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LOCATING ELECTRIC VEHICLE BATTERY COLLECTION FACILITY WITHIN THE FRAMEWORK OF SUSTAINABILITY AND CIRCULAR ECONOMY

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MSC IN LOGISTICS ENGINEERING

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JURY APPROVAL PAGE

We certify that, as the jury, we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master in Science.

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ABSTRACT

LOCATING ELECTRIC VEHICLE BATTERY COLLECTION FACILITY WITHIN THE FRAMEWORK OF SUSTAINABILITY AND CIRCULAR ECONOMY

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With the increasing number of vehicles in recent years, problems such as fossil fuel use and air pollution have emerged. Alternative ways have been sought to eliminate these negative effects. In this direction, important studies on the use of electric vehicles and the use of renewable and sustainable energy have begun. Studies on electric vehicles have brought with it developments in charging stations and batteries. Today, important studies are carried out on stations that will provide faster charging for electric vehicles and batteries that allow reuse. In this study, we sought to integrate electric vehicle charging stations into a sustainability and circular economy framework, using them not only for charging but also as hubs for collecting and recycling end-of-life electric car batteries. As a result of the article review in our study, we decided that fuzzy analytic hierarchy process (FAHP) was the most appropriate method. We determined the scales, compared the scales with FAHP, and based on the results we obtained, we conducted a case study for the province of Izmir.

Keywords: FAHP, electric vehicle charging stations, sustainability, circular economy, batteries

ÖZ

SÜRDÜRÜLEBİLİRLİK VE DÖNGÜSEL EKONOMİ ÇERÇEVESİNDE ELEKTRİKLİ ARAÇ PİLİ TOPLAMA TESİSİNİN KONUMLANDIRILMASI

Gezer, Remziye İlayda

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Ağustos 2024

Son yıllarda artan araç sayısı ile fosil yakıt kullanımı ve hava kirliliği gibi problemler ortaya çıkmıştır. Bu olumsuz etkileri yok etmek için alternatif yollar aranmaya başlanmıştır. Bu doğrultuda elektrikli araç kullanımı, yenilenebilir ve sürdürülebilir enerji kullanımı hakkında önemli çalışmalar yapılmaya başlanmıştır. Elektrikli araçlar konusundaki çalışmalar beraberinde şarj istasyonu ve batarya konusundaki gelişmeleri de getirmiştir. Günümüzde elektrikli araçlara daha hızlı şarj imkânı sağlayacak istasyonlar ve tekrar kullanıma izin veren bataryalar konusunda önemli çalışmalar yürütülmektedir. Bu çalışma kapsamında elektrikli araç şarj istasyonlarının sürdürülebilirlik ve döngüsel ekonomi çerçevesinde konumlandırılmasını ve bu şarj istasyonlarının aynı zamanda ömrünü tamamlamış elektrikli otomobil bataryalarının toplanması ve gerş dönüşüme gönderilmesi için bir konum olmasını hedefledik. Çalışmamız için yapılan makale taraması sonucunda en uygun yöntemin bulanık analitik hiyerarşi prosesi (BAHP) olduğuna karar verdik. Ölçekleri belirledik, BAHP ile ölçek karşılaştırması yaptık ve elde ettiğimiz sonuçlardan yola çıkarak İzmir ili için örnek olay çalışması gerçekleştirdik.

Anahtar Kelimeler: BAHP, elektrikli araç şarj istasyonu, sürdürülebilirlik, döngüsel ekonomi, batarya

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Remziye İlayda Gezer

İzmir, 2024

TEXT OF OATH

I declare and honestly confirm that my study, titled “LOCATING ELECTRIC VEHICLE BATTERY COLLECTION FACILITY WITHIN THE FRAMEWORK OF SUSTAINABILITY AND CIRCULAR ECONOMY” and presented as a Master’ s Thesis, has been written without applying any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

REMZIYE ILAYDA GEZER

08.08.2024

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SYMBOLS AND ABBREVIATIONS

SYMBOLS:

$\tilde{A}$ A Triangular Fuzzy Number Comparison Matrices

m, l, u Fuzzy Numbers

M_{gi}^{j} Triangular Fuzzy Numbers of Pairwise Comparison Matrices

n Number of matrices

i Represents The Row Number

j Denotes The Column Number

W and W' Normalized Final Weight Vector and Final Weight Vector

ABBREVIATIONS:

HEV Hybrid Electric

BEV Fully Electric

PHEV Plug-in Hybrid

EV Electric Vehicle

TWh Terawatt-Hours

WEG Wind Power Generation

ICE Internal Combustion Engine

IEA International Energy Agency

CE Circular Economy

LIB Lithium-ion Batteries

AHP Analytic Hierarchy Process

FAHP Fuzyy Analytic Hierarchy Process

PROMETHEE The Preference Ranking Organization Method

SMART Simple Multi Attribute Rating Technique

1. CHAPTER: INTRODUCTION

Electric vehicles have a long history. The first electric vehicle model was developed in the Netherlands in 1835 by Professor Straitingh. With the development of electric vehicles, governments have realized that these vehicles are environmentally friendly and have started to give economic incentives to these vehicles. Automakers such as Tesla, Mercedes Benz and Ford produce and develop vehicles with many different features in order to have an important place in the electric vehicle market (Aydın et al., 2018).

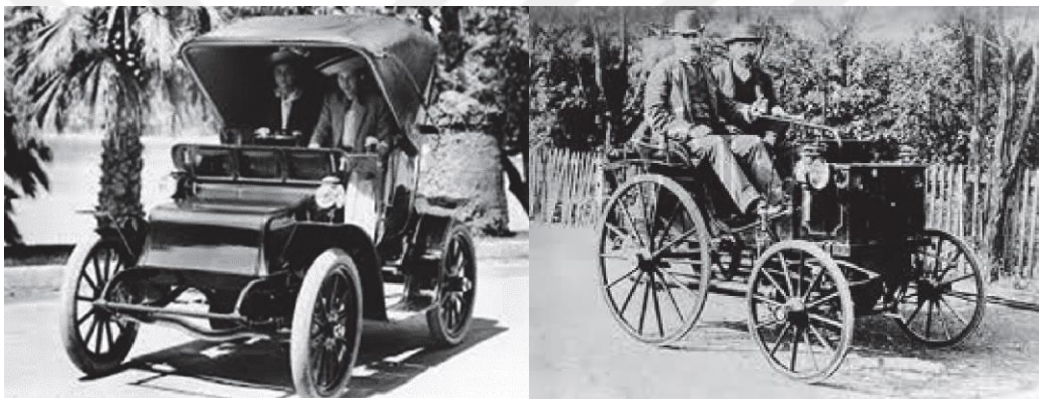

Figure 1.1. First electric car prototypes

Source: Enerjibes, 2018.

Electric vehicles can be grouped under three categories: hybrid electric (HEV), fully electric (BEV), and plug-in hybrid (PHEV). When we look at fully electric (BEV) vehicles, they do not need an engine or gasoline. Battery power satisfies this need. Hybrid electric (HEV) vehicles contain two engines, electric and gasoline. Its battery can only be charged by regenerative braking. Finally, when we look at the Plug-in hybrid (PHEV), we can say that it consists of both an electric and a gasoline engine, but the difference in hybrid electric vehicles is that the battery energy is provided by both the gasoline engine and rthe egenerative brakes (Gönül et al., 2021).

Figure 1.2. Electric vehicles developed at different times

Source: Driving, 2018

In order to increase the use of electric vehicles, it is very important to understand the benefits to the environment and human health. These benefits include reduced management costs due to the no need for fluid or lubrication changes for cooling, less pollution due to zero local emissions, reduced consumption, reduced noise level due to extremely quiet engines, and no circulation restrictions due to no pollution, unlike conventional vehicles (Caruso,2017). Also, vehicles with internal combustion engines need a complex system because they convert burning fuel into energy. For this reason, the risk of malfunction is very high in oil and filters. On the other hand, electric vehicles are produced with a simpler engine installation because they are powered directly from the battery. This significantly reduces the maintenance costs and risk of the breakdown of electric vehicles (Sezen,2017). In addition to these benefits, the high purchasing costs of electric vehicles, low driving ranges, and the insufficient amount of charging stations are the disadvantages (Aydın et al., 2018). Today, almost all automobile manufacturers also produce electric vehicles. When we look at the sales of electric vehicles in the world, we can say that Tesla has a huge

market share in this sector and has a significant advantage in sales. Figure 1.3 shows the worldwide sales of electric cars for 2022. We can say that HongGuang, Hyundai, Dolphin, Nissan, Volvo and Ford are in the 20th place following Tesla in sales.

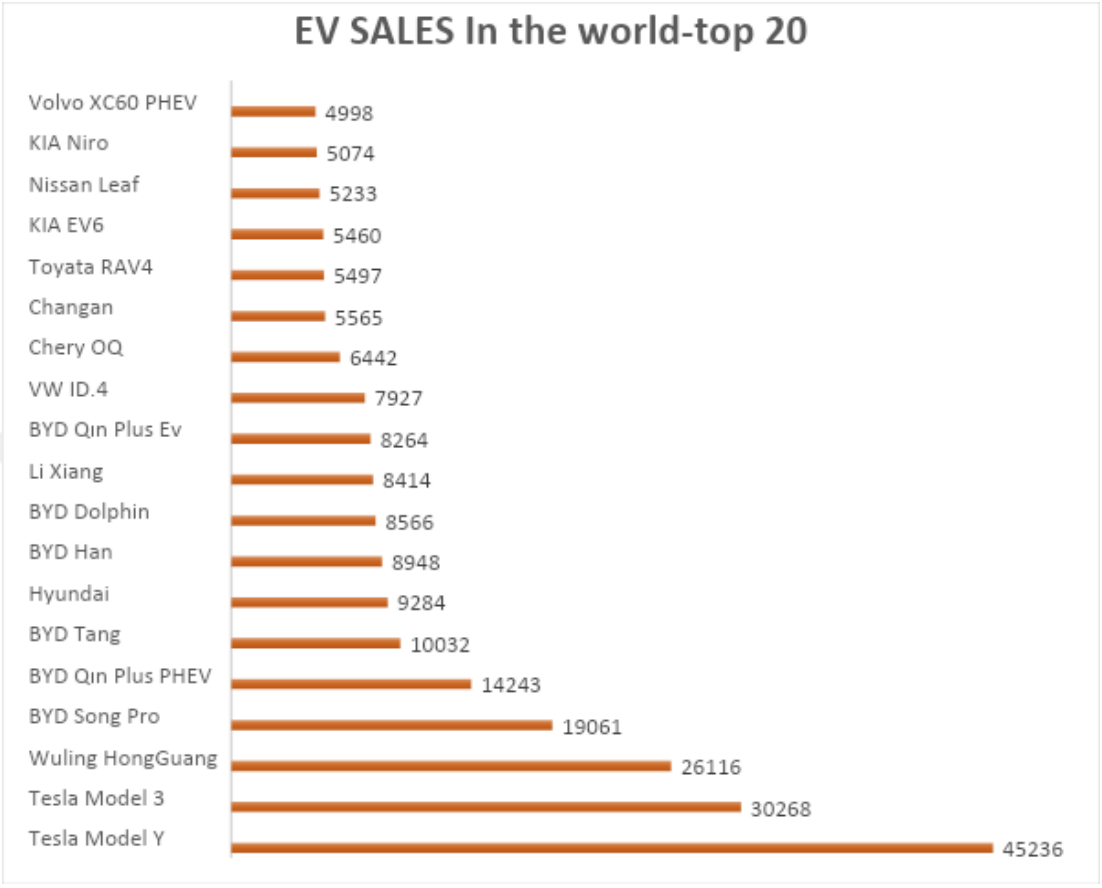

Figure 1.3. World Plugin Vehicle Sales-Top 20

Source: Ev Volumes, 2022

Based on an analysis of Figure 1.4, the number of electric car sales in Turkey climbed from 106 in 2015 to 11851 in 2021, a significant growth. It is predicted that the number of electric vehicles in Turkey will reach 2.5 million by the end of 2030 (Gonul et al., 2021).

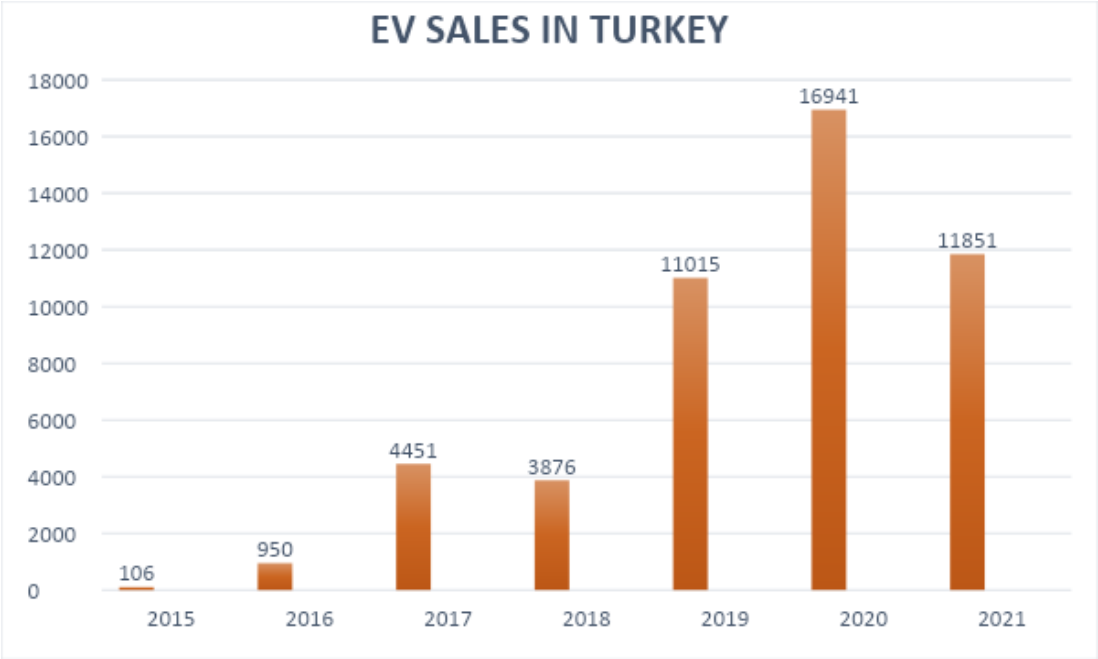

Fıgure 1.4. Ev sales in Turkey

Source: TEHAD, 2022

The genesis of electric vehicles (EVs) began in the 18th century and, after continuous evolution over three centuries, the global fleet of electric cars exceeded 5.1 million in 2018. Interestingly, 2 million cars have been registered in one year (2017-18) only almost doubling the number of cars. Apart from this, the global stock of electric two-wheelers, electric buses, light commercial vehicles and trucks is 260 million, 460000 units, 250000 units and 1.000-2.000, respectively, at the end of 2018 (Verma,2020).

The charging facilities are also growing in the same proportion and there are 5.2 million light-duty vehicle chargers serving and 157000 fast chargers for buses. As a result, in 2018, a total of about 58 terawatt-hours (TWh) electricity is consumed by the EVs.(Verma,2020)

With the increase in electric cars, the need for charging stations has also increased. Charging stations control the energy transfer to electric vehicles, and the location of these stations is very important. The number of stations is based on the expected demand of the different energy carriers, expected profit, corporate strategies of the car manufactures and energy suppliers, and government regulations (Sarmiento,2020). If charging stations are installed close to electrical substations, it is possible to avoid waste of electricity. But as it is known, most of the electrical

substations are far from the city center (Ghosh,2020). In addition to this, the fact that the charging stations are close to renewable energy sources in the location selection for sustainability and the reuse of batteries with a circular economy are among the topics on the agenda about electric vehicles. Renewable energy-based power plants are generally installed in far-flung areas and transmitted to the populous land to be used for electric vehicle (EV) charging and for domestic consumption. An alternative solution involves utilizing wind power generation (WEG) and photovoltaic (PV) arrays installed on rooftops of houses, offices, and parking facilities, directly supplying renewable electricity for charging electric vehicles (EVs) (Badia et al., 2020). Reusing retired EV batteries for secondary applications has a very low cost and delays the polluting recycling step. In addition, extending battery lifetimes also contributes to reducing waste and resource usage (Jiao,2016).

Moreover, one thing is also clear the dependency on carbon-based generation has to be reduced to take full advantage of the EV otherwise there could be more carbon emissions in future with the EVs as compared with conventional vehicles. In 2018, 41 million tons of carbon-dioxide equivalent was emitted by the EVs, while saving 36 million tons of carbon-dioxide equivalent compared to an equivalent internal combustion engine (ICE) fleet. The savings in carbon-dioxide emission can be greater with the low carbon sources based generation (Verma,2020).

The number of EVs on the market is estimated to be between 40-70 million in 2025, according to research by the International Energy Agency (IEA). According to another study by the IEA, it is estimated that there will be 26% electric vehicles in the most optimistic scenario and 8% in the most pessimistic scenario for 2040. According to Bloomberg, with a more optimistic forecast, it predicts that sales of electric vehicles will increase by 54% (Electric Vehicles to Accelerate to 54% of New Car Sales by 2040 | BloombergNEF, n.d.).

Based on these realized and expected increases, we aimed to develop a method for positioning EV charging stations by considering sustainability and circular economy, and we applied this method to the city of Izmir, Turkiye. In order to find this out, we focused on the questions of which parameters are important in the selection of the facility location and how to determine the method in this context. We also focused on which of these charging stations could also be a collection area for electric vehicle batteries.

The increase in the number of electric vehicles also brought to mind the question of how to recycle electric vehicle batteries. In addition to a lot of research on this subject, this question has also been the subject of many news. While we argue that the increase and use of electric vehicles is beneficial in terms of sustainability and circular economy, it is also possible to say that it is necessary to examine this in its entirety and deal with the recycling of batteries. Experts estimate that lithium demand will reach three to four million metric tons by 2030. The number of electric vehicles in Europe is expected to reach 70% by 2040. However, there is no standard method for recycling EV batteries. For this reason, legislators in the European Union (EU) are planning to introduce some regulations regarding the disposal of electric vehicle batteries. These rules will require that all metals inside the battery be recycled after disposal. In this way, 70% of each EV battery will be recycled. For this reason, this study focused on 3 important aspects to position electric vehicle charging stations within the scope of sustainability and circular economy. These scales are shown in Figure 1.5.

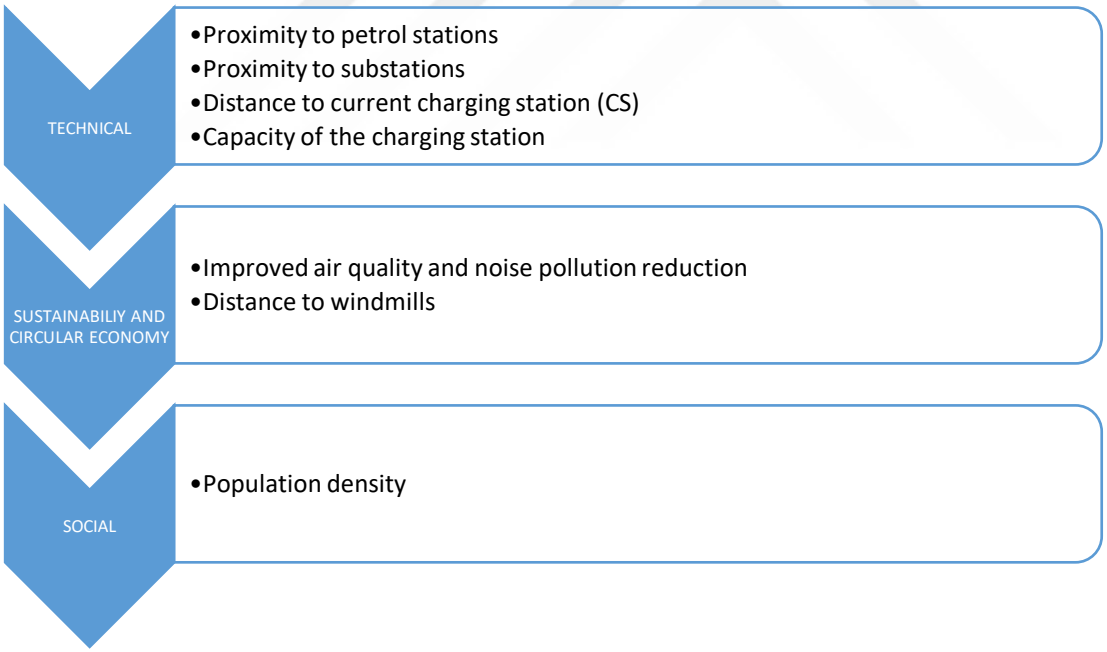

Figure 1.5. Features for positioning of electric vehicle charging stations within the scope of circular economy and sustainability

1.1 Circular Economy and Sustainability

The circular economy is a multidisciplinary field. This field brings together different approaches, tools and methods for a sustainable society (Velenturf & Purnell, 2021). While the circular economy promises continuity of economic development, it also aims to eliminate waste and reduce resource consumption (Sehnem et al.,2022). When we look at sustainability, it is the ability to meet our needs in a balanced way both today and in the future. For this reason, it is not possible to think of the concepts of circular economy and sustainability as different from each other. The need for a new system, which arises from the problems we currently experience such as noise pollution, air pollution and waste caused by cars, is about to be eliminated with electric vehicles. But one of the important points is to ensure the sustainability of this system. Based on the research and articles written, we decided that there are 2 major criteria when we reconcile sustainability and circular economy with electric vehicles. These are, improved air quality and noise pollution reduction and distance to windmills. Firstly, since electric vehicles run entirely on batteries, they do not need any exhaust system. These vehicles are extremely quiet and do not create air pollution or noise pollution. Secondly, one of the most important factors when positioning charging stations is the sustainability of this charging station. Since we aim to ensure sustainability while positioning the charging station, these locations must be positioned as close to the windmills. Another important factor is to ensure that the batteries used in electric vehicles are recycled without waste. There are many articles and research on the recycling of these used batteries. But the factories that will provide this recycling are just starting to operate. In addition to recycling batteries, it is also important which type of batteries are used in electric vehicles within the scope of sustainability and circular economy. When we look at their impact on the environment, it is possible to say that lithium-sulfur batteries are more environmentally friendly, providing up to 90% less impact than NMC batteries (Martins et al.,2021). Lithium-ion batteries are one of the most preferred types of energy storage due to their high energy and power density, relatively long life, fast response and decreasing costs. These features make Lithium-ion batteries a suitable candidate when we consider renewable energy integration. When we look at the reuse of batteries within the scope of circular economy, we can separate the battery pack from the vehicle and we can use it as an electrical energy storage system. Also,

we can disassemble the pack at modules and reassemble to new batteries. This battery can be subjected to a series of processes to recover some of the valuable cells in the battery. As a result, thanks to all these stages, a reduction in cost and an improvement in sustainability are achieved(Martins et al.,2021).

1.2 Technical

Another important scale for positioning charging stations is technical. Petrol offices are places where drivers frequently stop to rest, eat and meet other needs. Positioning of existing gas stations according to frequently used traffic routes, and station requirements for fossil fuel vehicles although different, are considered suitable places for electric vehicles (Bilgilioglu,2022). For this reason, we argue that in terms of the efficiency of charging stations, it is better to place them closest to gas stations rather than placing them in isolated places. In addition, the charging life of the batteries should be calculated and the distances between charging stations should be adjusted accordingly. Also, to reduce electricity losses, charging stations should be installed near the electricity substation. Many times, drivers have to travel extra to charging stations because these stations are located far from electrical substations (Ghosh, 2020). Lastly, the capacity of charging stations is another important scale while positioning charging stations.

1.3 Social

One of the most important points for location selection is the preference levels and population density of these places. In terms of efficient use of charging stations, it is important to position them on the sides of densely populated or frequently used highways.

2. CHAPTER: PROBLEM DEFINITION

With the increasing number of electric vehicles, the need for electric vehicle charging stations must be met correctly. The time that people spend charging their electric vehicles will decrease with busy lifestyles and metropolitan life. In order to properly meet the need for electric vehicle charging stations with the increasing number of electric vehicles, we aimed to develop a method for positioning the charging stations of electric vehicles by taking sustainability and circular economy into consideration and collecting the batteries of electric vehicles at these charging stations for recycling purposes, and we investigated this method for the city of Izmir. In order to develop this method, we scanned the articles in the literature and determined the scales and methods that were appropriate for our subject and purpose. We obtained the necessary data from appropriate sources and used this data in weighing and comparing the features.

3. CHAPTER: LITERATURE REVIEW

This section mainly underpins the strand of literature related to the study shown in Table 1. Positioning the charging stations of electric vehicles, taking into account sustainability and circular economy, and collecting the batteries of electric vehicles at these charging stations for recycling purposes are primarily discussed. This research appears to be vital in contributing to sustainability and the circular economy.

The fact that fossil fuels are exhaustible and harmful to the environment, the goals of constituting a sustainable and cleaner environment, and developments in battery technologies have led to a tendency towards electric vehicles instead of the vehicles which have traditional internal combustion engines working with fossil fuels (Cakmak, 2022). Therefore, the popularity of electrical vehicles is increasing. With the development of technologies, the number of electric vehicles raised the required quantity of charging stations (Arayici, 2018). With these increases, many researchers began to focus on sustainable transportation. Within sustainable transportation systems, the adoption of electric vehicles (EVs) is considered a potential solution to problems such as energy security, climate change, urban-air quality, and public health (Alboleda, 2021). To enhance environmental sustainability, many countries will electrify their transportation systems in their future smart city plans, so the number of electric vehicles (EVs) running in a city will grow significantly (Leung et al., 2014). A transition from high-emission producing and fuel-consuming vehicles to low-emission electric vehicles is recommended as a solution to reduce the effects of climate change, improve air quality, alleviate health-related risks and increase sustainability (Guler et al., 2020). Electric vehicles run on electrical energy that can be obtained from sustainable sources instead of fossil fuels; They are new vehicle technologies that make a positive contribution to global warming with zero emissions. However, the most obvious disadvantages of electric vehicles are the high

initial purchase costs of the vehicles, the inadequacy of charging station infrastructure, their short range and the weight of their batteries (Aydın et al., 2018). In another article, less pollution, reduced consumption, reduced costs of management, lack of circulation constraints and reduced noise level are listed as the advantages of electric vehicles (Caruso et al., 2017). Another researcher stated that the reasons for the increasing interest in electric vehicles are zero emissions, reduced fossil fuel use, efficiency and low noise (Dorin et al., 2021).

In another article, researchers argued that sustainability through CE to achieve a common goal will only be successful if there is an ecosystem that pays equal attention to all business models and relevant stakeholders and if this system is implemented based on a holistic perspective (Bertassini, 2021). In another article, it is argued that circular strategies (reuse, reduce or recycle) do not have a good impact on sustainability, on the contrary, they can have a positive impact because there are trade-offs or burden shifts between the different dimensions of sustainability (environmental, economic and social) (Kulakovskaya et al., 2022). Another research argues that circularity does not directly make the system sustainable, but this will only be possible if the environmental, social and economic features of sustainability are taken into consideration (Avellána et al., 2022).

To identify the criteria influencing relevant decision-making, a literature search was conducted in Google Scholar and Scopus scientific libraries during the period when this study took place (December 2022 and July 2024). Studies irrelevant to the scope of this article were excluded, and 41 articles contributed to this study. In addition, some technical reports and the relevant legal framework were used to support the definition of the criteria. Many researchers have studied this issue and considered different features. The criteria were selected as demographic, economic, environmental and transportation-based (Dascioglu et al., 2019). In the other research, Technical, Environmental, Institutional, Economic and social were chosen as features (Mishra et al., 2022). One of the studies researched a combination of sustainability and circular economy. They focused on three main pillars (i.e., environment, eco- nomic, and social) of sustainability (Hasheminasab et al., 2021). In another study, three main criteria were determined: geographical features, energy and urban features taking into account the studies in the literature. Sub-criteria related to geographical features; slope, proximity to forest areas, proximity to water

resources, proximity to fault lines and proximity to landslide areas. Sub-criteria for energy; proximity to petrol stations, proximity to substations and proximity to existing electric vehicle charging stations. Sub-criteria of urban features; population density, proximity to public spaces and proximity to main roads (Alkan et al., 2023). In the other article, 9 data layers were used to determine the most suitable site. These criteria are; population density, proximity to main roads, slope, proximity to shopping malls, proximity to official institutions and recreation areas, land value, proximity to petrol stations, proximity to transportation stations, and proximity to parking lots (Bilgilioglu, 2022). Recycling end-of-life batteries in electric vehicles has environmental and economic importance in terms of reusing the precious metals contained in them (Guven et al., 2019). Understanding the current scenario and future perspectives is important for strategies of new battery design, recycling routes and reverse logistics, as well as policies for sustainable development (Martins et al., 2021). Lithium-ion batteries (LIBs) are the batteries most preferred by manufacturers and users because they are low-cost and have high energy density. Primary raw materials are running out, and to reduce this raw material consumption, the opportunity to use secondary raw materials can be created by recycling primary raw materials (Wasesa et al., 2022). In another article, researchers claim that hybrid and plug-in hybrid electric technologies play an important role in reducing emissions and increasing the fuel efficiency of electric vehicles. Lithium-ion batteries are one of the most preferred types of energy storage due to their high energy and power density, long life, reduced cost and fast response (Hamidi et al., 2013). In another article, business models of different EV stakeholders that facilitate battery reuse are presented, interviews with different EV sectors are conducted, and based on industrial reports and academic literature, we analyze how battery reuse can facilitate business model innovation for sustainability in the EV industry. The results highlight the importance of cross-industry partnerships, battery ownership, and policy support for battery secondary use. The results also reveal battery reuse as a link between the energy and transportation sectors and its potential as a catalyst for restructuring the electric vehicle business model (Jiaoa et al., 2016).

The approach of the AHP helps analyze a complex problem in a hierarchical structure model that contains the goal, the factors, and the alternatives. The primary objective of AHP is to evaluate the alternatives, through pairwise comparisons of the

factors of the model (Anthopoulos et al., 2021). Also, regarding the hierarchical objective function, the AHP methodology has the highest coincidence with the problem cir- cumstances. Also, AHP is used to evaluate and weigh up the criteria set in one of the studies (Hasheminasab et al., 2021). AHP generally uses precise information in the decision-making process. As a result of this situation, some imbalances may be encountered in the scaling of judgments (Guler et al., 2020). AHP has been criticized for being inadequate in handling uncertainty and indecision situations in the pairwise comparison process (Ertugrul, 2007). In another article, it was desired to place charging stations in different locations within the university, and for this reason, FAHP, The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Simple Multi-Attribute Rating Technique (SMART) methods were used. It has been determined that FAHP gives the best results (Asnaz et al., 2021).

Table 3.1. Summary of the literature investigated.

Authors	***Context***	***Approach/methods***	***Keywords***	***Country/region***
Cakmak et al. (2022)	In this study, the quantitative situation of the electric vehicle charging station infrastructure in Turkey on a provincial basis as of the end of 2020 was discussed and two new metrics were proposed to evaluate the EV charging station infrastructure.	Data-driven analysis	Infographics, Electrical vehicles, Metrics, Charging station, Turkey.	Turkey
Arayıcı et al. (2018)	The answer to the question of which of the locations determined for possible charging stations should be invested is sought.	MATLAB, Yalmip/Cplex programs	Electric Vehicle, Charging Station Placement, Optimization	Turkey
Rio et al. (2021)	Understanding circular economy and sustainability	case studies		Switzerland

Bertassini et al. (2020)	Developing a theoretical framework composed of five building blocks (mindsets, values, behaviours, capabilities and competences) that guide the transition towards a CE-oriented culture aiming to achieve sustainability in business.	Publications found were coded and analysed through qualitative data analysis software.	Change management, circular economy, organizational behaviour, organizational culture, sustainability, sustainable development	Brazil
Anthopoulos et al. (2021)	This study introduces a multi-criteria decision-making (MCDM) framework for EV charging infrastructure deployment and operation, which respects both the economic and the technical aspects for public charging stations.	AHP	electric vehicle; EV; charging stations; MCDM; AHP; business model; smart city; smart mobility	Greece
Cardenas et al. (2020)	This article proposes a systemic approach based on previous models, which integrates all the components and relationships and incorporates the analysis of sustainability into the EV-adoption process.	SICOTEV module	System thinking, EV adoption, conceptual model, causal loop diagram, system structure	Colombia
Leung et al.	Based on these new perspec-tives, we formulate the EV charging station placement problem (EVCSPP) in this paper. We prove that the problem is nonde- terministic polynomial-time hard. We also propose four solution methods to tackle EVCSPP, and evaluate their performance on various artificial and practical cases.	Iterative MILP, Greedy Approach, Effective MILP, Chemical Reaction Optimization, YALMIP/CPLEX program	Charging station, electric vehicle (EV), location, smart city planning.	Hong Kong
Gulten et al. (2017)	Estimation of optimum locations for EV charging stations in Ankara, Turkey is realized by using data mining methods in this paper.	Gaussian Mixture Model (GMM), case study	Electric vehicle; charging station; optimal location; spectral clustering; gaussian mixture model.	Turkey

Tuzkaya et al. (2019)	The primary objective of this research is to locate the electric charging stations in Istanbul considering the flow of the paths.	Case study, Flow-refuelling location model	Flow-refuelling location model, Assignment problem, Electric vehicles, Electric charging stations	Turkey
Rajesh et al. (2022)	In this paper, the charging station that uses both wind and solar renewable energies has been proposed. Analytical and single diode model is used.	MATLAB-Simulink.	Solar panels, Wind turbines, Renewable energy systems, EV charging systems.	India
Guler et al. (2020)	In this study, the location selection of electric vehicle charging stations is realized by taking many different criteria into account and benefiting from the feature of managing and analyzing spatial data of Geographic Information Systems (GIS).	FAHP, case study	Open-source Geographic Information Systems (GIS) Software, Fuzzy Analytic Hierarchy Process (FAHP), Electric Vehicle, Location Selection, İstanbul.	Turkey
Wasesa et al. (2022)	This study aims to evaluate the lithium-ion batteries (LIBs) recycling process as a part of the supply chain network and assess its long-term economic and environmental impacts.	simulations	Lithium-ion battery Recycling Agent-based model System dynamics Hydrometallurgy Simulation	Indonesia
Martins et al. (2021)	This paper presents an overview of current and future vehicles used worldwide.	Data-driven analysis	Li-ion battery Critical metals Sustainability Recycling routes	Brasil
Hasheminasab et al. (2022)	This study aims to combine Sustainability and Circular Economy as two critical performance criteria in the context of building industry projects in order to move toward the integrated assessment model.	PMADM, ITARA, AHP, CoCoSo	Circular Economy (CE), Sustainability Energy consumption, Green building, PMADM, ITARA, AHP, CoCoSo	
Mishra et al. (2022)	This study helps realize the rebound effects of consumer-centric community energy initiatives considering CE principles from a governance literature perspective.	AHP, case study	Circular economy, Value-focused thinking, Energy transition, Community energy, Sustainable development goals	India

Alkan et al. (2023)	The aim of this study is to determine the potential locations for EVCS to be established in Konya.	AHP, case study	Electric vehicle charging stations, Analytical Hierarchy Process, Geographic Information Systems, Site selection	Turkey
Asnaz et al. (2021)	In this study, aim is focusing on charging station infrastructure planning for EVs and Balikesir University Cagis Campus was used as an application model.	FAHP, SMART, PROMETHEE	Electric vehicles, charging station placement, queuing theory, multi-criteria decision analysis, FAHP, SMART, PROMETHEE.	Turkey
Guven et al. (2019)	In this study, environmental management of end-of-life batteries from electric vehicles is evaluated within the context of reduce, reuse, recycle and recovery. Considering all alternatives, reuse will contribute to the economic and environmental aspects by increasing the useful life of the batteries.	Data-driven analysis	Waste battery, Waste management, Air pollution, Zero emission, Green technology	Turkey
Bilgilioglu (2022)	This study aims to select a suitable site for the new electric vehicle charging station using GIS-based MCDM methods throughout the province of Ankara.	GIS, FAHP, MCDM, case study	Geographic Information Systems (GIS); Electric Vehicle; Charging station; Fuzzy Analytical Hierarchy Process (FAHP); Multi-Criteria Decision Making (MCDM)	Turkey
Bashaireh et al. (2023)	In this paper, aim is developing a framework for optimal placement of EV charging stations using Particle Swarm Optimization (PSO).	MATLAB, DIgSILENT, Case study	electric vehicles, distribution system, charger placement, particle swarm optimization, EV charging	Jordan
Demirtas et al. (2021)	This study was carried out on the selection of suitable locations for charging stations, taking into account the charging capacities and car's range of electric vehicles in intercity transportation.	ArcGIS Pro, Data-driven analysis	Electric vehicle, Electric vehicle charging station, Isodistance polygon	Turkey

Marco et al. (2017)	The aim of this research is to assess whether energy capacity and internal resistance measurements of Li-ion based modules can be optimized, reducing the test duration to a value that may facilitate further End-of-Life (EoL) options.	Data-driven analysis		UK
Hamidi et al. (2013)	This paper investigates the integration of wind power, Photovoltaic (PV) solar power, and Li–Ion battery energy storage into a DC microgrid–based charging station for Electric Vehicles (EVs).	Simulink, MPPT control algorithms	Energy Storage System; Renewable Energy; Second–Life Battery.	USA
Verma et al. (2020)	The aim of this work is to design a single-phase electric vehicle (EV) charging station (CS), which is to be implemented in homes for the EVs and feeding the domestic demand.	AMETEK Terra SAS	EV, PV Array, Wind Energy Generation, V2G, Reactive Power, V2H, Power Quality.	India
Shukl et al. (2021)	The work implements the common DC bus electric vehicles (EVs) charging infrastructure based on hybrid renewable energy sources such as solar photovoltaic (PV) and fuel cell.	OPAL-RT software Digital storage oscilloscope (DSO)	Fuel Cell Stack, Power Quality, Distributed Energy Resources, Solar Photovoltaic (PV) Array	India
Wasesa et al. (2022)	This study aims to evaluate the lithium-ion batteries (LIBs) recycling process as a part of the supply chain network and assess its long-term economic and environmental impacts.	ArcGIS Pro, Data-driven analysis	Lithium-ion battery Recycling Agent-based model System dynamics Hydrometallurgy Simulation	Indonesia

Martins et al. (2021)	This paper presents an overview of current and future vehicles used worldwide. An increase from 1.3 to 2 billion vehicles is expected worldwide until 2030; an outstanding demand will occur mainly in BRICS countries.	Data-driven analysis	Li-ion battery Critical metals Sustainability Recycling routes	Brazil
Hossain et al. (2021)	The main idea behind this project is to use Solar Photo- Voltaic (PV) panel to convert solar energy into electric energy and fed it to a DC microgrid-based EV charging station.	MPPT algorithm Simulation Data-driven analysis	PV Solar System, MPPT, Renewable Energy Storage.	India
Zhang et al. (2023)	This study contributes theoretically to research on closed-loop supply chains of EV power battery recycling and provides a reference for practitioners under different recycling scenarios to make optimal collection and low-carbon decisions.	Simulation Data-driven analysis	Closed-loop supply chain Power battery recycling Carbon emission reduction Electric vehicle Echelon utilization	China
Evans et al. (2016)	This paper presents business models of different EV stakeholders that facilitate battery reuse. Based on interviews with different EV sectors, industrial reports and academic literature, analyzing how battery reuse could facilitate business model innovation for sustainability in the EV industry.	Case study	Business models; sustainability; innovation; electric vehicles; battery secondary use; energy storage; renewables	UK
Obrecht et al. (2021)	This paper aims to forecast the availability of used but operational electric vehicle (EV) batteries to integrate them into a circular economy concept of EVs' end-of-life (EOL) phase.	Case study	Electricity storage, Scenario analysis, Battery electric vehicle, EV, EOL, Beyond end-of-life, Forecast, Photovoltaic, PV, Self-sufficiency	Slovenia

Aydın et al. (2018)	Within the scope of this study, it was tried to be researched and put forward what kind of a method (design stages) should be followed regarding the usability of open or closed car parks in cities as effective charging stations, and how this situation would affect the capacity of the car parks was examined.	Data-driven analysis	Electric Vehicle, Charging Station, Parking, Capacity, Global Warming.	Turkey
Pal et al. (2021)	In this work, a distribution network is taken to place charging station at optimal nodes and a road network is considered to simulate traffic flows.	Arithmetic optimization Algorithm, Data-driven analysis	Distributed generation, electric vehicle (EV), electric vehicle charging station, optimal allocation, traffic flow, uncertainty.	India
Bertassini et al. (2021)	Study proposes a theoretical framework addresses the requirements for the transition towards CE from the organizational perspective. It is conducted a systematic review aiming to identify the relations between CE and culture.	Theoretical framework	Change management, circular economy, organizational behaviour, organizational culture, sustainability, sustainable development	
Riva et al. (2021)	The purpose of this study is to analyze the strategic role of sustainability and a circular economy for a green strategy.	Case study	Circular economy, green strategy, sustainability, strategic vision, environmental strategy, innovation	Italy
Tuzkaya et al. (2019)	The studies about Electric Vehicles (EV) have gained importance and increased in the last years depending on the environmental concerns of the classic transportation systems.	Case study	Flow-refuelling location model, Assignment problem, Electric vehicles, Electric charging stations	Turkey

Arya et al. (2021)	This paper focuses on, firstly to investigate the fast-charging impact on the grid. Secondly, to provide a solution by integrating renewable energy sources (such as solar PV) along with a battery in dc bus to reduce this effect.	Simulation, Data-driven analysis	Electric Vehicle Charging, Bi-directional Neutral Point Clamped (NPC) Converter, Control of DC-DC converter, Voltage dip, Solar PV system.	Pradesh
Gonul et al. (2021)	In this study, an overview of Turkey's position in EV technology is presented.	Case study	Electric vehicle (EV) Charging station Renewable integration Energy policy Vehicle to grid (V2G) Turkey	Turkey
Demirkıran et al. (2021)	In this study, a simulation model of a charging station connected to the grid supported by photovoltaic panel is created by MATLAB\Simulink based on the times spent in shopping centers, the number of vehicles and charging stations available for İzmir.	MATLAB\Simulink	Electric Vehicle, Photovoltaic, Solar Energy, Charging Station.	Turkey

4. CHAPTER: DATA COLLECTION

Since one of the most important subscales when positioning electric vehicle charging stations is the distance to windmills, we prepared a table indicating the windmills in Izmir and the powers of these windmills within the scope of the study. The district with the highest wind power energy is Karaburun, while the district with the lowest is Selçuk shown in Table 4.1.

Table 4.1. District-based windmills power table in Izmir

Source: Enerji Atlası, 2023

DISTRICT	POWER (MW)
KARABURUN	345.05
BERGAMA	365
BORNOVA	80
CESME	219.8
BAYINDIR	55
KINIK	50
KIRAZ	50
TIRE	92
ALIAGA	174
URLA	95
FOCA	35
SEFERIHISAR	54
DIKILI	27.8

MENEMEN	33.1
KEMALPASA	40
SELCUK	22

Since we aimed to carry out an preliminary analysis for Izmir in our study, we found highway usage data for Izmir shown in Table 4.2. and a map of available charging stations shown in Figure 4.1. and Figure 4.2.

Table 4.2. 2022 Izmir highways, annual average daily traffic values

Source: Karayolları Genel Müdürlüğü (KGM) ,2023

NAME	**DISTANCE-KM**	**LIGHT VEHICLE VEHICLE/DAY**	**HEAVY VEHICLE VEHICLE/DAY**	**TOTAL VEHICLE/DAY**
KEMALPASA-SEFERIHISAR	12.5	52.186	4.576	56.762
SEFERIHISAR-URLA	9.7	25.897	2.951	28.848
URLA-KARABURUN	9.2	18.089	2.390	20.479
KARABURUN-URLA	12.5	14.727	2.035	16.762
URLA -CESME	17.0	13.790	1.908	15.698
ALACATI-CESME	11.1	5.963	1.098	7.061

Table 4.3. 2022 Izmir highways, annual average daily traffic values (Continued)

Source: Karayolları Genel Müdürlüğü (KGM) ,2023

NAME	DISTANCE-KM	LIGHT VEHICLE VEHICLE/DAY	HEAVY VEHICLE VEHICLE/DAY	TOTAL VEHICLE/DAY
BORNOVA-MENDERES	11.1	37.343	13.139	50.482
MENDERES - TORBALI	13.6	34.447	11.411	45.858
TORBALI-SELCUK	21.6	26.285	8.660	34.945

Table 4.3. 2022 Izmir highways, annual average daily traffic values (Continued)

Source: Karayolları Genel Müdürlüğü (KGM) ,2023

NAME	DISTANCE-KM	LIGHT VEHICLE VEHICLE/DAY	HEAVY VEHICLE VEHICLE/DAY	TOTAL VEHICLE/DAY
BALCAVO-GAZIEMIR	9.6	58.353	5.899	64.252
GAZIEMIR-HIGHWAY DIVISION	9.0	67.924	10.982	78.906
HIGHWAY DIVISION-UNIVERSITY DIVISION	11.5	90.810	21.535	112.345
UNIVERSITY DIVISION-KARSIYAKA	9.7	74.167	26.129	100.296

Figure 4.1. Map of available charging stations in Turkey

Source: Google Maps, 2024

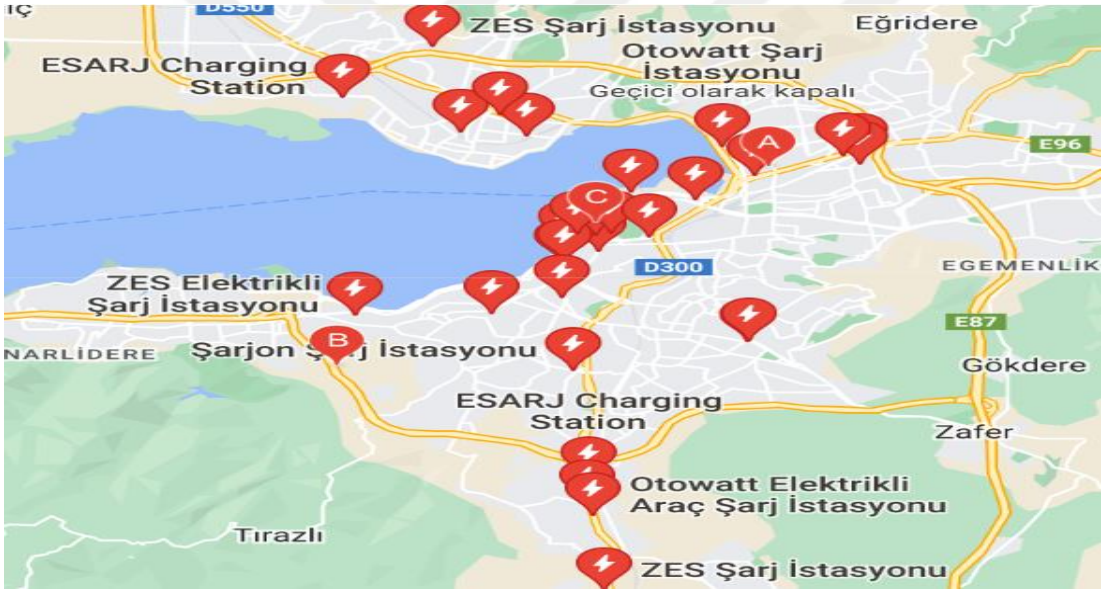

Figure 4.2. Map of available charging stations in Izmir

Source: Google Maps, 2024

5. CHAPTER: METHODOLOGY

When the studies in the literature are examined, it has been seen that the locations of charging stations vary according to different features. We chose to use the FAHP method in our study because it provides the most accurate results when dealing with unclear data, which was the case for us. In this way, meaningful outputs were obtained by analyzing spatial data for electric charging station location selection, which is a complex problem. AHP uses precise data in the decision-making phase, so imbalances occur when scaling judgments. In order to prevent this situation, researchers have developed a method that does not require precise data, called the fuzzy hierarchy process (Guler,2019). When decision-makers need to decide in uncertain circumstances, they can use Fuzzy AHP. There are certain fuzzy number ranges and the one we use is the 10- features approach shown in Table 5.1.

Table 5.1. Linguistic Variables and Fuzzy Number features

Source: Lei et al., 2013

Linguistic Variable	Fuzzy Number	Fuzzy Number features
Identical	1	(1, 1, 1)
A little more important	3	(2, 3, 4)
More important	6	(5, 6, 7)
Much more important	9	(8, 9, 10)
A little less important	1/3	(1/2, 1/3, 1/4)
Less important	1/6	(1/5, 1/6, 1/7)
Much less important	1/9	(1/8, 1/9, 1/10)

When we look at the stages of the fuzzy hierarchy method;

The first step is to draw the hierarchical chart. Then, the features weights for pairwise comparison should be decided and a pairwise comparison matrix should be created(1).

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

In the next step, we calculate the pairwise comparison matrix for each step (2);

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \quad (2)$$

In the fourth step it is necessary to calculate the size of the features relative to each other (3);

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 \quad if \quad m_2 \geq m_1 \\ 0 \quad if \quad l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \quad otherwise \end{cases} \quad (3)$$

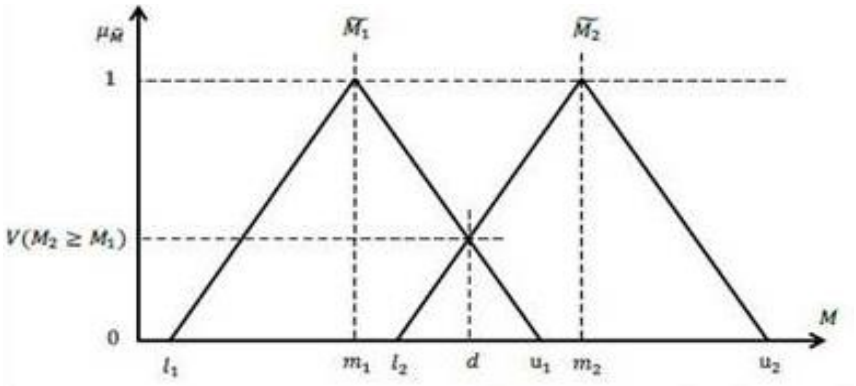

Figure 8. Intersection point between M_1 and M_2 (Dağdeviren, 2008)

Then, the weights of the criteria and alternatives in the comparison matrix should be calculated;

$$d'(A_i) = Min\ V\ (S_i \geq S_k) \quad k = 1,2,\ldots,n \quad , \quad k \neq i \tag{4}$$

$$W' = (d'(A_1), d'(A_2), \ldots\ldots, d'(A_n))^T \quad A_i(\ i = 1,2,\ldots,n) \tag{5}$$

Finally, the final weight vector needs to be calculated. To calculate the final weight vector, the calculated weight vector in the previous step should be normalized, then (6);

$$W\ = (d\ (A_1), d\ (A_2), \ldots\ldots, d\ (A_n))^T \tag{6}$$

Based on the formula, we named our measurements for the first step and determined the fuzzy values for their importance in line with the opinions we received from experts and we obtained the criterion comparison matrix shown in Table 5.2.

Table 5.2. Features and Abbreviation

Features	Abbreviation	Features	Abbreviation
Proximity to petrol stations	A1	Improved air quality and noise pollution reduction	B1
Proximity to substations	A2	Distance to windmills	B2
Distance to the current device	A3	Population density	C1
Capacity of the charging station	A4		

6. CHAPTER: CASE STUDY FOR IZMIR

In the first step, to obtain the pairwise comparison matrix, we compared all the determined features with each other according to fuzzy weights and obtained the following pairwise comparison matrices shown in Table 6.1.

Table 6.1. Pairwise comparison matrices of determined main features

	A1			A2			A3			A4			B1			B2			C1		
A1	1.00	1.00	1.00	5.00	6.00	7.00	5.00	6.00	7.00	2.00	3.00	4.00	0.10	0.20	0.01	0.10	0.10	0.10	0.30	0.30	1.00
A2	0.10	0.20	0.01	1.00	1.00	1.00	0.30	0.30	0.50	0.30	0.30	1.00	0.30	0.30	1.00	0.10	0.10	0.10	0.30	0.30	1.00
A3	0.10	0.20	0.01	2.00	3.00	4.00	1.00	1.00	1.00	8.00	9.00	10.0	0.30	0.30	1.00	0.10	0.20	0.20	2.00	3.00	4.00
A4	0.30	0.30	1.00	2.00	3.00	4.00	0.10	0.10	0.10	1.00	1.00	1.00	0.10	0.20	0.01	0.10	0.10	0.10	0.30	0.30	1.00
B1	5.00	6.00	7.00	2.00	3.00	4.00	2.00	3.00	4.00	5.00	6.00	7.00	1.00	1.00	1.00	0.10	0.10	0.10	0.10	0.20	0.01
B2	8.00	9.00	10.0	8.00	9.00	10.0	5.00	6.00	7.00	8.00	9.00	10.0	8.00	9.00	10.0	1.00	1.00	1.00	5.00	6.00	7.00
C1	2.00	3.00	4.00	2.00	3.00	4.00	0.30	0.30	0.50	2.00	3.00	4.00	5.00	6.00	7.00	0.10	0.20	0.20	1.00	1.00	1.00

Then, we took the geometric means of each features, summed the average results of the features, and placed the sums among themselves in increasing order as Table 6.2.

Table 6.2. The geometric mean of the main features.

	GEOMEAN		
A1	0.15	0.18	0.23
A2	0.20	0.25	0.34
A3	0.17	0.21	0.27
A4	0.15	0.19	0.24
B1	0.12	0.14	0.16
B2	5.20	5.86	6.50
C1	0.19	0.24	0.32
Total	6.18	7.06	8.06
Inverse	0.16	0.14	0.12
Increasing Order	0.12	0.14	0.16

Then, we found the fuzzy weight degrees of each cell and our Mi value, and we normalized the result in Table 6.3. As a result, we found that the B2 scale is the most important feature while determining the location of the electric vehicle charging stations within the scope of sustainability and circular economy shown in Table 6.3.

Table 6.3. Table of normalized values for main features

	Fuzzy Weight			Mi	Normalized
A1	0.018	0.026	0.037	0.027	0.027
A2	0.023	0.035	0.055	0.038	0.037
A3	0.021	0.029	0.043	0.031	0.031
A4	0.019	0.026	0.038	0.028	0.028
B1	0.014	0.019	0.025	0.020	0.019
B2	0.624	0.820	1.040	0.828	0.823
C1	0.023	0.033	0.051	0.035	0.035
Total				1.006	1.000

After finding the most important scale in our study, we compared the alternatives that were suitable for us according to the scales by applying the same steps and calculations.

Table 6.4. Pairwise comparison matrices of determined alternatives for Proximity To Petrol Stations

Proximity To Petrol Stations	Kemalpasa			Seferihisar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.0	2.00	3.00	4.00	0.25	0.33	0.50
Seferihisar	0.14	0.17	0.20	1.00	1.00	1.00	0.25	0.33	0.50	8.00	9.00	10.0	0.14	0.17	0.20	0.10	0.11	0.13
Urla	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	8.00	9.00	10.0	0.14	0.17	0.20	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.10	0.10	0.11	0.13
Cesme	0.14	0.17	0.20	5.00	6.00	7.00	5.00	6.00	7.00	8.00	9.00	10.0	1.00	1.00	1.00	0.14	0.17	0.20
Bornova	2.00	3.00	4.00	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	5.00	6.00	7.00	1.00	1.00	1.00
Menderes	0.14	0.17	0.20	5.00	6.00	7.00	5.00	6.00	7.00	8.00	9.00	10.0	2.00	3.00	4.00	0.14	0.17	0.20
Torbalı	0.14	0.17	0.20	5.00	6.00	7.00	0.14	0.17	0.20	8.00	9.00	10.0	2.00	3.00	4.00	0.14	0.17	0.20
Selcuk	0.10	0.11	0.13	0.14	0.17	0.2	0.14	0.17	0.20	8.00	9.00	10.0	0.10	0.11	0.10	0.10	0.11	0.13
Balcova	0.10	0.11	0.13	0.1	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.10	0.10	0.11	0.13
Gazıemır	0.10	0.11	0.13	0.25	0.33	0.5	0.25	0.33	0.50	5.00	6.00	7.00	0.10	0.11	0.10	0.10	0.11	0.13
Karsıyaka	0.10	0.11	0.13	0.14	0.17	0.2	0.14	0.17	0.20	2.00	3.00	4.00	0.10	0.11	0.10	0.10	0.11	0.13

Table 6.4. Pairwise comparison matrices of determined alternatives for Proximity To Petrol Stations (Continued)

Proximity To Petrol Stations	Menderes			Torbalı			Selcuk			Balcova			Gaziemir			Karsıyaka		
Kemalpasa	5.00	6.00	7.00	5.00	6.00	7.00	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0
Seferihisar	0.14	0.17	0.20	0.14	0.17	0.20	2.00	3.00	4.00	8.00	9.00	10.0	2.00	3.00	4.00	5.00	6.00	7.00
Urla	0.14	0.17	0.20	0.14	0.17	0.20	2.00	3.00	4.00	8.00	9.00	10.0	2.00	3.00	4.00	5.00	6.00	7.00
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.14	0.17	0.20	0.25	0.33	0.50
Cesme	0.25	0.33	0.50	0.25	0.33	0.50	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0
Bornova	5.00	6.00	7.00	5.00	6.00	7.00	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0
Menderes	1.00	1.00	1.00	0.25	0.33	0.5	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0
Torbalı	2.00	3.00	4.00	1.00	1.00	1.00	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0	8.00	9.00	10.0
Selcuk	0.10	0.11	0.13	0.1	0.11	0.13	1.00	1.00	1.00	8.00	9.00	10.0	2.00	3.00	4.00	2.00	3.00	4.00
Balcova	0.10	0.11	0.13	0.1	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.14	0.17	0.20	0.25	0.33	0.50
Gazıemır	0.10	0.11	0.13	0.1	0.11	0.13	0.25	0.33	0.50	5.00	6.00	7.00	1.00	1.00	1.00	2.00	3.00	4.00
Karsıyaka	0.10	0.11	0.13	0.1	0.11	0.13	0.25	0.33	0.50	2.00	3.00	4.00	0.25	0.33	0.50	1.00	1.00	1.00

Table 6.5. The geometric mean of the alternatives for Proximity To Petrol Stations.

	GEOMEAN		
Kemalpasa	4.00	5.01	5.89
Seferihisar	0.68	0.83	1.01
Urla	0.81	0.97	1.17
Karaburun	0.16	0.18	0.21
Cesme	1.88	2.22	2.67
Bornova	6.20	7.29	6.99
Menderes	2.27	2.71	3.22
Torbalı	1.88	2.23	2.59
Selcuk	0.44	0.51	0.59
Balcova	0.16	0.18	0.21
Gaziemir	0.38	0.45	0.55
Karsıyaka	0.25	0.30	0.36
Total	19.10	22.89	25.46
Inverse	0.05	0.04	0.04
Increasing Order	0.04	0.04	0.05

Table 6.6. Table of normalized values of the alternatives for Proximity To Petrol Stations

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.16	0.22	0.31	0.23	0.22
Seferihisar	0.03	0.04	0.05	0.04	0.04
Urla	0.03	0.04	0.06	0.05	0.04
Karaburun	0.01	0.01	0.01	0.01	0.01
Cesme	0.07	0.10	0.14	0.10	0.10
Bornova	0.24	0.32	0.36	0.31	0.30
Menderes	0.09	0.12	0.17	0.13	0.12
Torbalı	0.07	0.10	0.13	0.10	0.10
Selcuk	0.02	0.02	0.03	0.02	0.02
Balcova	0.01	0.01	0.01	0.01	0.01
Gaziemir	0.01	0.02	0.03	0.02	0.02
Karsıyaka	0.01	0.01	0.02	0.01	0.01
Total				1.03	1.00

6.1. Discussion of Results

As a result of an extensive literature review, we can say that the most important main feature for electric vehicle charging station locations, which are decided by taking sustainability and circular economy into consideration, are technical, sustainability and circular economy and their subscales proximity to petrol stations, proximity to substations, distance to the current device, capacity of the charging station, improved air quality and noise pollution reduction, distance to windmills, population density. In the first stage, we compared these subscales with each other and determined the scale that was superior to the others. After completing all the steps in our method, we found that the most important measure was proximity to windmills shown in Table 8. After that, when we compared all the alternatives according to their proximity to petrol stations, it was determined that Bornova was the best alternative shown in Table 9. Then, when we compared all the alternatives according to their proximity to the substations, it was determined that the best alternatives were Urla, Cesme, Bornova, and Karsıyaka shown in Table 12. After that, when we compared all the alternatives according to their proximity to current charging stations, Cesme was

found to be the best alternative Table 15. Then, when we compared all the alternatives according to the capacity of the charging stations, it was determined that the best alternative was Karsıyaka shown in Table 18. Later, when we compared all the alternatives according to Improved air quality and reduction of noise pollution, Bornova was found to be the best alternative shown in Table 21. When we compared all the alternatives according to the distance to the windmills, it was determined that Karaburun was the best alternative shown in Table 24. After that, when we compared all the alternatives according to population density, it was determined that the best alternative was Bornova shown in Table 27. Finally, when we compared the results of all the alternatives, it was seen that Bornova was the most suitable alternative for the positioning of the charging station. Bornova is not only the optimal choice for a charging station in Izmir, but it can also serve as a collection point for electric car batteries. Used electric vehicle batteries can be collected here and sent for sorting and recycling.

7. CHAPTER: CONCLUSIONS AND FUTURE WORK

With increasing environmental pollution, population and traffic, the need for electric vehicles is increasing day by day. While meeting this need, ensuring sustainability and acting within the scope of a circular economy is one of the most important topics.

This study aims to select the most important features for positioning electric vehicle charging stations from multi-criteria decision-making problems using the FAHP method within the framework of sustainability and circular economy. Proximity to petrol stations, proximity to substations, distance to the current charging station, capacity of the charging station, improved air quality and noise pollution reduction, distance to windmills, and population density factors were taken into account in the evaluation of charging station alternatives.

We did not take important criteria such as slope, fault lines, equipment cost and waste management as a basis because all of these data have the same result for Izmir province. These features can be taken into consideration when applying to another province in another study.

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APPENDICES

Proximity To Substations	Kemalpasa			Seferihisar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Seferıhısar	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Urla	8.00	9.00	10.	8.00	9.00	10.0	1.00	1.00	1.00	8.00	9.00	10.0	1.00	1.00	1.00	1.00	1.00	1.00
Karaburun	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	8.00	9.00	10.	8.00	9.00	10.0	1.00	1.00	1.00	8.00	9.00	10.0	1.00	1.00	1.00	1.00	1.00	1.00
Bornova	8.00	9.00	10.	8.00	9.00	10.0	1.00	1.00	1.00	8.00	9.00	10.0	1.00	1.00	1.00	1.00	1.00	1.00
Menderes	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Gaziemir	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.0	8.00	9.00	10.0	1.00	1.00	1.00	8.00	9.00	10.0	1.00	1.00	1.00	1.00	1.00	1.00

Proximity To Substations	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13
Seferıhısar	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.11	0.13
Urla	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00
Menderes	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Gazıemır	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	0.10	0.11	0.12
Seferıhısar	0.15	0.17	0.18
Urla	1.00	5.80	1.00
Karaburun	0.12	0.13	0.15
Cesme	1.00	5.80	1.00
Bornova	1.00	5.80	1.00
Menderes	0.10	0.11	0.12
Torbalı	0.13	0.14	0.15
Selcuk	0.13	0.14	0.15
Balcova	0.13	0,14	0.15
Gazıemır	0.13	0.14	0.15
Karsıyaka	1.00	5.80	1.00
Total	5.00	24.29	5.22
Inverse	0.20	0.04	0.19
Increasing Order	0.04	0.19	0.20

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.01	0.02	0.02	0.02	0.01
Seferıhısar	0.01	0.03	0.03	0.03	0.01
Urla	0.04	1.10	0.20	0.44	0.22
Karaburun	0.01	0.02	0.03	0.02	0.01
Cesme	0.04	1.10	0.20	0.44	0.22
Bornova	0.04	1.10	0.20	0.44	0.22
Menderes	0.01	0.02	0.02	0.01	0.01
Torbalı	0.01	0.02	0.03	0.02	0.01
Selcuk	0.01	0.02	0.03	0.02	0.01
Balcova	0.01	0.02	0.03	0.02	0.01
Gazıemır	0.01	0.02	0.03	0.02	0.01
Karsıyaka	0.04	1.11	0.20	0.44	0.22
Total				1.96	1

Distance To Current CS	Kemalpasa			Seferıhısar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	2.00	3.00	4.00	2.00	3.00	4.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Seferıhısar	0.25	0.33	0.50	1.00	1.00	1.00	2.00	3.00	4.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Urla	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0,13
Cesme	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00	2.00	3.00	4.00
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50	1.00	1.00	1.00
Menderes	1.00	1.00	1.00	2.00	3.00	4.00	2.00	3.00	4.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	2.00	3.00	4.00	2.00	3.00	4.00	2.00	3.00	4.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	5.00	6.00	7.00	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	5.00	6.00	7.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50	0.25	0.33	0.50
Gazıemır	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50	0.25	0.33	0.50
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50	0.25	0.33	0.50

Distance To Current CS	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	1.00	1.00	1.00	0.25	0.33	0.50	8.00	9.00	10.00	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13
Seferıhısar	0.25	0.33	0.50	0.25	0.33	0.50	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Urla	0.25	0.33	0.50	0.25	0.33	0.50	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.14	0.17	0.2	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00	2.00	3.00	4.00
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00	2.00	3.00	4.00
Menderes	1.00	1.00	1.00	0.25	0.33	0.50	8.00	9.00	10.00	8.00	9.00	10.00	0.10	0.11	0.13	8.00	9.00	10.00
Torbalı	0.25	0.33	0.50	1.00	1.00	1.00	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	0.10	0.11	0.13	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00	0.25	0.33	0.50	0.25	0.33	0.50
Gazıemır	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	1.00	1.00	1.00	0.25	0.33	0.50
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	0.22	0.25	0.30
Seferıhısar	0.22	0.26	0.32
Urla	0.25	0.30	0.37
Karaburun	0.12	0.13	0.15
Cesme	2.00	6.47	4.00
Bornova	1.18	4.94	2.37
Menderes	0.12	1.13	0.17
Torbalı	0.15	0.69	0.20
Selcuk	0.16	0.18	0.20
Balcova	0.27	1.19	0.44
Gazıemır	1.10	2.71	1.74
Karsıyaka	0.75	3.60	1.32
Total	6.60	21.89	11.66
Inverse	0.15	0.04	0.08
Increasing Order	0.04	0.08	0.15

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.01	0.02	0.05	0.03	0.02
Seferıhısar	0.01	0.02	0.05	0.02	0.02
Urla	0.01	0.03	0.06	0.03	0.02
Karaburun	0.01	0.01	0.02	0.01	0.01
Cesme	0.09	0.56	0.60	0.41	0.31
Bornova	0.05	0.43	0.36	0.28	0.21
Menderes	0.01	0.09	0.02	0.04	0.03
Torbalı	0.01	0.06	0.03	0.03	0.02
Selcuk	0.01	0.02	0.03	0.018	0.01
Balcova	0.01	0.10	0.06	0.06	0.04
Gazıemır	0.05	0.23	0.26	0.18	0.13
Karsıyaka	0.03	0.31	0.20	0.18	0.13
Total				1.318516378	1

Capacity Of The Charging Station	Kemalpasa			Seferıhısar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	2.00	3.00	4.00	0.25	0.33	0.50	8.00	9.00	10.00	0.25	0.33	0.50	0.10	0.11	0.13
Seferıhısar	0.25	0.33	0.50	1.00	1.00	1.00	0.14	0.17	0.20	8.00	9.00	10.00	0.10	0.11	0.13	0.10	0.11	0.13
Urla	2.00	3.00	4.00	5.00	6.00	7.00	1.00	1.00	1.00	8.00	9.00	10.00	0.25	0.33	0.50	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0,1	0,11	0,13	0.10	0.11	0.13
Cesme	2.00	3.00	4.00	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	1.00	1.00	1.00	0.25	0.33	0.50
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	1.00	1.00	1.00
Menderes	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	2.00	3.00	4.00	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	0.25	0.33	0.50	2.00	3.00	4.00	0.25	0.33	0.50	8.00	9.00	10.00	0.14	0.17	0.20	0.10	0.11	0.13
Selcuk	0.10	0.11	0.13	0.25	0.33	0.50	0.10	0.11	0.13	5.00	6.00	7.00	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	5.00	6.00	7.00	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50
Gazıemır	5.00	6.00	7.00	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00

Capacity Of The Charging Station	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	0,14	0,17	0,2	0.14	0.17	0.20	0.10	0.11	0.13
Seferıhısar	8.00	9.00	10.00	0.25	0.33	0.50	2.00	3.00	4.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Urla	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	0.25	0.33	0.50	0.25	0.33	0.50	0.10	0.11	0.13
Karaburun	0.25	0.33	0.50	0.10	0.11	0.13	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	8.00	9.00	10.00	5.00	6.00	7.00	8.00	9.00	10.00	0.25	0.33	0.50	0.25	0.33	0.50	0.25	0.33	0.50
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00	0.25	0.33	0.50
Menderes	1.00	1.00	1.00	0.10	0.11	0.13	0.25	0.33	0.50	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	8.00	9.00	10.00	1.00	1.00	1.00	5.00	6.00	7.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	2.00	3.00	4.00	0.14	0.17	0.20	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	0.33	0.50
Gazıemır	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	0.33	0.50
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00	2.00	3.00	4.00	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	0.15	0.18	0.23
Seferıhısar	0.13	0.15	0.18
Urla	0.17	0.21	0.28
Karaburun	0.11	0.12	0.14
Cesme	0.37	1.25	1.09
Bornova	0.25	4.32	1.41
Menderes	0.14	0.16	0.19
Torbalı	0.13	0.25	0.31
Selcuk	0.11	0.13	0.15
Balcova	0.70	2.08	1.41
Gazıemır	0.70	2.08	1.41
Karsıyaka	2.00	6.24	4.00
Total	5.00	17.20	10.85
Inverse	0.20	0.05	0.09
Increasing Order	0.05	0.09	0.20

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.01	0.01	0.04	0.02	0.02
Seferıhısar	0.01	0.01	0.03	0.02	0.02
Urla	0.01	0.02	0.05	0.02	0.03
Karaburun	0.01	0.01	0.03	0.02	0.02
Cesme	0.02	0.11	0.22	0.12	0.08
Bornova	0.01	0.39	0.28	0.23	0.17
Menderes	0.01	0.01	0.03	0.02	0.02
Torbalı	0.01	0.02	0.06	0.03	0.02
Selcuk	0.01	0.01	0.03	0.02	0.02
Balcova	0.04	0.19	0.28	0.17	0.12
Gazıemır	0.04	0.19	0.28	0.17	0.12
Karsıyaka	0.12	0.57	0.80	0.49	0.36
Total				1.35	1

Improved Air Quality And Noise Pollution Reduction	Kemalpasa			Seferıhısar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Seferıhısar	0.14	0.17	0.20	1.00	1.00	1.00	2.00	3.00	4.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Urla	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	0.14	0.17	0.20	0.25	0.33	0.50	0.25	0.33	0.50	8.00	9.00	10.00	1.00	1.00	1.00	0.10	0.11	0.13
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00
Menderes	0.25	0.33	0.50	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Torbalı	5.00	6.00	7.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50
Selcuk	0.10	0.11	0.13	0.25	0.33	0.50	0.14	0.17	0.20	8.00	9.00	10.00	0.25	0.33	0.50	0.10	0.11	0.13
Balcova	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Gazıemır	2.00	3.00	4.00	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50

Improved Air Quality And Noise Pollution Reduction	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	2.00	3.00	4.00	0.14	0.17	0.20	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50	0.10	0.11	0.13
Seferıhısar	0.25	0.33	0.50	0.10	0.11	0.13	2.00	3.00	4.00	0.25	0.33	0.50	0.14	0.17	0.20	0.10	0.11	0.13
Urla	0.14	0.17	0.20	0.10	0.11	0.13	5.00	6.00	7.00	1.00	1.00	1.00	0.25	0.33	0.50	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	0.14	0.17	0.20	0.10	0.11	0.13	2.00	3.00	4.00	0.25	0.33	0.50	0.14	0.17	0.20	0.10	0.11	0.13
Bornova	8.00	9.00	10.00	5.00	6.00	7.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00
Menderes	1.00	1.00	1.00	0.25	0.33	0.50	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50	0.10	0.11	0.13
Torbalı	5.00	6.00	7.00	1.00	1.00	1.00	8.00	9.00	10.00	5.00	6.00	7.00	2.00	3.00	4.00	0.25	0.33	0.50
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	0.25	0.33	0.50	0.14	0.17	0.20	5.00	6.00	7.00	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Gazıemır	2.00	3.00	4.00	0.25	0.33	0.50	8.00	9.00	10.00	2.00	3.00	4.00	1.00	1.00	1.00	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	8.00	9.00	10.00	0.10	0.11	0.13	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	1.15	1.43	1.75
Seferıhısar	0.42	0.53	0.67
Urla	0.45	0.54	0.67
Karaburun	0.10	0.11	0.12
Cesme	0.27	0.33	0.42
Bornova	6.75	7.85	8.90
Menderes	1.00	1.25	1.58
Torbalı	3.30	4.00	4.84
Selcuk	0.18	0.21	0.26
Balcova	0.55	0.67	0.81
Gazıemır	1.45	1.86	2.30
Karsıyaka	3.45	4.04	4.70
Total	19.12	22.88	27.07
Inverse	0.05	0.04	0.03
Increasing Order	0.03	0.04	0.05

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.04	0.06	0.09	0.06	0.06
Seferıhısar	0.01	0.02	0.03	0.02	0.02
Urla	0.01	0.02	0.03	0.02	0.02
Karaburun	0.01	0.01	0.01	0.01	0.01
Cesme	0.01	0.01	0.02	0.02	0.02
Bornova	0.25	0.34	0.46	0.35	0.33
Menderes	0.03	0.05	0.08	0.05	0.05
Torbalı	0.12	0.17	0.25	0.18	0.17
Selcuk	0.01	0.01	0.01	0.01	0.01
Balcova	0.02	0.03	0.04	0.03	0.02
Gazıemır	0.05	0.08	0.12	0.08	0.08
Karsıyaka	0.12	0.17	0.24	0.18	0.17
Total				1.04	1

Distance To Windmills	Kemalpasa			Seferıhısar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	0.25	0.33	0.50	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13	0.14	0.17	0.20
Seferıhısar	2.00	3.00	4.00	1.00	1.00	1.00	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13	0.25	0.33	0.50
Urla	5.00	6.00	7.00	5.00	6.00	7.00	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13	2.00	3.00	4.00
Karaburun	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00	2.00	3.00	4.00	8.00	9.00	10.00
Cesme	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50	1.00	1.00	1.00	8.00	9.00	10.00
Bornova	5.00	6.00	7.00	2.00	3.00	4.00	0.25	0.33	0.50	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00
Menderes	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Torbalı	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Gazıemır	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Karsıyaka	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13

Distance To Windmills	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Seferıhısar	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Urla	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Karaburun	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Cesme	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00
Menderes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Torbalı	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Selcuk	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Balcova	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gazıemır	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Karsıyaka	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	1.26	1.45	0.19
Seferıhısar	1.60	1.88	0.19
Urla	2.74	3.07	0.25
Karaburun	6.62	7.37	1.00
Cesme	5.83	6.67	0.50
Bornova	2.22	2.61	0.19
Menderes	0.10	0.11	0.12
Torbalı	0.10	0.11	0.12
Selcuk	0.10	0.11	0.12
Balcova	0.10	0.11	0.12
Gazıemır	0.10	0.11	0.12
Karsıyaka	0.10	0.11	0.12
Total	20.89	23.74	3.09
Inverse	0.04	0.04	0.32
Increasing Order	0.04	0.04	0.32

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.05	0.07	0.06	0.06	0.06
Seferıhısar	0.06	0.09	0.06	0.07	0.07
Urla	0.11	0.14	0.08	0.11	0.11
Karaburun	0.27	0.35	0.32	0.31	0.31
Cesme	0.24	0.32	0.16	0.24	0.24
Bornova	0.09	0.12	0.06	0.09	0.09
Menderes	0.01	0.01	0.04	0.02	0.02
Torbalı	0.01	0.01	0.04	0.02	0.02
Selcuk	0.01	0.01	0.04	0.02	0.02
Balcova	0.01	0.01	0.04	0.02	0.02
Gazıemır	0.01	0.01	0.04	0.02	0.02
Karsıyaka	0.01	0.01	0.04	0.02	0.02
Total				1.01	1

Population Density	Kemalpasa			Seferıhısar			Urla			Karaburun			Cesme			Bornova		
Kemalpasa	1.00	1.00	1.00	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Seferıhısar	0.14	0.17	0.20	1.00	1.00	1.00	2.00	3.00	4.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Urla	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	0.14	0.17	0.20	0.25	0.33	0.50	0.25	0.33	0.50	8.00	9.00	10.00	1.00	1.00	1.00	0.10	0.11	0.13
Bornova	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	1.00	1.00	1.00
Menderes	0.25	0.33	0.50	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Torbalı	5.00	6.00	7.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50
Selcuk	0.10	0.11	0.13	0.25	0.33	0.50	0.14	0.17	0.20	8.00	9.00	10.00	0.25	0.33	0.50	0.10	0.11	0.13
Balcova	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	8.00	9.00	10.00	2.00	3.00	4.00	0.10	0.11	0.13
Gazıemır	2.00	3.00	4.00	5.00	6.00	7.00	2.00	3.00	4.00	8.00	9.00	10.00	5.00	6.00	7.00	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	0.25	0.33	0.50

Population Density	Menderes			Torbalı			Selcuk			Balcova			Gazıemır			Karsıyaka		
Kemalpasa	2.00	3.00	4.00	0.14	0.17	0.20	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50	0.10	0.11	0.13
Seferıhısar	0.25	0.33	0.50	0.10	0.11	0.13	2.00	3.00	4.00	0.25	0.33	0.50	0.14	0.17	0.20	0.10	0.11	0.13
Urla	0.14	0.17	0.20	0.10	0.11	0.13	5.00	6.00	7.00	1.00	1.00	1.00	0.25	0.33	0.50	0.10	0.11	0.13
Karaburun	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13
Cesme	0.14	0.17	0.20	0.10	0.11	0.13	2.00	3.00	4.00	0.25	0.33	0.50	0.14	0.17	0.20	0.10	0.11	0.13
Bornova	8.00	9.00	10.00	5.00	6.00	7.00	8.00	9.00	10.00	8.00	9.00	10.00	8.00	9.00	10.00	2.00	3.00	4.00
Menderes	1.00	1.00	1.00	0.25	0.33	0.50	8.00	9.00	10.00	2.00	3.00	4.00	0.25	0.33	0.50	0.10	0.11	0.13
Torbalı	5.00	6.00	7.00	1.00	1.00	1.00	8.00	9.00	10.00	5.00	6.00	7.00	2.00	3.00	4.00	0.25	0.33	0.50
Selcuk	0.10	0.11	0.13	0.10	0.11	0.13	1.00	1.00	1.00	0.14	0.17	0.20	0.10	0.11	0.13	0.10	0.11	0.13
Balcova	0.25	0.33	0.50	0.14	0.17	0.20	5.00	6.00	7.00	1.00	1.00	1.00	0.10	0.11	0.13	0.10	0.11	0.13
Gazıemır	2.00	3.00	4.00	0.25	0.33	0.50	8.00	9.00	10.00	2.00	3.00	4.00	1.00	1.00	1.00	0.10	0.11	0.13
Karsıyaka	8.00	9.00	10.00	2.00	3.00	4.00	8.00	9.00	10.00	8.00	9.00	10.00	0.10	0.11	0.13	1.00	1.00	1.00

	GEOMEAN		
Kemalpasa	1.14	1.43	1.75
Seferıhısar	0.42	0.53	0.67
Urla	0.45	0.54	0.67
Karaburun	0.10	0.11	0.12
Cesme	0.27	0.33	0.42
Bornova	6.75	7.85	8.90
Menderes	1.00	1.25	1.58
Torbalı	3.30	4.01	4.84
Selcuk	0.18	0.21	0.26
Balcova	0.55	0.67	0.81
Gazıemır	1.45	1.86	2.30
Karsıyaka	3.45	4.04	4.70
Total	19.12	22.88	27.07
Inverse	0.05	0.04	0.03
Increasing Order	0.03	0.04	0.05

	Fuzzy Weight			Mi	Normalized
Kemalpasa	0.04	0.06	0.09	0.06	0.06
Seferıhısar	0.01	0.02	0.03	0.02	0.02
Urla	0.01	0.02	0.03	0.02	0.02
Karaburun	0.01	0.01	0.01	0.01	0.01
Cesme	0.01	0.01	0.02	0.01	0.01
Bornova	0.25	0.34	0.46	0.35	0.33
Menderes	0.03	0.05	0.08	0.05	0.05
Torbalı	0.12	0.17	0.25	0.18	0.17
Selcuk	0.00	0.01	0.01	0.01	0.01
Balcova	0.02	0.03	0.04	0.03	0.02
Gazıemır	0.05	0.08	0.12	0.08	0.08
Karsıyaka	0.12	0.17	0.24	0.18	0.17
Total				1.04	1

	Proximity To Petrol Stations	Proximity To Substations	Distance To Current CS	Capacity Of The Charging Station	Improved Air Quality And Noise Pollution Reduction	Distance To Windmills	Population Density	Results
Kemalpasa	0.22	0.01	0.01	0.01	0.06	0.06	0.06	0.45
Seferıhısar	0.04	0.01	0.02	0.01	0.02	0.07	0.02	0.02
Urla	0.04	0.22	0.02	0.02	0.02	0.11	0.02	0.45
Karaburun	0.01	0.01	0.01	0.01	0.01	0.31	0.01	0.36
Cesme	0.10	0.22	0.31	0.08	0.02	0.24	0.02	1.01
Bornova	0.30	0.22	0.21	0.17	0.33	0.09	0.33	2.52
Menderes	0.12	0.01	0.03	0.01	0.05	0.02	0.05	0.30
Torbalı	0.10	0.01	0.02	0.02	0.17	0.01	0.17	0.52
Selcuk	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.09
Balcova	0.01	0.01	0.04	0.12	0.02	0.01	0.02	0.27
Gazıemır	0.02	0.01	0.13	0.12	0.08	0.01	0.08	0.47
Karsıyaka	0.01	0.22	0.13	0.36	0.17	0.01	0.17	1.11