GIS AND FUZZY AHP BASED AREA SELECTION FOR ELECTRIC VEHICLE CHARGING STATIONS

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ABSTRACT:

Significant work is being done to protect the world and ecosystem. Innovative approaches are being explored to reduce the harm of the methods used to sustain life. Mobility is an essential issue that affects people and society in today's life. Automobiles are the most commonly used vehicle for mobility in private life and public service activities such as transportation. One of the important subjects that should be applied to environmentally sensitive methods is transportation. One of the major problems encountered today is the harmful effects of internal combustion motor vehicles. Electric vehicles are preferred because they work efficiently and with the least damaging effect on the environment. The location of electric vehicles is a complicated problem because it depends on many different factors. In this study, fuzzy analytical hierarchy process (Fuzzy AHP) as multi-criteria decision-making (MCDM) methods and geographic information systems (GIS) to manage data which can be used for the location selection of electric vehicles charging stations are researched. The study area was determined by three neighboring districts boundaries city of Istanbul in Turkey.

1. INTRODUCTION

Electricity of passenger vehicles can profit from the solution of three important difficulties today. First, electric vehicles can reduce greenhouse gas emissions by using electricity instead of gasoline, depending on the electricity sources. In addition, electric vehicles are less harmful to the environment and people by decreasing emissions from exhausts. Also, electric vehicles can lessen the consumption of gasoline and provide relief from imported dependence on petrol (Michalek et al., 2011).

The growth in the popularity of electric vehicles is helped by the fact that it is more environment-friendly than the conventional internal combustion engines and the rising oil prices. Electric vehicles are rapidly adopted not only by policy creators but also by the public. In this perspective, many countries consider resourceful policies that encourage the dissemination of relevant technologies (Massiani, 2015).

The construction of the network of electric vehicle charging structures, the availability for the users, the construction of the charging stations and the charging cost to be paid by the users are the conditions directly influencing the adaptation of the electric vehicles and the extent of the development and application of the electric vehicles. In this direction, it is significant that the electric vehicle charging stations are selected suitably (Jia et al., 2012).

There are several studies exist concerning the location selection of the electric charging stations in the literature. Zhao and Li (2016) have carried out a study using fuzzy Delphi and hybrid multi-criteria decision making (MCDM) methods with regard to extended sustainability for the suitable siting of electric vehicle charging stations. According to study results, environment sub-criteria had more effective than other sub-criteria. He et al. (2016) have aimed that the combination of local limitations of supply and request on public electric vehicle charging stations in terms of facility location models. The study had a comparison of the three distinct location models for electric vehicle ideal charging locations in Beijing, China. Xiang et al. (2016) have conducted a study that suitably determines the siting and sizing of electric vehicle charging stations in the sense of relations among power and transportation businesses.

He et al. (2018) have investigated that the electric vehicle’s driving range has an important effect on optimal charging station location. Güler and Yomralıoğlu (2018) have conducted research to find optimal location of electric vehicle charging stations utilizing geographic information systems (GIS) and analytical hierarchy process (AHP).

GIS can be used as a solution tool for different problems thanks to the ability to operate spatial data. Roodposhti et al. (2014) have created GIS-based erosion sensitivity maps using fuzzy analytical hierarchy process (FAHP) and PROMETHEE II, which are Multi-Criteria Decision Making (MCDM) techniques. Eight geographic data layers related to erosion were used in the study. Lin and Lin (2013) have proposed to concept a fuzzy GIS model from real estate valuation using the AHP. Twenty different criteria were selected and evaluations were carried out. By using GIS, spatial and semantic data were analyzed together and the results were obtained.

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Zhang et al. (2015) used the FAHP and GIS for the study area in Shandong province of China to identify suitable areas for tobacco farming. Twenty suitability criteria were used, including climate conditions, soil formation, and topography. Güler and Yomralıoğlu (2017) have investigated alternative suitable sites for landfill using GIS and AHP in Istanbul, Turkey.

In this study, it is aimed to find a solution to the problem of choosing the location of the electric vehicle charging station using the FAHP with GIS.

2. METHODOLOGY

The location selection of electric vehicle charging station study was carried out in Turkey's Istanbul city limits. The boundaries of the study area are circumscribed by Uskudar, Atasehir and Kadikoy districts. While selecting the study area, population and electric vehicle usage potential are considered. The above-mentioned districts have a population of 423,372, 533,570 and 451,453 respectively. According to the statistics of the year 2017, it is noticed that these are among the most populated districts of Istanbul.

Districts containing the study area are adjacent to each other. The study area map is presented in Figure 1. In the study area, there is urban fabric as a dense land class. Transportation routes and green areas are also located in the working area.

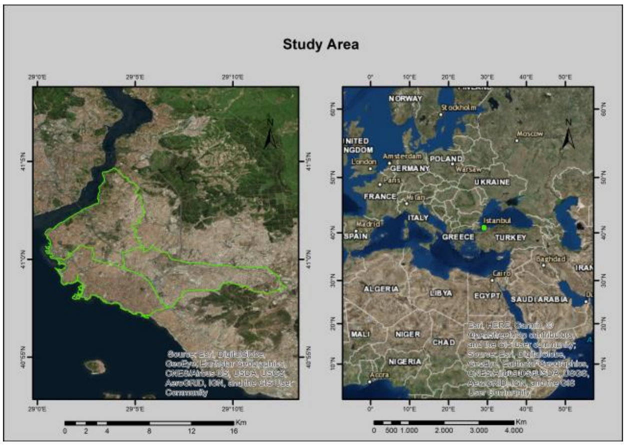

Figure 1. Study area

Difficulties are encountered in evaluating and determining weights when the ratios of the selectivity factors are not existing. In such cases, the AHP method, which is one of the MCDM methods, can be operated. AHP solves complex problems with the help of hierarchical structuring, which is created by alternatives. The pairwise comparisons created in the hierarchy are based essentially on judgments, rather than as a total list of all decisions and criteria (Saaty, 1980).

Many decision-making and problem-solving tasks are complicated to understand quantitatively. Yet, people can evaluate these situations as flawless or faulty by using information. Fuzzy set theory resembles human thinking with the use of approximate knowledge and ambiguities in decisions. It provides improbability and unclearness mathematically and provides tools to deal with many problems with inherently incorrect measurements (Kahraman et al., 2004).

The fuzzy set theory is an addition to classical set theory (Zadeh, 1965). The fuzzy set theory can be considering it as a system that tries to eliminate the uncertainty of the class of objects whose boundaries cannot be identified sharply (Zadeh, 1996).

Because of the fuzziness is general characteristics of decision-making problems, fuzzy AHP has been developed for this problem (Mikhailov and Tsvetinov, 2004). The FAHP allows the decision makers to state their preferences in approximate or adaptable ways using fuzzy numbers when adding fuzziness to inputs. Besides, it adds fuzziness to decisions (Wang et al., 2008).

Most of the basic steps included in FAHP with AHP are similar. The use of fuzzy numbers instead of discrete numbers the procedure of settling priorities in pairwise matrices can be distinguished as the difference between the two methods (Pazand et al., 2014).

It can be considered that the environment should take less damage while electric vehicle charging stations are being settled. For this reason, the lower sub-criteria score was given to the areas near the green areas. Higher values are assigned to areas far from green areas (Fig. 2).

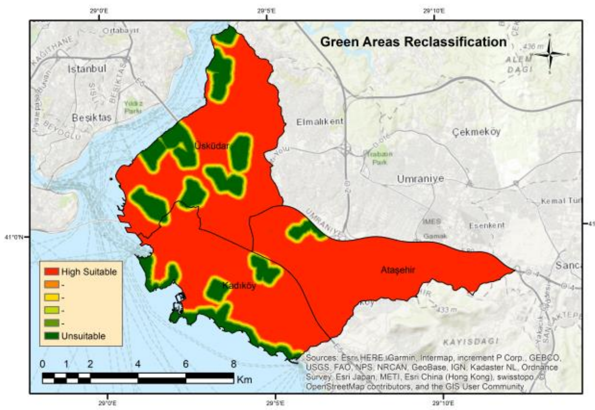

Figure 2. Distance to green areas map

Roads are one of the effective factors from the point of electric vehicle usage. Users will be able to charge their vehicles more easily at charging stations close the roads. In this context, regions close to roads have high values whereas distant regions have low sub-criteria values (Fig. 3).

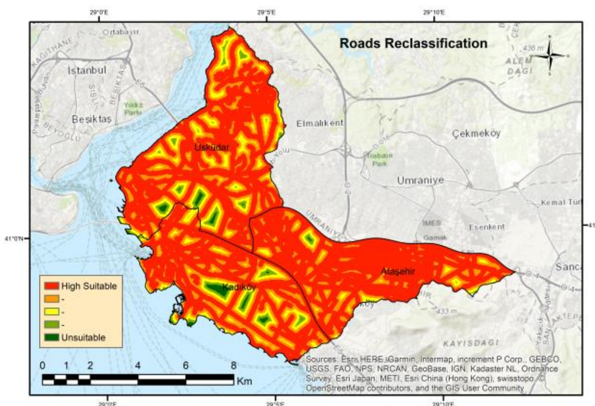

Figure 3. Distance to roads map

Parking lots are places that can be preferred for electric vehicle charging stations. One of the places where users leave their vehicles for general use, parking lots can provide more proficient use of charging times. High values have been appointed to locations close to parking lots (Fig. 4).

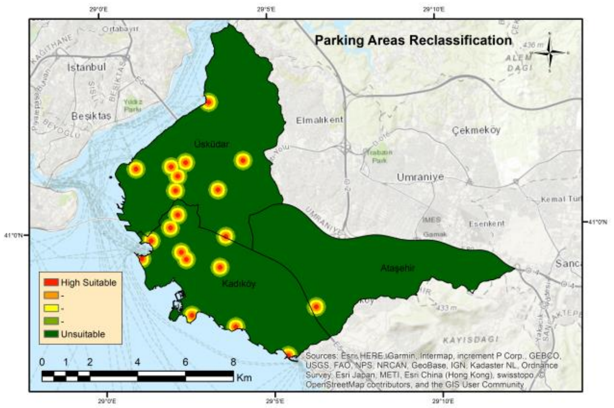

Figure 4. Distance to parking areas map

In this study, fuzzy extent analysis method based on triangular fuzzy numbers is applied (Chang, 1996). First, object set and goal set are accepted. In this method, each object is taken and extent analysis for each goal is performed respectively. Thus, extent analysis values for each object can be obtained. Then, the value of fuzzy synthetic extent is determined regarding each object. The degree of possibility is obtained for each pair triangular fuzzy numbers. Lastly, the weight vector is determined using a degree of possibility for a convex fuzzy number and the non-fuzzy number is obtained with normalization of the weight vector.

The previous works were examined to decide the location of the electric vehicle charging station and the pairwise matrix used in FAHP was established (Chen et al., 2016; Wu et al., 2016; Zhao and Li, 2016). The criteria weights were then calculated using the FAHP method. Table 1 shows the criteria weights used in the research.

Criteria	Weights
Distance to Green areas	0,199512
Slope	0,085254
Distance to Roads	0,087558
Distance to petrol stations	0,078252
Distance to shopping malls	0,082142
Distance to park areas	0,093695
Income rates	0,096743
Land values	0,088906
Population density	0,092447
Distance to transportation stations	0,095492

Table 1. Criteria weights

3. RESULTS

It is aimed to obtain the results by using the criteria weights calculated with FAHP method together with the spatial analysis features of GIS. A map layer was created for each criterion applied in the study.

All map layers have the same coordinate system. Weighted sum analysis was used in GIS software. Each map layers have been prepared in raster data format with the same pixel value for the analysis. The results were acquired by entering the weight analysis of each criterion. The map showing the suitability of location selection as a result of the analysis is displayed in Figure 5.

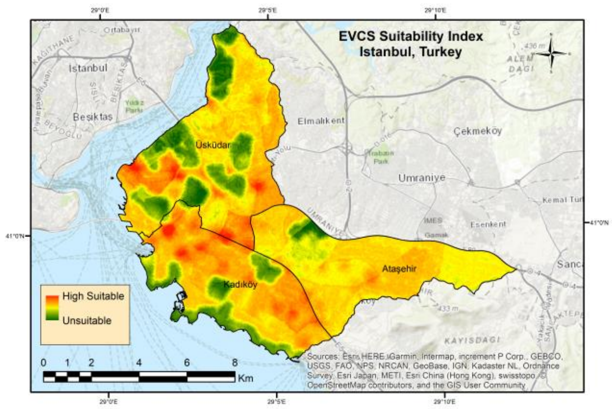

Figure 5. Suitability index

It is seen that the high suitable class areas appearing in the map prepared as a result of the study are high-value regions in terms of the accessibility of the user in selecting the location of the electric vehicle charging station. Among the three districts, Kadikoy is the most suitable district in the study.

In the FAHP hierarchy, environmental, economic and social criteria are used which are effective in selecting the location of the electric vehicle charging station. The criterion used in the multi-criterion system created gives a depth to the finding of the optimal areas in the site selection. In the conducted study the effect of the decision-making process was revealed by using GIS in three provinces in Istanbul. With the growing use of electric vehicles, a methodology has been applied which can be utilized by decision makers.

In future works will be carried out using different FAHP techniques to calculate the weights of the criteria. The resulting products obtained by AHP and FAHP methods will be compared. The hierarchy used will be updated and a different hierarchy with sub criteria will be applied. Data from green areas of environmental criteria will be derived from the classification of the satellite image.

The development of electric vehicles is continuing day by day. In the day when energy is included in the significance working areas, an approach has been applied in the selection of the location of the charging station using FAHP of the MCDM methods with the support of the spatial analysis provided by the GIS.

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