy membership functions were used to rank factor layers within themselves in the preference analysis, and the AHP was applied to rank them against each other (Sener et al, 2010). Each factor was converted to raster using the appropriate technique. Then, linear fuzzy membership function with proper parameters were performed to convert each preference factor to a common scale, as shown in Figure 4.

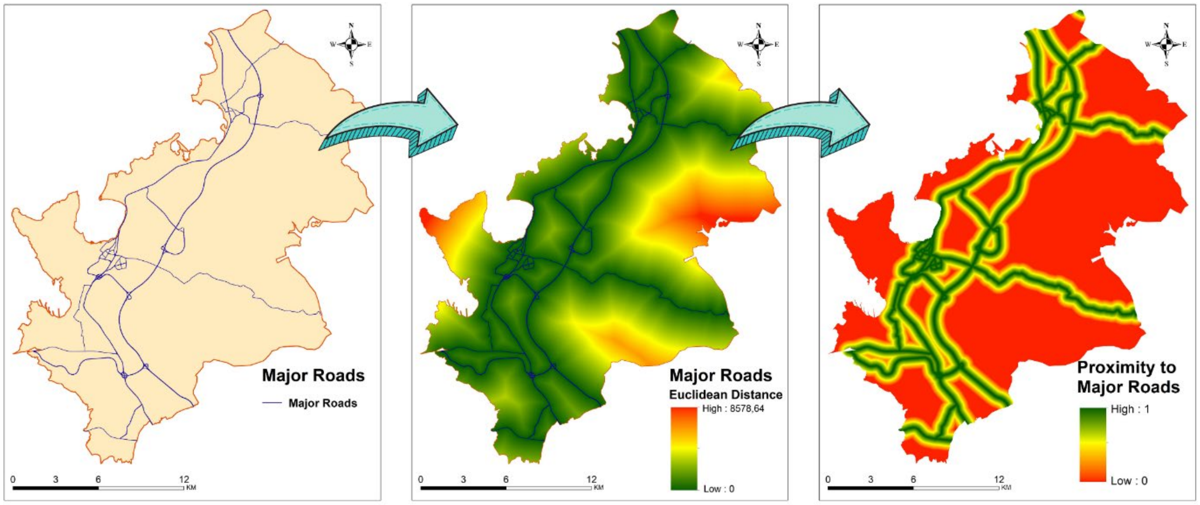

Figure 4: Fuzzy membership process

The rasterization method determined for each factor and the minimum and maximum values used for the fuzzy membership process are shown in Table 4. All of these procedures were carried out with the help of ArcGIS software.

Table 4: Criteria and preference factors, rasterization techniques, linear fuzzy membership function parameters (min and max) and Analytic Hierarchy Process weights.

Criteria	Factor	Rasterization	Min	Max	Weights
Accesibility	Proximity to major roads	Euclidean Distance	1000	30	0,292
	Proximity to bus stops	Euclidean Distance	1000	0	0,076
	Proximity to metro stations	Euclidean Distance	3000	0	0,034
	Population	IDW	min	max	0,168
Environment	Proximity to water bodies	Euclidean Distance	max	min	0,065
	Distance to industrial area	Euclidean Distance	max	min	0,195
Topography	Slope	Dem to slope	15%	0	0,113
	Surface area (ha)	Polygon to raster	15	0	0,057

T.L. Saaty developed the AHP to make the decision-making process more successful (Saaty, 2004). According to Saaty (Saaty, 2004), the analytic hierarchy process is a decision mechanism that humans use instinctively when faced with a decision-making challenge (Ajaj et al, 2019). This mechanism is not taught to humans, but it has existed since their inception.

For the AHP method, pairwise comparisons were made between the criteria and the weights of the criteria in the site selection analysis were determined. In order to compare the significance of factors to each other or how dominant they are over each other by considering the criteria or properties, we need scaled numbers that indicate this (Ajaj et al, 2019). The weighted averages based on paired comparisons were calculated using Saaty's table of standard values (Yalcinkaya, 2020). The relative relevance of accessibility, environmental and topographical criteria was assessed, and weighted averages were computed (Table 4). Each preference factor was given the same treatment. Afterwards, the global weights for each component were calculated. The weighted sum tool in ArcGIS was used to aggregate all of the criteria and build a suitability index map. The final land suitability map was in raster format with 5 m cell size resolution since the input fuzzified rasters were prepared in 5 m cell size resolution. The regions over the suitability index threshold value were then identified as potential hospital sites.

RESULTS:

In this study, we examined at how to choose the best site for a hospital, before proceeding to the pereference analysis based on the determined criteria, exclusion analysis was performed as detailed in the method section. As shown in Figure 5, just 12 percent of the research area was found to be suitable as a consequence of this analysis.

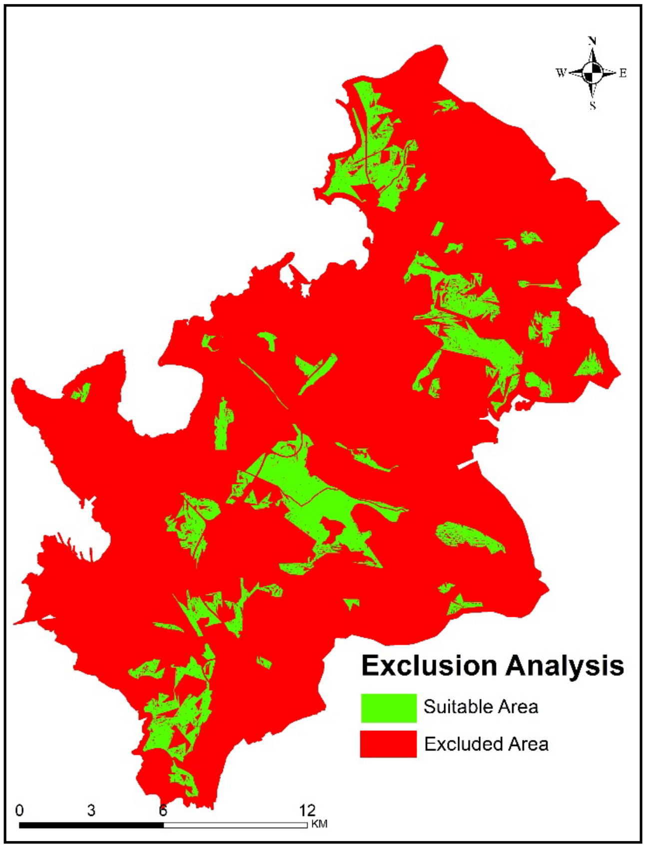

Figure 5: Exclusion Analysis

Many different criteria, such as noise pollution, air pollution, land values and proximity to green areas, can be evaluated according to country conditions or other properties for hospital site selection, but based on the data obtained in this study, eight factors were determined under three main criteria.

To execute suitability analysis, rasters were produced for these eight parameters, and fuzzy membership was done in accordance with the minimum-maximum values determined for these factors. (Figure 6). In these maps created by applying linear membership,, "1" denotes 100 percent membership, whereas "0" indicates no membership for the factor of interest.

In order to rank the appropriate areas among themselves, the criteria and factors were weighted according to each other. AHP was used to calculate the weights of each criterion and preference factor. As a result, "proximity to major roads" and "distance to industrial area" emerged as the most important parameters. However, "proximity to metro stations" and "surface area" were the least essential criteria. (Table 4).

The "weighted sum" operation was conducted using the fuzzified factors depicted in Figure 6 and weights produced with the AHP, and the suitability index map was generated as a result. (Figure 7). The blank regions reflect prohibited locations, while the color ramp depicts eligible places. The green sections are 100 percent suitable for a hospital, whereas the red portions are unsuitable.

As a consequence of this research, the highest sutibility index has been observed along the main road that runs north-south, as they are remote from water resources and forest areas and have good transit connections.

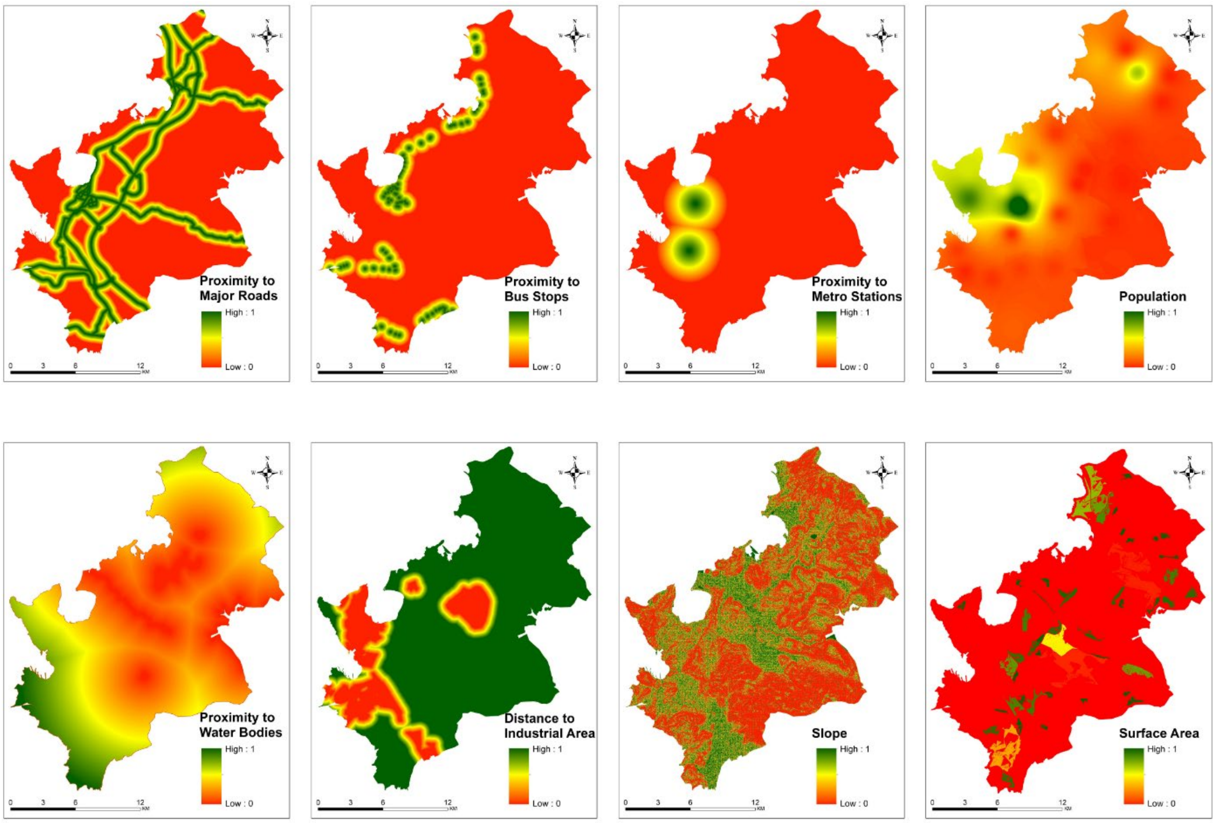

Figure 6: Fuzzied maps for each factor

In the study named "An AHP-based GIS for a New Hospital Site Selection in the Kirkuk Governorate" conducted by (Ajaj et al, 2019), the suitability index between 0.164 and 0.252 is low, between 0.252 and 0.296 is medium, between 0.296 and 0.458 is high and 0.458. - 0.538 are designated as very high level suitable. Based on this study, three potential hospital sites were determined by converting areas with a suitability score greater than 0.6 into point data.

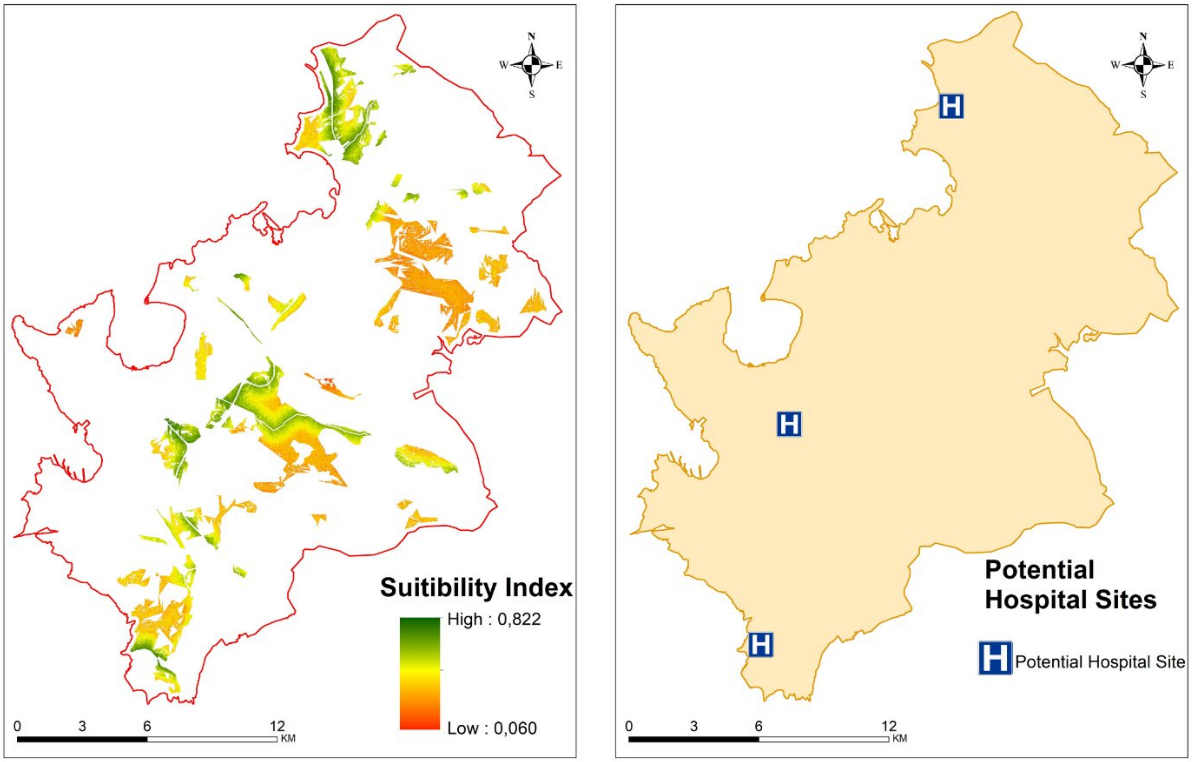

Figure 7: Suitibility index and potential hospital sites

CONCLUSION:

In this study, a model was developed using the fuzzy Analytical Hierarchy Model and GIS to discover the most ideal sites for hospitals, which is one of the most important basic equipment areas for inhabitants, and it was applied to the İzmir Aliağa district. According to the nature of the function to be selected, a site suitability study may be performed by analyzing a variety of factors. The criteria for selecting a hospital location in the study were molded in accordance with the availability of data. Adding criteria such as property information, land values, medical waste centers, noise level, air pollution level, and so on would improve the study's quality, but such data was not available.

This study serves as a guide for local leaders and national government officials in determining the best location for new hospitals. when all components are not evaluated together in site selection studies; It is an expected result to choose and invest in places with low accessibility, high traffic density, high construction costs in geographically challenging lands, far from medical waste facilities. Handling all economic, environmental and spatial data with such Multi-Criteria Decision Analysis will increase the operability of these functions, which are vital for the city.

Compliance with Ethical Standard

Conflict of Interests: We have no conflict of interest to declare.

Ethics Committee Approval: Ethics committee approval is not required for this study**.**

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