CBS Tabanlı Arazi Uygunluk Analizi: Çiğli İlçesi Örneği

Nur Sinem PARTİGÖÇ

Şehir ve Bölge Planlama Bölümü, Pamukkale Üniversitesi, Denizli, Türkiye
npartigoc@pau.edu.tr
(Geliş/Received:07.04.2017; Kabul/Accepted:12.11.2017)
DOI: 10.17671/gazibtd.304355

***Özet*—** Günümüzde kentler insanların gündelik ve sosyal ihtiyaçlarını karşılayamamaktadır. Bunun sonucunda, yerleşim alanları, aslında yerleşmeye uygun olmayan alanlara doğru kaymaya başlamıştır. Bu durum, yapılaşmamış alanların zarar görmesine, ekolojik dengenin bozulmasına ve çeşitli afetlerin meydana gelmesine neden olmaktadır. Bu tür sorunların yaşanmaması için şehirlere uyum içinde eklenecek planlı yeni yerleşim alanları kurulması sağlanmalıdır. Mekansal planlama çalışmalarında ve mekansal araştırmalarda yer seçimi ve uygunluk analizlerinin yapılması için sıklıkla tercih edilen yöntemlerden biri Çok Kriterli Karar Verme yöntemidir. Bu yöntemin uygulanması sürecinde Coğrafi Bilgi Sistemleri (CBS)'nden önemli ölçüde yararlanılmaktadır. Bu çalışmanın amacı, İzmir kentinin merkez ilçelerinden biri olan Çiğli ilçesinin merkezi ve yakın çevresinde yeni gelişim alanları için önerilen çözüm yöntemi kapsamında belirlenen alternatifler arasından en uygun alanın yer seçim kriterlerine göre belirlenmesi ve Coğrafi Bilgi Sistemleri kullanılarak yerleşilebilirlik analizinin yapılmasıdır. Mekânsal analizlerden elde edilen sonuçlara göre, ilçe merkezinin doğusunda kalan ve kentsel dönüşüm kapsamına alınan bölge, diğer alternatif alanlarla karşılaştırıldığında, yeni gelişim alanları bakımından uygun bulunmuştur. Analiz sonuçları tartışılmış ve alan özelinde çeşitli öneriler geliştirilmiştir.

***Anahtar Kelimeler*—** Yerleşime uygunluk analizi, Analitik Hiyerarşi Süreci (AHP), Coğrafi Bilgi Sistemleri (CBS), Kentsel gelişim.

GIS – Based Land Suitability Analysis in Çiğli District

***Abstract*—** Recently the supply of communal and social needs of the citizens in urban areas is inadequate due to the increasing demand. As a result, urban settlements have shifted towards unsuitable areas. This shift has caused damage to natural areas, disrupted the ecological balance and has led to the occurrence of various disasters. Recent opportunities exist to build livable and well-planned cities. Urban development strategies for new settlement areas should be developed in order to prevent critical problems in urban areas. Suitability analysis is one of the several methods that can be applied for the development of these strategies. The implementation of this method benefits from GIS. The aim of the study is to determine the most suitable areas among defined alternatives due to the proposed solution method for new settlement in Çiğli district (Izmir) and its surroundings according to the suitability factors and also to implement the suitability analysis by using GIS. According to the results, the selected region located in the eastern part of the district center and also known as the urban renewal area was found to be suitable for new development in Çiğli district. The results of the analysis are discussed and a variety of policies have been developed.

***Keywords*—** Suitability analysis, Analytical Hierarchy Process (AHP), Geographic Information System (GIS), Decision makers, Urban development.

1. INTRODUCTION

Cities are insufficient to mankind in today's information and technology age. Also, they do not meet citizens' needs and demand in terms of urban facilities [12, 46]. Several factors such as the attractiveness of city centers promising comfortable and well-accepted conditions especially in the metropolitan cities, the increasing housing and urban facilities demands because of the rapid population growth, the occupation of unsuitable areas to meet this increasing demand of citizens, the change of production and consumption patterns in urban areas, etc. cause inadequacy of citizen's demands. Due to the increasing demand in urban areas, urban settlements have shifted towards unsuitable areas that are inconvenient to settle such as agricultural areas, forests, pastures, forages, wetlands, dip

slopes, risky areas, etc. This shift has caused damage to natural areas, disrupted the ecological balance, and has led to the occurrence of various disasters [8, 26]. In today's world, cities, where everything is designed to maintain a qualified lifestyle for citizens, have been transformed into more livable and sustainable places through urban renewal projects and also designed to respond to every need of citizens in urban areas [35].

New opportunities exist to build livable and well-planned cities. In this context, urban development strategies for new settlement areas should be developed by decision makers considering the local dynamics that refer the characteristics special to study area in order to optimize urban problems on a local and regional scale, prevent critical problems that may occur in the future such as disaster risk, the inadequacy of citizens' demand in terms of housing and security, exceeding the carrying capacity in the face of increasing demand, the irreversible destruction of natural sources, etc.

The suitability analysis is one of the several methods that can be applied for the development of these strategies. This method aims for the area within the study to be used in accordance with its potential and to also benefit from it [33]. There exist various factors (natural and human factors) that affect the suitability in urban areas such as topographic factors (elevation, aspect, slope, slope, curvature, etc.), meteorological factors (temperature, rainfall, humidity, etc.) [33], land use capability classes, land use patterns (residential areas, open and green areas, industrial areas, etc.), lithology (limestone, conglomerate, basalt, travertine, alluvium, etc.) [21, 33], accessibility (the distance to public spaces, transportation lines, residential areas, open and green areas, fault lines, rivers, etc.) [41], hydrogeology (groundwater, lakes, dams, rivers, sea, etc.) [14], noise (the distance to the airport, railways, main arterials, etc.), disaster risk (flooding, earthquake, landslide, etc.) [8], level of air pollution (the levels of SO_2, NO_2, $PM_{2.5}$, CO_2 pollutant concentrations) and also the preferred heating types in residential areas (gas, electricity, coal, wood, etc.) [31].

Site selection is a complex problem and offers a range of alternatives and preferences for decision makers. In other words, the site selection and the determination of suitable areas cannot be defined unilaterally and easily [7, 47]. The suitability analysis is one of the several methods that can be applied for the development of these preferences. It is also frequently preferred for site selection in spatial planning studies. This analysis is not only used in research areas such as environmental planning, ecology, city and regional planning, hydrology and water resources, forestry and transportation but also in the phases of management and decision in agriculture, risk management, health investments, and resource allocation [42]. Additionally, this method is easily applicable and comprehensive; it is a common tool to make the most appropriate selection among several independent variables in the study area [40]. The implementation of this method benefits from Geographic Information Systems (GIS).

The method of suitability analysis has found an application area with the development of GIS and has also been one of the most practical and effective of tools [2]. Also, the spatial information technologies such as GIS are often preferred in different studies related to the mapping techniques and spatial data analysis [45]. In terms of the combination of different layers and the ability to coordinate large-scale data, GIS is often a preferred tool [24]. A range of empirical studies exist in the literature that is linked to suitability analysis using ArcMap software with some qualifications such as weighted overlay, reclassification, making of thematic maps, etc. [6, 16, 23, 29, 34, 39]. In addition to the empirical studies conducted at an international level, various studies and research exist in the literature that is based on suitability analysis and site selection in the cities of Turkey [1, 3, 8, 9, 13, 14, 15, 21, 25, 32, 33, 40, 41, 43].

The aim of the study is to determine the most suitable areas among defined alternatives due to the proposed solution method for new settlement in the Çiğli district and its surroundings according to the suitability factors and also to implement the suitability analysis by using GIS. Natural and human factors are considered in terms of the suitability of new development areas (alternative areas) in Çiğli district. Following the establishment of alternative areas to settle, these areas are evaluated in accordance with certain factors such as topography, land use patterns, accessibility, noise, air pollution, and the preferred heating types, especially in residential areas. According to the analysis results performed using the ArcMap software, in comparison with other alternative areas, the selected region that is located in the eastern part of the district center and also known as the urban renewal area is found to be suitable for the new development areas in Çiğli district. The results of analysis are discussed and a variety of implications are developed.

2. STUDY AREA

The study area is the district of Çiğli which is located in the northern part of the metropolitan city of Izmir, the third largest city in Turkey with a total population of 4.168.415 (as of 2015). The northern part of Izmir has mostly been developed as industrial zones, the eastern part has been largely characterized by agriculture, and the western and southern parts have touristic and residential areas. The total area of Çiğli district is 13.352 hectare (133.52 km^2) covering approximately 17% of the total area of Izmir [17]. Çiğli district is one of the leading districts of the city in terms of population. According to the results of the Turkish Statistical Institute's Address Based Population Registration, as of 2015, the district has a total population of 182.349 [38]. In the district's area, there exists an industrial zone (Ataturk Organized Industrial Zone), a very large recreational area including one of the largest zoos in Turkey (Sasalı Natural Life Park), a military zone including a military airport, a regional railway station, and commercial and residential areas differing in densities [5]. According to the Geographical Coordinate Systems, the district of Çiğli falls between 38° 29' 22" latitude and 27°

03' 08" longitude (UTM Zone 35 N – WGS 84). The location of Çiğli district in Izmir city and Turkey are represented in Figure 1a, Çiğli district within the boundaries as the study areas is represented in Figure 1b and also a site photo from Çiğli district is represented in Figure 1c.

(c)

Figure 1. The location, district boundaries and site photo of Ciğli district

It is known that topography is one of the most important determinants of the built environment in Izmir. Principally, housing establishments and regional infrastructure are located on sloping lands, plains and coastal areas. Areas that are open to urban settlement are fairly limited due to the topographic features of the city [19]. The study area has a broad coastal plain and the average elevation of the settlement area in the district from sea level is 1.5 meters. The characteristic of the coastal plain is a marsh. These settlement areas are located in the northern and north – eastern parts of the district [5]. In terms of climatic characteristics, the district of Çiğli has a typical Mediterranean climate characterized by hot, dry summers and mild, rainy winters. The highest temperature in the month of July was 37.8°C and the lowest temperature in the month of January was -2.2°C in 2010. The average annual rainfall is 490 mm and also the average natural moisture is approximately 79% [18].

The Izmir Ataturk Organized Industrial Zone, located in the borders of the district of Çiğli, opened in 1990 and has a total area of approximately 700 hectares. It is located in the north – western part of Izmir and is 25 km away from the city center. This industrial zone is one of the most important production, employment and export centers in Turkey [17]. In addition to the industrial facilities in the district, there exist agricultural activities and the total areas of the agricultural activities are approximately 13.351 hectares. The total agricultural land is made up of 26% irrigated and 74% non-irrigated land [18]. Among several transportation facilities, a military airport, highway routes, rail lines, buses, and minibuses are commonly used. The military airport is located in the north – western part of the district (Kaklıç Military Airport). In terms of urban infrastructure, the main transmission line of natural gas that has been installed by the firm IzmirGas passes from this district [20].

There are two important physical plans for the district of Çiğli, which has an 80% structured environment. The first plan is the 1/25.000 scaled Izmir Metropolitan Area Master Plan prepared by the Metropolitan Municipality of Izmir in the year 2012 and the second plan is the 1/5.000 scaled Çiğli Master Development Plan prepared by the Municipality of Çiğli in the year 2013. New transport links for the light rail lines, the stratification of current roads, urban renewal projects for two neighborhoods named Güzeltepe and Şirintepe, the reorganizing of land use patterns as residential areas in middle and high density, industrial and commercial areas, open and green areas, etc. are among the many decisions of these plans.

The presence of different land-uses and dwelling types, its size and high population related to noise and accessibility parameters, its location within Izmir city, the existence of various heating types and its topography related slope, air quality and also aspect parameters in the study are main reasons for choosing Çiğli district as the study area. In similar way, the alternative areas for the new settlements in Çiğli district and its surroundings are determined according to their certain characteristics. Among these characteristics, different locations of alternative areas (close to Izmir Bay, district center or main transportation routes, etc.), various slope and aspect values due to the features of topography in these sites, the differentiation of proffered heating types in domestic heating and also changing air quality regarding to their location are primary reasons for determining alternative areas. Figure 2 shows the location of alternative areas in Çiğli district.

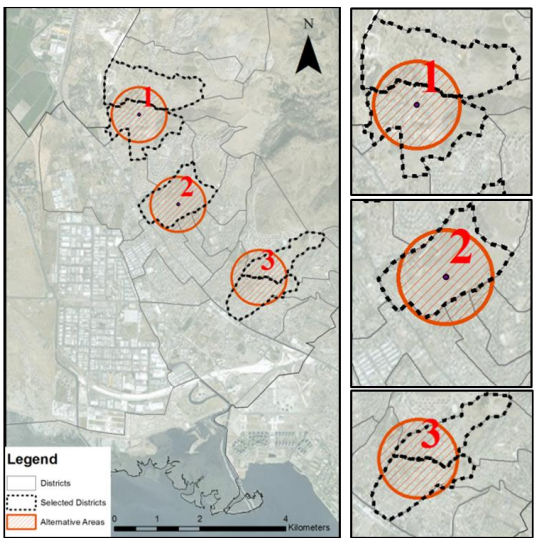


Figure 2. Alternative areas for new developments in Çiğli districts

3. MATERIALS AND METHODS

The determination of suitable areas for new investments, developments areas, land use decisions, etc. is a multi - dimensional phenomenon. So, there is no reason for the preference of a single – dimensional method to accurate this type of multi – dimensional problems. Actually, a decision making process for the site selection includes any measurement of trade-offs among various factors [55, 57]. This process has two main stages: (1) determining a measure / scale for the related factors in terms of the priority, (2) determining weights of alternatives [56]. This structure of this process can be used to frame the Analytical Hierarchy Process (AHP). The AHP is a multi-criteria decision-making (MCDM) approach which is based on the evaluation of different alternatives in terms of different criteria [60]. Thus, it plays an important role in real life problems such as decision making processes for new investments, business activities, industrial engineering applications, environmental planning, ecology, city and regional planning, hydrology and water resources, forestry and transportation, risk management, health investments, and resource allocation [42]. In the implementation of AHP, there are mainly three stages as the determination of criteria weights, the scaling of option scores and the ranking the options. While the computing the criteria weights, a numerical scale from j to k is used that is called as "Scale of Relative Importance" and also translates the decision maker's qualitative evaluations of the relative importance among different criteria using numbers as shown in Table 1 [59].

Table 1. Scale of Relative Importance [59]

Value of *ajk*	**Interpretation**
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

It is definitely known that the geographical data is a raw material and this type of data can be useful for the decision making processes. Geographic Information Systems (GIS) has a critical role in especially making spatial decisions with regards to various graphical operations using this data. GIS can be defined as a special type of information systems which manipulates the data about points, lines and polygons for mapping and analyzing things happen on earth [58]. GIS and MCDM can benefit from each other in decision making processes. Because of the complex and multi – dimensional structure of MCDM problems, GIS techniques and tools provide important advantages.

Several factors that affect site selection in urban planning exist and these factors vary depending on the scope of this study which is an example of GIS - based MCDM problem. Among these various factors, topography, land use, accessibility, noise, air pollution, and types of heating are chosen for this study. The data obtained from different institutions in order to constitute a base map for the study area and to make the spatial analyses are shown in Table 2. There are factors other than those mentioned that represent the local dynamics of the study which are not used in this study. For example, meteorological factors are not used in the analysis made due to the scale of the selected area and there being no significant differences within this area. Although Izmir is a high-risk area for disaster, the area of study is not located in a critical region, therefore this factor was eliminated. In addition, the selected area is currently a residential area and is mainly a built-environment, so it is obvious that agricultural activities cannot be made in these areas in terms of land usability.

Table 2. The data obtained from the different institutions

Data Type	**Data Source**	**Maps**
GDEM (Digital Elevation Model)	ASTER and NASA	The analysis maps for slope and aspect
The current land use of Çiğli district	Çiğli Municipality	The analysis map for land use patterns
The coordinated base map for Çiğli district	Izmir Metropolitan Municipality	The coordinated base map representing the alternative areas
The location of natural gas lines in Çiğli district	IzmirGas Company	The analysis map for preferred heating types in domestic
The level of air pollutant (SO_2 and NO_2) concentrations	Department of Scientific Research Projects, Dokuz Eylul	The analysis map for air pollution
Satellite images	Google Earth	The analysis maps for noise and accessibility

The primary purpose of this study is to determine the most suitable areas among defined alternatives due to the proposed solution method for new settlement in Çiğli district and its surroundings. For this purpose, this study is conducted in certain stages. The first stage entail determining certain factors that affect the suitability of alternative areas in the district such as topography, land use patterns, accessibility, noise, air pollution, and the preferred heating types, especially in residential areas. In the consideration of these factors, the literature research, field survey and the data about the local dynamics of the study area have been taken into account.

In the second stage, a factor analysis is carried out using the data obtained from the different institutions in vector format and also the chosen factors are classified according to the levels of suitability that has a scale of relative importance between 1 and 7 (Table 3). Marginally suitable areas are expressed with the value "1", moderately suitable areas are expressed with the value "3", suitable areas are expressed with the value "5", and highly suitable areas are expressed with the value "7". Intermediate values are expressed with 2, 4 and 6. The scale has seven levels because there are seven choosing factors (slope, aspect, land use pattern, accessibility, noise, air pollution, and the preferred heating types) in the scope of this study. The weighted values in this scale are determined with regard to the decision maker's qualitative evaluations of the relative importance among different criteria using AHP method.

Table 3. The scale of relative importance

1	2	3	4	5	6	7
→						
Marginally suitable		Moderately suitable		Suitable		Highly suitable

Thus, the weight of chosen factors in the suitability analysis has a significant effect in the process of analyzing [4]. Following the conversion of analysis maps from vector format to raster format, the resulting maps have been analyzed according to this formula:

$$SSA = (S \times 7) + (L \times 6) + (Ac \times 5) + (H \times 4) + (A \times 3) + (N \times 2) + (P \times 1)$$

SSA represents the weighted arithmetic mean value of the given factors for alternative areas' suitability, ***S*** represents the slope of the alternative areas, ***L*** represents the land use patterns of the alternative areas, ***Ac*** represents the accessibility from the alternative areas to urban facilities, ***H*** represents the preferred heating types in domestic areas, ***A*** represents the aspect of the alternative areas, ***P*** represents the level of air pollutants measured in definite periods of the year (SO_2 and NO_2) and ***N*** represents the distance to the several sources causing noise. While the numbers from 1 to 7 in the scale of relative importance refer the level of suitability in Table 3, the numbers from 1 to 7 in this formula refer to the weighted values for chosen factors. Table 4 shows the symbol, factor classes, area size / distance, area percentage, class values and also weighted values of chosen factors.

The variables related to chosen factors are determined due to the geographical features, land use types, distances from the alternative areas to another area, spatial data for heating types and also measurements for air quality in Çiğli district. For example, the factor classes of land use pattern have four area types because the obtained data from base map and satellite images include only these land usages except any industrial facilities or other land usages. Therefore, the area sizes / distances and the percentage of these land use types in proportion of alternative sites' areas are measured in square meters / meters using ArcMap software. The class values of factor classes between 1 and 7 refer to the priority of these areas in the process of determining the most suitable areas among defined alternatives due to the proposed solution method for new settlement in Çiğli district and its surroundings. In other words, every factor chosen for the suitability analysis has a weighted value. Finally, the weighted value expressed with the number "6" for land use pattern refers to the level of suitability as almost highly suitable areas due to the scale of relative importance.

Table 4. The chosen factors and their weighted values

Factor Name	Factor Classes	Area Size / Distance	Percentage (%)	Class Value	Weighted Values
Land use pattern *(L)*	Residential area	353.014 m^2	57.54	7	6
	Public area	11.231 m^2	1.83	1	
	Green area	51.076 m^2	8.32	3	
	Open area	198.209 m^2	32.31	5	
Slope *(S)*	% 0 - 3	556.419 m^2	95.24	7	7
	% 3 - 9	20.259 m^2	3.47	5	
	% 9 - 15	7.520 m^2	1.29	3	
	% 15 - 20	0.033 m^2	0.01	1	
	% 20 <	-	-	0	
Accessibility *(Ac)*	Dist. to public area	429 m	3.77	7	5
	Dist.to green area	408 m	3.88	3	
	Dist.to transport	994 m	8.74	5	
	Dist.to center	2684 m	23.60	3	
	Dist.to coast	6858 m	60.30	1	
Aspect *(A)*	North (N,NE,NW)	3.038 km^2	0.547	3	3
	South (S,SE,SW)	549.45 km^2	98.99	7	
	West	2.510 km^2	0.45	5	
	East	-	-	1	
	Plain	0.011 km^2	0.002	0	
Preferred heating type *(H)*	Natural gas	34.657 m^2	5.65	7	4
	Other types	329.588 m^2	53.72	3	
	No type	249.285 m^2	40.63	1	
Noise *(N)*	Dist. to airport	5305 m	70.20	0	2
	Dist.to rail	1251 m	16.54	1	
	Dist. to transport	1001 m	13.25	3	
Air pollution *(P)*	Good	541.766 m^2	100	7	1
	Moderate	-	-	5	
	Unhealthy for sensitive groups	-	-	3	
	Unhealthy	-	-	1	
	Very unhealthy	-	-	0	
	Hazardous	-	-	0	

3.1. The Chosen Factors for the Suitability Analysis

The site selection and the determination of suitable areas to settle have a complex structure that consists of not only natural and spatial characteristics (land use pattern, location, climate, slope, land use capability, geological and geomorphological features, lithology, etc.) but also the results of human activities (noise, air pollution, socio-cultural and economic characteristics, the legal and administrative structure, etc.). In order to correctly evaluate and meet the demands (sites of new development, urban transformation etc.) regarding sites that will be developed within localized areas, a comprehensive analysis of this complex structure and the relationship between its components must be conducted. Accordingly, three alternative new development areas within Çiğli district are evaluated in terms of suitability according to natural and human factors. In this study, every factor chosen for the suitability analysis has a weighted value expressed as a number between 1 and 7. In other words, there are four types of suitability; marginally suitable (expressed as number "1"), moderately suitable (expressed as number "3"), suitable (expressed as number "5") and highly suitable (expressed as number "7"). Non - suitable areas are expressed as number "0".

3.1.1. Land Use Pattern

The land use patterns are divided into five categories; residential areas, public areas, open areas, green areas and industrial areas. The data related to the land use patterns are obtained from The Metropolitan Municipality of Izmir and also a detailed data set is constituted using this data. The selection of land use patterns as a factor related to suitability is extremely significant to the prevention of unplanned and uncontrolled urban development. Within the analysis of the three alternative areas, 57.54% of residential areas (expressed with the value "7") are determined as highly suitable, 32.31% of open areas (expressed with the value "5") as suitable, 8.32% of green areas (expressed with the value "3") as moderately suitable, and 1.83% of open areas (expressed with the value "1") as marginally suitable areas for settlement. Moreover, according to the scale of relative importance, I. and III. Alternative areas consist of suitable and highly suitable areas for settlement (Figure 2), while marginally suitable areas are located in the northern part of the II. Alternative area (Figure 3c).

3.1.2. Slope

The slope factor is one of the main components of the suitability analysis because the increase of the slope creates a disaster risk in settlement areas. The analysis map for the slope of alternative areas is derived from GDEM (Digital Elevation Model) and the obtained slope values are determined as a percentage (%). In the slope map consisting of whole Çiğli district, the slope values are divided into five categories including 0-3%, 3-9%, 9-15%, 15-20%, over 20%. In the analysis, it is monitored that 95.24% of areas with 0-3% slope in three alternative areas consist of highly suitable areas (expressed as number "7"), 3.47% of areas with 3-9% slope consist of suitable areas (expressed as number "5"), 1.29% of areas with 9-15% slope consist of moderately suitable areas (expressed as number "3"), 0.01% of areas with 15-20% slope consist of marginally suitable areas (expressed as number "1"). Areas of over 20% slope consist of not suitable areas and are assigned a value of "0". Therefore, according to the scale of relative importance, there exist suitable and highly suitable areas in the I. Alternative area, while marginally suitable and moderately areas are located in the II. and III. Alternative areas (Figure 3e).

3.1.3. Accessibility

The alternative areas in Ciğli district are evaluated in terms of accessibility using the coordinated base map obtained from Izmir Metropolitan Municipality and the satellite images obtained from Google Earth. The accessibility values are divided into five categories; the distance to public areas (expressed as number "7"), distance to transportation routes (expressed as number "5"), distance to green areas (expressed as number "3"), distance to the district center (expressed as number "3") and distance to the coast (expressed as number "0"). The unit of distance is used as meters (m). According to the classification of distances which is based on walking distances by the regulations related to physical plans; the distance from the center points of alternative areas to public areas is approximately 429 meters, the distance from the center points of alternative areas to transportation routes is approximately 994 meters, the distance from the center points of alternative areas to green areas is approximately 408 meters, the distance from the center points of alternative areas to the district center is approximately 2684 meters and the distance from the center points of alternative areas to the coast is approximately 6858 meters. Additionally, according to the scale of relative importance, it is observed that the distance of I. Alternative area is far away from the coast, the district center and transportation routes, while II. and III. Alternative areas are quite close to every location (Figure 3a).

3.1.4. Aspect

The aspect factor that means the compass direction of mountain slopes' faces has a strong influence on several issues such as temperature, topography, microclimate, etc. Also, it is definitely known that the aspect is an important factor in terms of site selection in urban areas. In most cases in Turkey, a south - facing slope (including south – east, south – west) is warmer than a sheltered north - facing slope (including north – east, north – west) [11, 44]. In the analysis map for the aspect obtained from GDEM (Digital Elevation Model), the aspect factor values are divided into five categories; the slopes of south, south – east and south – west (expressed as number "7"), the slope of west (expressed as number "5"), the slopes of north, north – east and north – west (expressed as number "3") and the slope of east (expressed as number "1"). Because there are no slopes in the plain areas, the value "0" was assigned for the aspect factor in these areas. Moreover, according to the scale of relative importance, it is observed that there exist suitable and highly suitable areas in the south – eastern parts of the II. and III. Alternative areas, while marginally suitable and moderately areas are located in the north – western parts of III. Alternative area (Figure 3d).

3.1.5. Preferred Heating Type

The usage of fossil fuels in domestic heating and industrial production processes not only increase resource consumption but also cause environmental problems on a local and regional scale such as climate change, air pollution, etc. [30]. The use of natural gas as the preferred type of domestic heating has a significant effect on the reduction of air pollution, which has become a widely environmental and public health problem [37]. There are several types of heating other than natural gas such as asphaltite, wood, coal, and fuel oil [22]. The analysis map is prepared by using existing natural gas lines in Çiğli district obtained from the IzmirGas company, the heating types factor values are divided into three categories

including natural gas as the preferred heating type (expressed as number "7"), other types as the preferred heating type (expressed as number "3") and no type as the preferred heating type (expressed as number "1"). In the analysis, it is observed that 5.65% of natural gas as the preferred heating type in three alternative areas consist of suitable areas (expressed as number "7"), 53.72% of other types as the preferred heating type consist of suitable areas (expressed as number "3") and 40.63% of no type as the preferred heating type consists of suitable areas (expressed as number "1"). Therefore, according to the scale of relative importance, there exist highly suitable areas throughout alternative area I. and also in the north – western and south – eastern parts of alternative areas II and III, while marginally suitable areas are located throughout the II. and III. Alternative areas (Figure 3g).

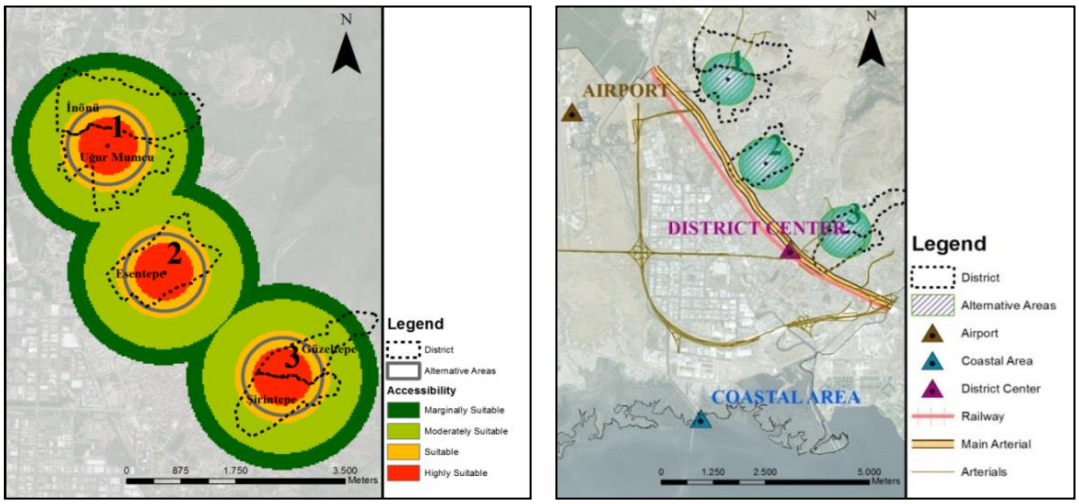
3.1.6. Noise

The noise factor values are divided into three categories; the distance to transportation routes (expressed as number "3"), the distance to railway (expressed as number "3") and the distance to the airport (expressed as number "0"). According to the classification of distances, the distance to transportation routes is approximately 1001 meters, the distance to the railway is approximately 1251 meters and the distance to transportation routes is approximately 1001 meters and the distance to the airport is approximately 5305 meters. Additionally, according to the scale of relative importance, alternative area I is quite closer than the other areas, the alternative area III is the most distant area and also the alternative area II is close to transportation routes and the railway (Figure 3b).

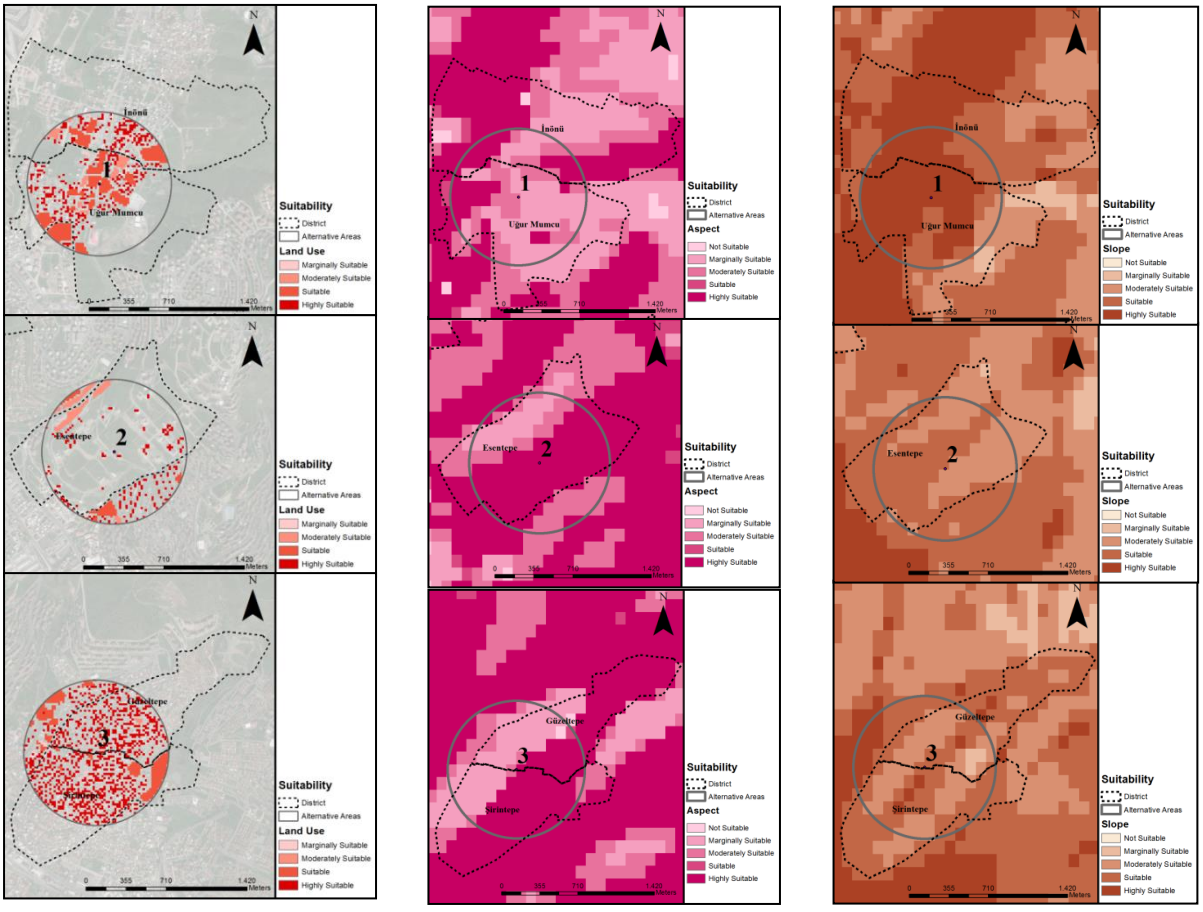
3.1.7. Air Pollution

As a result of industrialization, urbanization, heavy traffic and rapidly increasing population during the last 30 years, environmental issues have been threatening both human and natural life. Dense buildings and population, different urban activities, the increasing automobiles ownership, and the total number of vehicles in traffic can be generalized as the primarily reasons air pollution that affects urban areas [48]. In addition to these urban activities, different factors are significant contributors to reduce of urban air quality such as the reliance on fossil fuels in warming, industrial activities and traffic, dependence on the private automobiles, inefficient use of energy in buildings and public transportation, the use of incorrect and incomplete combustion techniques, the degradation of open and green areas, etc. [49, 50, 51, 54]. Air pollution in urban areas affects not only urban air quality, also quality of life, and public health directly [52, 53], and these circumstances lead to shift in planning decisions.

The analysis map for air pollution is prepared using the levels of air pollutants' concentrations (SO_2 and NO_2) obtained from the Department of Scientific Research Projects issued by Dokuz Eylul University. The levels of air pollutants are measured using passive diffusion tubes for a 4-week period (separately 2-week period for winter and summer seasons) in the district of Çiğli. The unit of air pollutant is $\mu g/m^3$. The air pollution factor values are divided into five categories; good (expressed as number "7"), moderate (expressed as number "5"), unhealthy for sensitive groups (expressed as number "3"), unhealthy (expressed as number "1"), very unhealthy and hazardous (expressed as number "0"). According to the air pollution index prepared by The Ministry of Environment and Urbanization, the range of 0 – 50 μg/m3 represents "good" values, 51 – 100 μg/m3 represents "moderate" values, 101 – 150 μg/m3 represents "unhealthy for sensitive groups" values, 151 – 200 μg/m3 represents "unhealthy" values, 201 – 300 μg/m3 represents "very unhealthy" values and also 301 – 500 μg/m3 represents "hazardous" values. Due to the measurement results for the level of air pollutants' concentrations, the levels of pollutants do not exceed the range of 0 – 50 μg/m3 and the index of air pollution is "good" in the study area (Figure 3f).

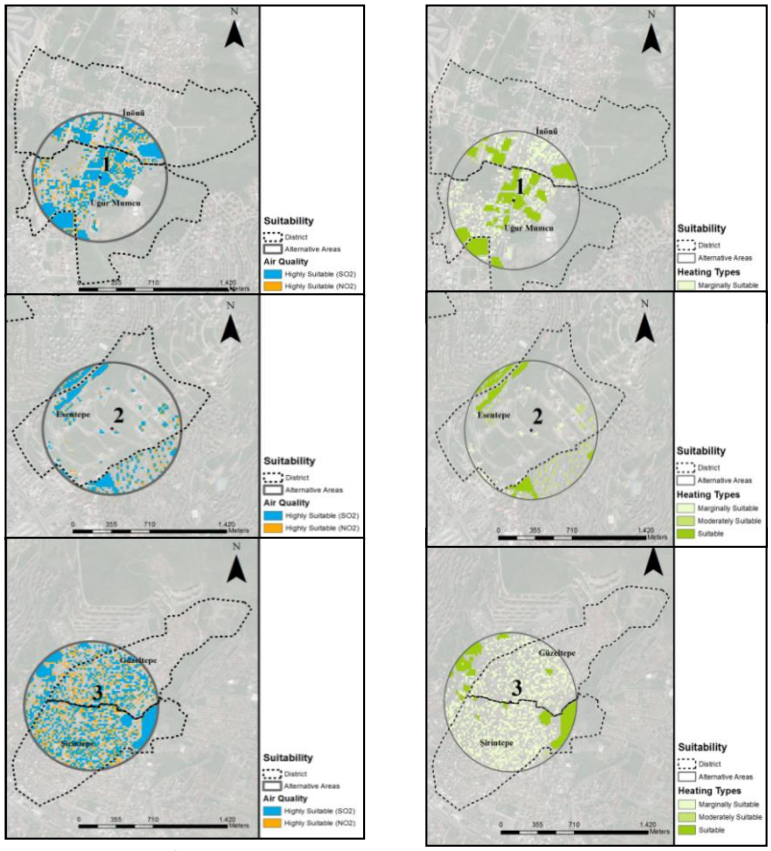


(a) (b)



(c) (d) (e)

Figure 3. The suitability analysis maps for each chosen factors (a, b, c, d, e)



(f) (g)

Figure 3. The suitability analysis maps for each chosen factors (f, g)

3.2. The Suitability Analysis

The alternative areas that are located in the eastern and northern parts of the district center are evaluated in accordance with the natural and human factors in terms of the site selection of new development areas in Çiğli district. Due to the analyses results, it is observed that 92.06% of the I. Alternative area consists of not suitable areas, 0.60% of this area consists of moderately suitable areas, 5.31% of this area consists of suitable areas and 2.03% of this area consists of highly suitable areas. Moreover, it is established that 91.86% of the II. alternative area consists of not suitable areas, 0.87% of this area consists of moderately suitable areas, 7.27% of this area consists of suitable areas. Highly suitable areas have not been observed for this area. Finally, it was confirmed that 71.43% of the III. alternative area consists of not suitable areas, 27.69% of this area consists of suitable areas and 0.87% of this area consists of highly suitable areas. Moderately suitable areas have not been detected in this alternative area (Table 5).

Table 5. The class distribution of suitability in accordance with the alternative areas

Class Values	Class Categories	I. ALTERNATIVE AREA		II. ALTERNATIVE AREA		III. ALTERNATIVE AREA	
		Area Size (m^2)	Percentage (%)	Area Size (m^2)	Percentage (%)	Area Size (m^2)	Percentage (%)
0	Not Suitable	723041	92.06	721440	91.86	561039	71.43
3	Moderately Suitable	4690	0.60	6850	0.87	0	0.00
5	Suitable	41741	5.31	57109	7.27	217509	27.69
7	Highly Suitable	15926	2.03	0	0.00	6850	0.87

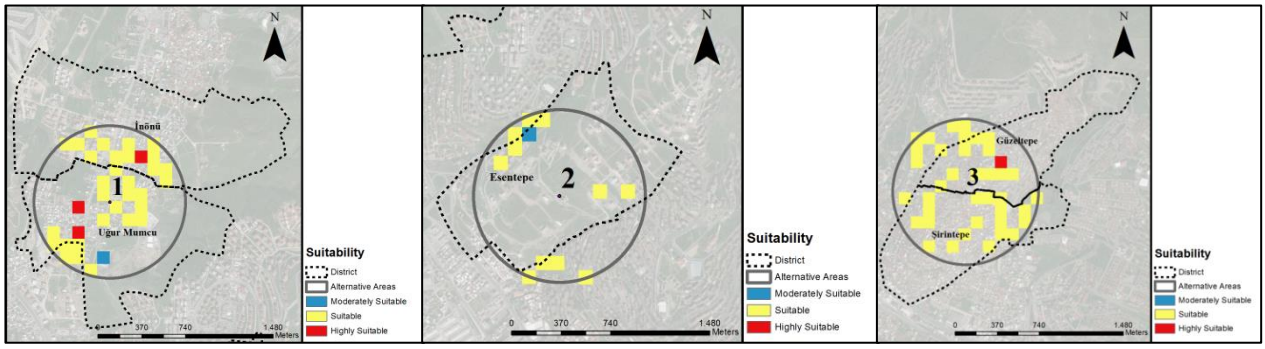


Figure 4. The final map of the suitability generated using the weighted overlay method

According to the results, it is revealed that the suitable areas are located mainly in the III. alternative area among the alternative areas for new development settlements. The main reasons for the selection of III. alternative area as the most suitable area are as follows; the dense use of residential areas in the land use pattern, more livable urban environment as a result of urban renewal projects, the existence of south slopes and faces overlooking the sea, lower slope values not posing a problem for new settlements, the existence of air corridors and good qualified air affected by predominant wind direction, being quite closer to the district center, the coast, railway, transportation routes and green areas, being less affected by noise generating from the airport. Suitable areas are determined in the I. and II. alternative areas, however, they have not been chosen as they are not able to comply with all factors chosen for this particular study. Figure 4 gives a comparative look at the alternative areas in accordance with the suitability categories.

4. Discussion and Conclusions

The determination of the most suitable areas among defined alternatives due to the proposed solution method for new settlement in Çiğli district in accordance with the suitability factors and also the implementation of the suitability analysis by using GIS are the main purposes of this study. The natural and human factors are considered in terms of the suitability of three alternative areas that are located in the eastern and northern parts of the district center. Following the determination of alternative areas to settle, these areas are evaluated in accordance with certain factors such as the topography, land use patterns, accessibility, noise, air pollution, and the preferred heating types, especially in residential areas. Due to the factor-based classification and the suitability analysis results, it is revealed that the suitable areas are located mainly in the III. alternative area among the alternative areas for new development settlements. No highly suitable areas are observed within the area of suitability analysis when taking the slope and preferred heating type into account. Therefore, it can be said that these two factors affect the alternative areas negatively in the district center.

According to the suitability analysis considering all chosen factors for alternative areas, these areas are observed as not highly suitable (expressed as number “7”) or moderately suitable (expressed as number “3”) areas, but as suitable areas (expressed as number “5”) for new development areas to settle. The most suitable areas are located in the east part of the district center. Therefore, unsuitable areas are located mainly in the northern and north – eastern parts of the district center. Several conditions affected the site selection of alternative areas negatively such as the slope values above 9%, the high density public and green areas, the existence of north slopes and faces not overlooking the sea, the limited accessibility to urban facilities, etc.

In addition to the certain factors mentioned before, other factors exist that represent the local dynamics of the study area that are not used and analyzed in the study such as the meteorological factors (temperature, rainfall, humidity, etc.) [33], lithology (limestone, conglomerate, basalt, travertine, alluvium, etc.) [21, 33], hydrogeology (groundwater, lakes, dams, rivers, sea, etc.) [14], land use capability classes and also the existence of disaster risk [8]. Because of the small scale of the study area and the similarities in the parts of the study area in terms of meteorological features, the meteorological factors are not used during the analysis process. The alternative areas are currently residential areas and have a mainly built-environment, so any agricultural activities cannot be made in these areas in terms of land usability. Additionally, the study area is not located in a critical region in terms of disaster risk, so this factor was eliminated.

In the urban planning studies, the diversification of factors that determine the suitability and the evaluation of the settlements’ features (natural factors, distances, technical infrastructure facilities, the air quality, noise, disaster risks, etc.) should be evaluated comprehensively. The sustainable development is based on the results of these evaluations. The multi – criteria evaluation for site selection and suitability analysis have become more significant especially in urban renewal areas such as Güzeltepe and Şirintepe neighborhoods located in the III. alternative area.

The findings of this study are compared with the findings of other studies that are based on the suitability analysis in different cases and scales (local, urban and regional scales). In literature, a number of studies examine the GIS – based suitability analysis at in urban scale for cities in Turkey such as Süleymanpaşa case study (Tekirdağ) [33], Çanakkale case study [63], Malatya case study [14], Sivas case study [21], Iskenderun case study [8], Bolu case study

[61], Kocaeli case study [62] and Antakya case study [32]. The results of analyses in the scope of this study coincide with the results of these case studies. Özşahin and Kaymaz (2015) emphasize that the factor - based suitability analyses should be evaluated with urban residential areas and also the elements of natural environments in the context of city planning discipline [32]. Değerliyurt et al. (2014) has stated that the suitability analyses using various spatial data are quite important for to ensure the ecological sustainability and decrease the disaster risk especially in urban areas [8]. The location of chosen areas closer to urban centers and main transportation routes, less sloped area which are not avoid to place other settlements, the presence of public and open – green areas near these chosen areas as different land use types are the common features of the most suitable areas for new residential development areas. The findings of this study are provided consistency with other studies in terms of these common features. Moreover, a sizeable amount of studies related to the suitability analysis in especially rural and coastal areas [70, 71, 72] and GIS – based MCDM analysis determining the sustainable urban environments and land use planning [68, 69, 73, 74, 75] can be given as other studies performed in different cases.

A GIS – based MCDM analysis and the obtained results of this analysis for analyzing the most suitable areas for new residential developments areas are thought a very important source for the decision – makers in Çiğli district and as a contribution to the literature. This study can be a reference not only the determination of new development areas but also land use planning studies which will be conducted similar to this study.

It is known that the results of empirical studies including the evaluation of natural and human factors' effects in urban areas can be used in the decision-making processes within the urban planning discipline [32]. The suitability analysis is rewarding and explanatory not only in physical and spatial planning studies but also in the reduction of disaster risk and the protection of the natural environment [5, 8]. It is thought that the results of the suitability analysis and the thematic maps created can be a significant reference for decision – makers concerning new development areas and planning decisions for these areas in Çiğli district and its surroundings. A common data standard should be constituted including the suitability criteria and data layers in order to conduct more successful and comprehensive empirical studies in the future. Finally, it is a critical issue that these studies should be implemented on a sub-regional and neighborhood scale, instead of a regional scale to make extensive spatial analysis related to suitability.

REFERENCES

[1] H. M. Aslan, M. S. Yıldız, H. T. Uysal. Afet istasyonlarının kuruluş yeri seçiminde bulanık topsis yönteminin uygulanması: Düzce'de bir lokasyon analizi, Siyaset, Ekonomi ve Yönetim Araştırmaları Dergisi, Vol.3, No:2, 111-128, 2015.

[2] S.M.J. Baban, D.T.F.Canisius, K.J. Sant. Managing development in the hillsides of Trinidad and Tobago using geoinformatics, Sustainable Development, Vol.16, No:5, 314-328, 2007.

[3] Y. Balca. Düzenli depolama alanı belirlemede karar destek sistemi kullanımı, Doktora Tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul, 2015.

[4] Y. Chen, J. Yu, K. Shahbaz, E. Xevi. GIS-based sensitivity analysis of multi-criteria weights. 18th World IMACS / MODSIM Congress, Australia, 2009.

[5] Çiğli Municipality, 2012 – 2016 Stratejik Plan Raporu, İzmir, 2011.

[6] F. C.Dai, C. F. Lee, X. H. Zhang. GIS-based geo-environmental evaluation for urban land-use planning: a case study, Engineering Geology, Vol.61, 257-271, 2001.

[7] G. Dapueto, F. Massa, S. Costa, L. Cimoli, E. Olivari, M. Chiantore, B. Federici, P. Povero. A spatial multi-criteria evaluation for site selection of offshore marine fish farm in the Ligurian Sea, Italy, Ocean and Coastal Management, Vol. 116, 64–77, 2015.

[8] M. Değerliyurt, S. N. Çabuk, R. Aksu. Sürdürülebilir kentsel gelişim için yerleşime uygun alanların belirlenmesi: İskenderun kenti örneği, Coğrafyacılar Derneği Uluslararası Kongresi Bildiriler Kitabı, Muğla Sıtkı Koçman Üniversitesi, Muğla, Türkiye, 380 – 389, 2014.

[9] K.O. Demirarslan, M.K. Korucu, A. Karademir. Katı atık depolama alanlarının nihai yer seçiminde coğrafi bilgi sistemleri ve kirlilik dağılım modellerinin birlikte kullanımı, V.Hava Kirliliği ve Kontrolü Sempozyumu, Eskişehir, Turkey, 2013.

[10] Dokuz Eylul University, Department of Scientific Research Projects, Project No:2014.KB.FEN.006, Izmir, Turkey, 2014.

[11] Y. Dönmez. Umumi Klimatoloji ve İklim Çalışmaları. İstanbul Üniversitesi Basımevi, Fakülte Yayın No: 3248, Istanbul, Turkey, 1990.

[12] H. Durguter. Kent modelleri ve sürdürülebilir kent yönetimi, Turkish Studies – International Periodical for the Languages, Vol.7, No.3, 1053-1065, 2012.

[13] D. Ekinci, E. Sönmez. İstanbul konürbasyonunun yeni habitat adacığında CBS tabanlı jeoekolojı planlama analizi, Türk Coğrafya Dergisi, Vol.46, 2007.

[14] F. Engin, M.T. Şengün. CBS yardımı ile toplu konut alanları yer seçimi; Malatya örneği. TÜCAUM Uluslararası Coğrafya Sempozyumu Bildiriler Kitabı, Ankara, Turkey, 826 – 844, 2016.

[15] T. Erden, M.Z. Coşkun. Acil durum servislerinin yer seçimi: Analitik Hiyerarşi Yöntemi ve CBS entegrasyonu, İTÜ DERGİSİ, Vol.9, No.6, 37-50, 2011.

[16] J.P. Gupta. Land Use Planning in India, Journal of Hazardous Materials, Vol.130, 300- 306, 2006.

[17] Izmir Development Agency. 2014-2023 İzmir bölge planı ilçe toplantıları, Çiğli ilçe raporu, İzmir, Turkey, 2013.

[18] Izmir Directorate of Provincial Food Agriculte and Livestock Kullanım türlerine göre tarım arazisi dağılımı, İZKA 2014 - 2023 İzmir Bölge Planı İlçe Toplantıları, Çiğli İlçe Raporu, İzmir, Turkey, 2012.

[19] Izmir Metropolitan Municipality. 1/25000 ölçekli İzmir büyükşehir bütünü çevre düzeni planı açıklama raporu, İzmir, Turkey, 2012.

[20] IzmirGas Company. İzmir doğalgaz iletim hatları, İzmir GAZ Altyapı Şube Müdürlüğü, İzmir, Turkey, 2014.

[21] C.B. Karakuş, O. Cerit. Coğrafi Bilgi Sistemi kullanılarak Sivas kenti ve yakın çevresi için yerleşim açısından en uygun alanların belirlenmesi, Cumhuriyet Üniversitesi Fen Fakültesi Fen Bilimleri Dergisi, Vol.38, No.1,2017.

[22] Ç. Karapınar. Kahramanmaraş'ta doğalgaz kullanımının hava kalitesi üzerindeki etkisinin araştırılması, Yüksek Lisans Tezi, Kahramanmaraş Sütçü İmam Üniversitesi, Kahramanmaraş, 2012.

[23] D. Khan, S.R. Samadder. A Simplified multi-criteria evaluation model for landfill site ranking and selection based on AHP and GIS, Journal of Environmental Engineering and Landscape Management, Vol.23, No.4, 267-278, 2015.

[24] Ç. Kolat. Geographical information systems based microzonation map of Eskişehir downtown area. Yüksek Lisans Tezi, Orta Doğu Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, 2004.

[25] M. Küçükönder, M. Karabulut, M. Çok kriterli analiz yöntemi kullanılarak Kahramanmaraş'ta çöp depolama alanı tespiti. Coğrafi Bilimler Dergisi, Vol.5, No.2, 55-76, 2007.

[26] V.N. Martins, P. Cabral, D. Sousa Silva. Urban modelling for seismic prone areas: The case study of Vila Franca do Campo (Azores Archipelago, Portugal). Natural Hazards Earth Systems Science, Vol.12, 2731–2741, 2012.

[27] Ministry of Environment and Urbanisation. Hava kalitesi izleme istasyonları, 2017.

[28] Ministry of Environment and Urbanisation. Mekansal planlar yapım yönetmeliği, 2017.

[29] U.B. Nidumolua, C. Biea, H. Keulenb, C.A. Ski Dmo Re, K. Harmsena. Review of a land use planning programme through the soft systems methodology, Land Use Policy, Vol. 23, 187-203, 2006.

[30] N.S. Özcan. Kentsel hava kirliliğini etkileyen ve şehir planlama ile kontrol edilebilen fiziksel faktörlerin mekânsal istatistik yöntemleri ile incelenmesi, Doktora Tezi, Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, İzmir, 2016.

[31] N.S.Özcan, K.M. Çubukçu. Examination of the Relationship between Urban Air Pollution and Urban Planning Decisions in Çiğli Case, Izmir, Turkey, ASEAN-Turkey ASLI Conferences, ABRA International Conference on Quality of Life Proceedings, Izmir, 2015.

[32] E. Özşahin, Ç.K. Kaymaz. CBS ve AHS kullanılarak doğal çevre bileşenleri açısından kentsel mekânın yerleşime uygunluk analizine bir örnek: Antakya (Hatay), Doğu Coğrafya Dergisi, Vol.20, No.33, 2015.

[33] H. Pektezel. Süleymanpaşa'nın (Tekirdağ) CBS tabanlı jeoekolojik planlama analizi, The Journal of Academic Social Science Studies, Vol.35, 163 – 185, 2015.

[34] A.A. Qaddah, M.F. Abdelwahed. GIS-based site-suitability modeling for seismic stations: Case study of the northern Rahat volcanic field, Saudi Arabia. Computers and Geosciences, Vol.83, 193-208, 2015.

[35] P. Roberts. The Evolution, Definition, and Purpose of Urban Regeneration. Urban Regeneration a Handbook, SAGE Publications, London, 2000.

[36] Satellite images, Google Earth, 2017.

[37] G. Tuncel, A. Müezzinoğlu, S. Tuncel, A. Bayram, M. Odabaşı, S.C. Sofuoğlu. İzmir Aliağa endüstri bölgesinde hava kirliliğine neden olan organik ve inorganik kirleticilerin düzeylerinin, kaynaklarının ve sağlık etkilerinin belirlenmesi, TÜBİTAK 104Y276 Nolu Proje Raporu, İzmir, 2008.

[38] Turkish Statistical Institute. Adrese Dayalı Nüfus Kayıt Sistemi Sonuçları, 2015.

[39] P.D. Uy, N. Nakagoshi. Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. Urban Forestry and Urban Greening, Vol.7, 25-40, 2008.

[40] M. Uyan. MSW landfill site selection by combining AHP with GIS for Konya, Turkey. Environmental Earth Sciences, Vol.71, No.4, 1629-1639, 2014.

[41] M. Uyan, Ş. Yalpır. Çok kriterli karar verme modeli ve CBS entegrasyonu ile tıbbi atık sterilizasyon tesislerinin yer seçimi. Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, Afyon, Vol.16, 642-654, 2016.

[42] M.H. Vahidniaa, A. Alesheikhb, A. Ali Mohammadi, A. Bassirid. Fuzzy analytical hierarchy process in GIS application, the international archives of the photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B2, Beijing, 2008.

[43] G.P. Yal, H. Akgun. Landfill site selection utilizing TOPSIS methodology and clay liner geotechnical characterization: a case study for Ankara, Turkey, Bulletin of Engineering Geology and the Environment, Vol.73, No.2, 369-388, 2014.

[44] İ. Yalçınlar. Türkiye'de bazı şehirlerin kuruluş ve gelişmesinde jeomorfolojik temeller, İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi, Vol.16, 53-66, 1967.

[45] L.C. Mundia. Participatory mapping framework and guidelines from a GIS perspective, Environment and Ecology Research, Vol.4, No.5, 280-287, 2016.

[46] O.S. Adeola. Urban egalitarianism: the way forward to ensure sustainable urban design, practice and development in developing countries (The Nigerian Case), Environment and Ecology Research, Vol.4, No.3, 107-115, 2016.

[47] M.S. Moghadam, N. Rajabi, F. Zonghadr, K. Palad, S. Azimi. Examining the effective rate of environmental qualities on the security of citizens in urban designs using AHP model (Sepah and Molavi Districts in Qazvin City of Iran), Environment and Ecology Research, Vol.2, No.4, 178-184, 2014.

[48] M. Mansha, B. Ghauri, S. Rahman, A. Amman. Characterization and source apportionment of ambient air particulate matter ($PM_{2.5}$) in Karachi, Science of the Total Environment, Vol. 425, 176–183, 2012.

[49] Z. Grsic, D. Dramlic, D. Arbutina, N. Miljevic, S. Dramlic, P. Milutinovic, J. Kaljevic, S. Pavlovic, D. Joksimovic. Representativity of air quality control in

limited number of grid points, Journal of Environmental Protection and Ecology, Vol.15, No.1, 1–6, 2014.

[50] D. Dimitrovski, M. Dimitrovski, A. Jovanovski. Natural gas as a fuel in public passenger transportation in urban areas, Journal of Environmental Protection and Ecology, Vol.16, No.1,1–6, 2015.

[51] E. Bouhouras, S. Basbas. Policies towards sustainable city logistics: the case of Thessaloniki, Journal of Environmental Protection and Ecology, Vol.16, No.2, 417–423, 2015.

[52] G.Y. Deak, G.S. Tanase, V. Daescu, R. Csergo, E. Holban, A.I. Daescu, P. Marinescu, S. Aman. Health–environment relation: a key issue of Romanian environmental protection, Journal of Environmental Protection and Ecology, Vol.16, No.1, 304–315, 2015.

[53] H. Borhan, E.M. Ahmed, M. Hitam. CO2, Quality of Life and Economic Growth in East Asian 8. Journal of ASIAN Behavioural Studies (jABs), 13-25, 2013.

[54] S. Azimi, M.S.Moghaddam. Effect of mercury pollution on the urban environment and human health, Environment and Ecology Research, Vol.1, No.1, 12-20, 2013.

[55] L.T. Anderson. Seven methods for calculating land capability/suitability. Planning advisory service (PAS), Report No: 402, American Planning Association, Chicago, 1987.

[56] R. Banai-Kashani. A new method for site suitability analysis: The analytic hierarchy process. Environmental Management, 13 (6), 685–693, 1989.

[57] F.S. Chapin, E.J. Kaiser. Urban land use planning. University of Illinois Press, Chicago, 1979.

[58] K.J. Dueker. Land resource information systems: a review of fifteen years experience. Portland State University, Oregon, USA, 1979.

[59] T.L. Saaty. The Analytic Hierarchy Process. McGraw-Hill, New York, 1980.

[60] E. Triantaphyllou, S.H. Mann. Using The Analytic Hierarchy Process for Decision Making in Engineering Applications: Some Challenges. Inter'l Journal of Industrial Engineering: Applications and Practice, 2 (1), 35-44, 1995.

[61] E. Alparslan, F. Ince, B. Erkan, C. Aydöner, H. Özen, A. Dönertaş, S. Ergintav, F.S. Yağsan, A. Zateroğulları, I. Eroğlu, M. Değer, H. Elalmış, M. Özkan. A GIS model for settlement suitability regarding disaster mitigation, a case study in Bolu, Engineering Geology, 96, 126-140, 2008.

[62] C. Aydöner, D. Maktav. Deprem açısından yerleşim yeri uygunluk analizleri, Havacılık ve Uzay Teknolojileri Dergisi, Cilt: 6, Sayı: 1, s.: 53-62, 2013.

[63] C. Z. Çavuş, T. Koç. Çanakkale Boğazı Doğusunda Arazi Kullanım Uygunluğunun Yerleşme Açısından Analizi. Coğrafi Bilimler Dergisi, CBD,13 (1), 41-60, 2015.

[64] M. Akten. Isparta Ovasının Optimal Alan Kullanım Planlaması Üzerine Bir Araştırma, Basılmamış Doktora Tezi, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü, Isparta, 2008.

[65] M. Akten, S. Akten. Sürdürülebilir arazi kullanım planlaması için bir model yaklaşımı: tarım sektörü örneği, Biyoloji Bilimleri Araştırma Dergisi (BIBAD), 3 (1),85-89, 2010.

[66] M. Bagheri, W.N. Azmin. Application of GIS and AHP technique for land-use suitability analysis on coastal area in Terenggau, World Automation Congress (WAC), September, 19-23, Kobe-Japan, 2010.

[67] T. Cengiz. Peyzaj Değerlerinin Korunmasına Yönelik Kırsal Kalkınma Modeli Üzerine Bir Araştırma: Seben İlçesi (Bolu) Alpağut Köyü Örneği , Basılmamış Doktora Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara, 2003.

[68] T. Cengiz, C. Akbulak. Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation: a case study of Dümrek Village (Canakkale, Turkey), International Journal of Sustainable Development and World Ecology 16(4), 286–294, 2009.

[69] T.T. Duc. Using GIS and AHP technique for land-use suitability analysis, International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences (GIS-IDEAS), 4-6 December Hanoi, Vietnam, 2006.

[70] J. Malczewski. GIS-based land-use suitability analysis: a critical overview, Progress in Planning 62, 3-65, 2004.

[71] G.A. Mendoza. A GIS-based multicriteria approaches toland suitability assessment and allocation, Proceedings: Seventh International Symposium on Systems Analysis in Forest Resources, May 28-31, Traverse City-Michigan, ABD, 1997.

[72] P. Weerakoon. Integration of GIS based suitability analysis and multi criteria evaluation for urban land use planning: contribution from the analytic hierarchy process", Proceedings of the 2002 Asian Conference on Remote Sensing, Kathmandu-Nepal, 2002.