Determination of Optimal Location of Electrical Vehicle Charging Stations in Istanbul with Genetic Algorithm and Geographical Systems

Araştırma Makalesi/Research Article

Kazım YILDIZ[*1], Onur Yenigün[2], Tülin BOYAR[3]

[1]Marmara Üniversitesi, Teknoloji Fakültesi, Bilgisayar Mühendisliği, İstanbul, Türkiye
2,3Marmara Üniveritesi, Fen Blimleri Ensititüsü, Bilgisayar Mühendisliği, İstanbul, Türkiye
onuryenigun@marun.edu.tr, tulinboyar@marun.edu.tr, kazim.yildiz@marmara.edu.tr
(Geliş/Received:18.07.2023; Kabul/Accepted:31.10.2023)
DOI: 10.17671/gazibtd.1329029

***Abstract*—** The use of electric vehicles in Turkey is increasing from one day to the next. This study focuses on determining the efficient locations for the positioning of electric vehicle charging stations to be established in Istanbul. Geographic Information System was used in the study; a location map was created for the traffic density map of Istanbul and the existing electric vehicle charging stations The genetic algorithm was used to determine the points of highest charging inqury in the city and to calculate the charging demand satisfaction situation of the existing charging stations. The constraints are that the estimated charging demand is not met to a certain extent at the charging demand points and that the locations are at a maximum distance of 500 metres from the charging demand points. With the solution sets generated according to the genetic algorithm, 10 efficient locations were determined from the 223 Istanbul Parking Lot Operations datasets, representing the locations where the charging station is planned to be installed. The identified locations are the areas with high traffic in Istanbul. In this study, electric vehicle charging network operators can calculate the time to tolerate this cost for the installation of charging stations, which is quite costly; it suggests an approach to location planning so that electric vehicle users can satisfy their charging needs as quickly as possible without creating long queues.

***Keywords*—** electric vehicle charging station, electric vehicle charging station positioning, determination of electric vehicle charging station locations

Genetik Algoritma ve Coğrafi Sistemlerle İstanbul'daki Elektrikli Araç Şarj İstasyonlarının Optimal Konumunun Belirlenmesi

***Özet*—** Türkiye'de elektrikli araç kullanımı her geçen gün artmaktadır. Bu çalışmada, İstanbul'da kurulacak elektrikli araç şarj istasyonu konumlandırması için en verimli lokasyonların belirlenmesine odaklanılmıştır. Çalışmada Coğrafi Bilgi Sistemi kullanılmış; İstanbul trafik yoğunluk haritası ve mevcut elektrikli araç şarj istasyonları için lokasyon haritası oluşturulmuştur. Genetik algoritma kullanılarak, şehirde şarj talebinin en yüksek olduğu noktalar belirlenerek mevcut şarj istasyonlarının şarj talebini karşılama durumu hesaplanmıştır. Şarj talep noktalarında tahmini şarj ihtiyacının belirli bir oranda karşılanmaması ve lokasyonların şarj talep noktalarına maksimum 500 metre uzaklıkta olması koşulları aranmıştır. Genetik algoritmaya göre oluşturulan çözüm setleri ile şarj istasyonu kurulması planlanan lokasyonları temsil eden 223 İstanbul Otopark İşletmeciliği veri setinden en verimli 10 lokasyon belirlenmiştir. Belirlenen lokasyonlar İstanbul trafiğinin yoğun olduğu bölgelerdir. Bu çalışmada elektrikli araç kullanıcılarının uzun kuyruklar oluşturmadan şarj taleplerini mümkün olan en kısa sürede karşılayabilmeleri için konum planlamasına yönelik bir yaklaşım önerilmektedir.

***Anahtar Kelimeler*—** elektrikli araç şarj istasyonu, elektrikli araç şarj istasyonu konumlandırma, elektrikli araç şarj istasyonu yerlerinin belirlenmesi

1. INTRODUCTION

With the support of national policies, it is aimed to reduce the use of fossil fuel vehicles by expanding the use of electric vehicles all over the world in order to reduce environmental pollution. In addition, the fact that fossil fuel resources will be depleted in the near future has accelerated the widespread use of electric vehicles(EV). The rapid increase in the use of electric vehicles necessitates a strong station network throughout the country. The installation of charging stations and the expansion of the charging network are the most important steps in this direction. In our country, studies have been accelerated to expand the network of charging stations. The most important point in these studies is the location of charging stations and site planning. If the correct place cannot be determined and the facility planning is not efficient; various problems will arise both for the charging network operator and for electric vehicle owners, such as not meeting the charging demand and leaving the planned stations empty.

It has been observed in the literature that solutions to the same problem have been found using different approaches. The optimisation problem is defined as a complex combinatorial problem that aims to find the minimum number of critical charging station locations selected to cover the distance between any two nodes in the road network. The required input data is the road network configuration with distances and the assumed autonomy of EVs. The input information is used to generate the graph representing the road infrastructure with nodes as possible locations for charging stations. The application of the presented method is demonstrated on an example road configuration, highlighting its scalability, generality and computational cost[1].The linear programming approach used in this work has been useful for our study.

Multi-criteria decision-making systems were used in the study carried out to determine the appropriate location in the province of Ankara. In the study, the criteria affecting the location selection were determined; these criteria were weighted and combined with the Fuzzy Analytical Hierarchy Method; a map was created to determine the appropriate location. According to the results of the suitability map, the suggested locations were mostly central districts[2-3].

It was studied on the creation of the infrastructure of EV charging stations. The application model for the study is Balikesir University Cagis Campus. Vehicle entry and exit data were used and a survey was conducted to determine driver usage habits. With the obtained data, the ideal number for positioning the charging station has been determined by the queuing theory. Parking lots within the campus were determined as candidate locations and how the charging stations would be distributed was determined by multi-criteria decision-making methods. For the charging stations to be located in the province of Istanbul, a study was conducted to determine the locations to be invested from the candidate locations. In the study, a model was developed in the MATLAB program using the necessary data, and the optimal result is achieved by using YALMIP/Cplex. The model developed in the study yielded results independent of the data size[4-5].

Managing and analyzing spatial data, making calculations with data, etc. Geographic Information Systems (GIS) which have features were used. In the study aimed at positioning electric vehicle charging stations, the choice of location takes into account various criteria. Fuzzy Analytical Hierarchy Process (FAHP) was used to solve the location selection problem by evaluating the determined criteria. The GIS system was used in the analysis process of the electric vehicle positioning problem. In practice, three different districts of Istanbul were selected and the criteria values produced by the multi-attribute decision making method were processed with data layers in GIS and presented as a decision support system. [6,7,25].

The suitability of urban road connections for electric vehicle charging station installation was tried to be estimated. A spatial model consisting of parameters and weights was used. According to the results, transportation centers were determined as the factors that affect the EV charging station positioning of the parking areas in Greece.[8].

The total social cost model was presented, using Ireland as an example, and the operating costs of charging stations under different conditions were calculated. The study evaluated charging station installation costs under sub-headings. A genetic algorithm-based charge position optimization model was constructed to compare the correlation coefficient by dividing Ireland into squares with a rectangle covering. In the study, how long it will take to amortize the cost of a charging station, the power consumption per unit has been calculated and an optimization model has been proposed that minimizes the operating cost in line with the constraints. In addition, sensitivity analysis was conducted to determine which factors were effective on the total costs of charging stations; according to the results of the analysis, it was observed that the daily charging probability and the number of stations were effective[9].

Deep learning model Spatial-Temporal Graph-Informer (STGIN) was applied to predict whether electric vehicle charging stations can be used in the long term. Graph Convolutional Neural Network (GCNN) was used to graphically extract the charging data of urban charging stations according to location and time with the periodic charging data. Electric vehicle charging stations did not work nodes; roads are represented by their edges and a graphical view is obtained. The current charging data was tested with the STGIN model. Compared to other algorithms, it performed better on three different horizons. According to the results of the study, the STGIN model can successfully predict whether the electric vehicle charging station will be used for a long time [10].

They determined the 10 points that would be most efficient in positioning by using the city's traffic flow, existing EV charging points, city road lines and some road features for location selection for charging points to be located in the city of Västerås, Sweden. When the methodology of the study was examined, mapping techniques over GIS were used and optimization was carried out with a genetic algorithm [11-12].

In recent years, efforts to increase the use of electric vehicles have accelerated. With the widespread use of electric vehicles, there are problems in many areas such as range, accessories, and the use of charging stations for electric vehicles. Problems encountered or foreseen to be encountered, and solutions offered to problems; there are many researches and studies in the literature, such as optimization to popularize the use, correct positioning of charging stations, electric vehicle range analysis, and consideration of city electricity infrastructure[13-14].

This study focuses on identifying the characteristics that affect the selection of locations for the installation of electric vehicle charging stations and how to select locations using the identified characteristics. In order to position the EV charging stations at the right location, the locations with high charging demand were determined using Istanbul traffic data; the location information of the EV charging stations in Istanbul was used to select the locations without charging stations. To determine the ideal location, solution spaces were created using the genetic algorithm and the optimisation problem was solved using mixed integer linear programming[14,21,23].

The aim of this study are to identify the factors that will affect the efficient installation of electric vehicle charging stations throughout the province of Istanbul, to collect data on the identified factors, to present efficient installation proposals using genetic algorithms, and to make an innovative contribution to the literature by visualising the results using geographic information systems. This study consists of 3 parts: In the first part, the preliminary research on the subject and previous literature studies are included. In the second part, information about the GIS, the dataset and methods are explained. Finally the results and discussion are presented.

2. MATERIAL AND METHODS

Figure 1 Shows the overall design of the system. Traffic flow data and locations of existing EV charging stations were processed and visualised using GIS. The efficient locations among the alternative locations were determined using the genetic algorithm with the obtained data sets. The efficient locations among the alternatives were also visualised using GIS.

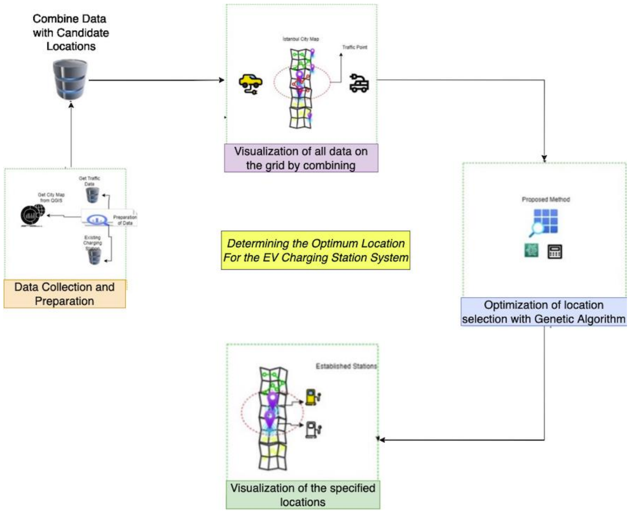


Figure 1. Overall architecture of the system

2.1. Datasets

In this study, a grid covering the provincial borders of Istanbul was created and each grid cell was used for the intersection of the data processed on GIS. Istanbul Province Surface area is 5.170km^2. A cell for the generated grid is 500m^2. For regions where no traffic flow data is available, the average of neighboring grid cells is used.

In the study, traffic flow of Istanbul, previously located electric vehicle charging stations and location datasets planned to be established were needed. The required datasets were obtained from the Istanbul Metropolitan Municipality website.

Table 1 shows a section from the traffic density dataset for the province of Istanbul. There are 1048519 records in the dataset, which contains the average number of vehicles, maximum-minimum speed and location information for traffic density points [15]. The fields of the records given as examples are presented in the table. Points determined by Longitude and Latitude information are traffic density points. There are minimum speed, maximum speed and average speed data for each traffic density point. Sample data were randomly selected from the regions with high traffic seen in the specified dataset.

Table 1. Traffic density dataset sample for Istanbul

	Longıtude	Latıtude	Mın Speed	Max Speed	Avg Speed
1	28.8446	41.1136	9	78	53
2	29.1522	41.0092	6	64	27
3	28.4711	41.0422	53	96	72
4	29.361	40.817	17	128	73
5	28.8446	40.9708	16	82	55
6	29.295	41.1081	68	152	93
7	28.7128	40.9927	6	91	49
8	28.8995	41.0696	6	46	15
9	28.8226	40.9982	6	114	59
10	28.9764	4,10971E+14	6	77	277

For the locations where charging stations are planned to be installed, the dataset containing the parking lot information of the Istanbul Municipality was used. It is preferred because it is open to access, it represents candidate locations.

Table 2 A section from the dataset used for the parking lots of the Istanbul Municipality is shown. The dataset contains information about 705 parking lots[16]. There are 9 data pertaining to each car park, these data are the district where the car park is located, the name of the car park, working hours, location information, vehicle capacity, car park type. “LONGITUDE” and “LATITUDE” fields are used for the location, and the “PARK_NAME” field is used to detect the station.

Table 2. A sample from the dataset for the parking lots of the Istanbul

	Park_Name	County_Name	Longıtude	Latıtude
1	Vali Konağı Caddesi 1	Şişli	28.988	41.0488
2	Şakayık Sokak 1	Şişli	28.9956	41.0495
3	Hüsrev Gerede Sokak 1	Şişli	28.995	41.0484
4	Sezai Selek Sokak 1	Şişli	28.996	41.0534
5	Maçka Caddesi 1	Şişli	28.993	41.0466
6	Maçka Caddesi 6	Şişli	28.9945	41.0478
7	Taşkışla Caddesi 3	Şişli	28.9913	41.0479
8	Vefa Bey Sokak 1	Beşiktaş	29.0066	41.0655
9	Müselles Sokak 2	Şişli	29.0116	41.0688
10	Vali Konağı Caddesi 1	Şişli	28.988	41.0488

The list of electric vehicles charging stations currently in use for the province of Istanbul has been pulled from the Istanbul Municipality website. The current charging station status near the charging stations planned to be located was obtained from this dataset and used to calculate the rate of fulfillment of the charging demand in the optimization modeling.

Table 3 The dataset containing the information about the existing charging stations within the provincial borders of Istanbul is sampled[17]. There are 223 records in the dataset. Each record contains the charging station number, station name, the coordinates of the station, the power of the charging units in the station, and the boundary information for the area of the station. “XCoord” and “YCoord” fields are used to position the charging stations on the grid.

Table 3. The dataset containing the information about the existing charging stations in Istanbul

	StationNo	StationName	Xcoord	Ycoord
1	10000	Eşarj - Akasya AVM, Acıbadem	29.054344	41.000813
2	10001	Eşarj - Akbatı AVM, Esenyurt	28.667032	41.055676
3	10002	Eşarj - ASF Otomotiv, Kartal	29.17877	40.917294
4	10004	SHARZ.NET - Veko Giz Plaza	29.0214538	41.1098236
5	10006	SHARZ.NET - Kemer Petrol	28.9046809	41.1692703
6	10007	SHARZ.NET - Koç Müzesi Deniz Otopark	28.9492851	41.0427988
7	10008	ZES-Migros Ataşehir	29.126572	40.991752
8	10009	ZES-Lukoil Esenyurt	28.676835	41.019524
9	10144	ZES-Pendik	29.254253	40.897597
10	10147	ZES-Novotel	28.979982	41.024665

2.2. Generating GIS Data

Driving roads within the provincial borders of Istanbul were created with the Open Street Map plugin over the GIS application. The study base layer was created with the Istanbul city coordinate boundaries. The parameters required for the optimization model were calculated by positioning all the data on the road layer created for the province of Istanbul. Figure 2 shows the ".shp" file created by the roads of the province of Istanbul, which was created through the GIS system. ERS:4326 coordinate reference system is used. Figure 2 shows the Istanbul roadmape was created form the GIS system.

Figure 2. Istanbul Roadmap was created from the GIS system, all data was combined by positioning the information obtained in other datasets on the file created in shapefile type.

Figure 3 shows the borders used for the Istanbul Road Map. In the coordinate system, the points consisting of the borders of the province of Istanbul were determined, and the grid system used in the study was created according to these borders.

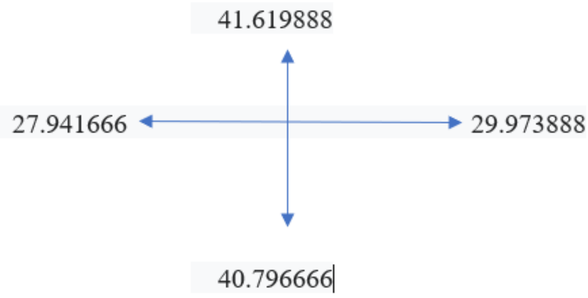


Figure 3. Istanbul provincial boundaries [18]

In Figure 4, the image of the grid to be used for calculations in the optimization model is presented. Each grid cell is $500m^2$. In the optimization model, the cell density (charging demand), the current number of charging stations and the planned charging station location are examined separately for grid cells.

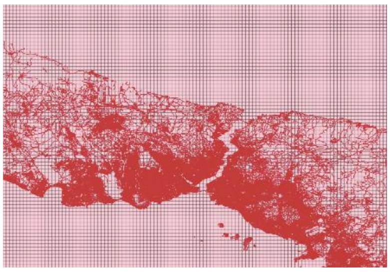


Figure 4 Istanbul province GIS grid layer

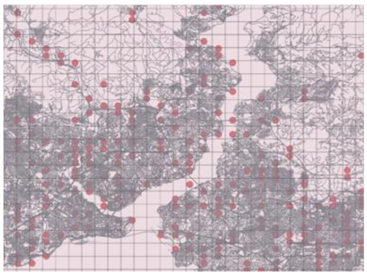
2.3. Dataset Preprocessing and Preparation

The datasets used in the study are in ".csv" and ".shp" file types. For the model developed in the GIS system and Python code environment, both file types were used in the study according to the varying needs.

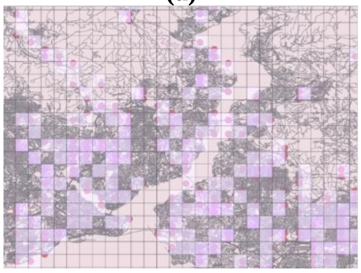
The dataset for the province of Istanbul includes the location of traffic points, the average number of vehicles, and the minimum-maximum speed information. The grid layer divides the Istanbul roadmap into cells. When the Istanbul Traffic Density dataset is added to the grid layer over the GIS system with its current locations, the image in Figure 4-a is obtained. A separate layer was created by selecting traffic points from each grid cell via the GIS system.

In this study, traffic points are considered as places where the charging demand will be intense. Grid cells with high charging demand are selected and used as input in the optimization function.

In Figure 5(a), the traffic density points for the province of Istanbul are shown. Figure 5(b) shows the intersection of the traffic density points with the GIS grid layer created for the province of Istanbul.



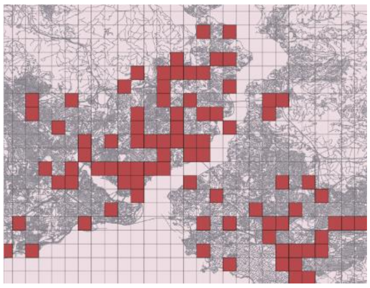
(a)



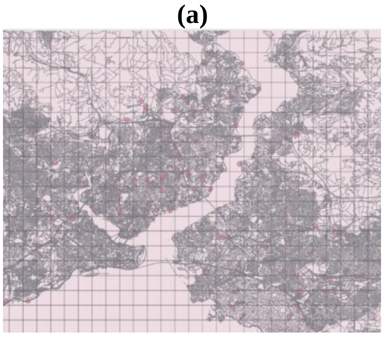
(b)

Figure 5 (a) shows the location of the traffic density points on the map, (b) The intersection of the traffic density points with the grid cells

In the dataset of electric vehicles charging stations already established in Istanbul; there are "Longitude" and "Latitude" information for charging stations, using these areas, charging stations are located on the Istanbul map. How many electric vehicle charging stations are located in each grid cell was calculated via GIS and added as a new field. If the existing electric vehicle charging stations are used in the selection of candidate locations; the charge formed in the grid cell determines the state of meeting the demand. Figure 6(a) shows the location of existing EV charging stations in grid cells, Figure 6(b) shows the locations of charging stations as points.



(a)



(b)

Figure 6 (a) Grid positioning of EV charging stations in Istanbul (b) EV charging station locations in Istanbul

Their locations on the grid were determined by using the location areas in the parking lot dataset of the Istanbul Metropolitan Municipality. The main purpose of this study is to identify 10 sites that will maximise the benefits of the car parks identified as candidate sites. According to the data obtained from other datasets of parking lots; it was evaluated according to the situation of being near the charging demand points. In the parameter used, car parks up to 500m close to the charging demand point are scored as "1", and those over 500m are scored as "0".

After the parking lots were located on the Istanbul map with their location information, it was determined which grid cell they were in on GIS. Figure 7 shows the intersections of the Istanbul Metropolitan Municipality Car Parks with the grid cells.

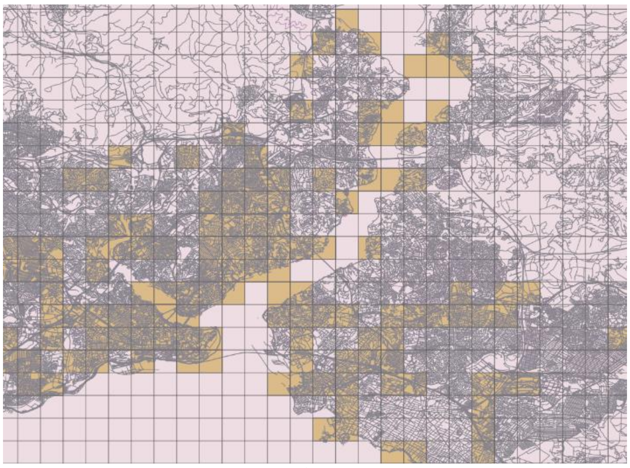


Figure 7. Positioning of İSPARK's locations on the Istanbul city map and intersections with grid cells

2.4. Genetic Algorithm and Optimization Techniques

In the genetic algorithm, which has a very wide application area, all possible solutions are coded as a series. One solution set is selected from the obtained sequence and accepted as the initial population. A fitness value is calculated for each population, and the calculated fitness values show the quality of each population in solution. A group of sequences is randomly selected according to a determined probability value and passed through the replication process. The fitness values of the new individuals emerging by multiplication are also calculated; undergoes crossover and mutation processes. This process flow continues until the predetermined number of generations. The iteration ends when the specified number of generations is reached. As a result, the appropriate sequence is selected according to the objective function[19,20,22,25].

Mixed integer linear programming is the optimization method that are generally preferred by researchers in recent years. It was used first among the classical methods, is a special type of linear programming. Linear programming, on the other hand, can be defined as a technique that minimizes or maximizes a linear cost function. The equation (1) for a linear optimization problem can be represented as [14,21,22,23]:

$$F(x) = C^T x \quad Ax < b \;\; while\ the\ input\ vector\ is{:}\ x = \{x_1, x_{2,} x_3 \dots \dots . x_n\} \quad (1)$$

A->It is the coefficient matrix for certain values.

B, c-> coefficient vectors for certain values.

A “Mixed Integer Linear Programming” consists of continuous variables, integers and constraints which is shown in equation 2[14,21,22,23]:

$$Z(X) = \min_{(x,y)} \{ cx + fy : (x,y) \in X \} \quad (2)$$

The set X is called the set of viable solutions and is defined by linear constraints m, non-negative constraints on variables x,y and integrity constraints on variables y. In matrix representation[14,21,23]:;

$$X = \{ (x,y) \in R_+^n \times Z_+^p : Ax + By \geq b \} \quad (3)$$

In equation 3, Z(X) shows the efficient objective value when optimization is made over the appropriate set of X. x and y refer to the n (column) vector of the continuous non-negative variables and the p (column) matrix of the integer non- negative variables, respectively. c $\in R^n$ and f $\in R^p$ are vectors of objective coefficients.b $\in R^m$ is the vector of the coefficients (column) on the right side of the constraints m. A and B are constraint matrices with real size coefficients (m × n) and (m × p), respectively.

In the proposed method; for candidate locations, charging station installations are simulated on grid cells that represent solution populations in the genetic algorithm, by keeping the charging station installation cost, daily charging rate, minute charging fee and energy consumption constant. The solution set variables are; it is the charging demand that increases or decreases according to the current charging station and traffic density. From the mutation results obtained, the candidate stations that tolerate the cost the fastest and provide profitability are selected for installation.

Equation 4 was used to construct the objective function for each of the existing charging stations[14,21,22,23]::

$$PrFunc = p[i] * t[i] * q[i] - c[i] \quad (4)$$

p=5-minute charging fee (TL)

t→120 Charging time for an average vehicle (min)

q→10000 Installation cost for a charging station

c→Total charge for charging station

v_0 = 0.05 Charging possibility for the charging station to be installed in the cells, p_e = 0.17 1kWh Electricity fee, l_j = 5 Maximum charging point to be set up for a station, alpha = 55 Average battery capacity (kWh), N = 10 Total number of stations planned to be installed. These constraint values used in parameters.

Creating Parameters: dr[i]= di[i] – array[i] * m[i] if dr<0 dr=0 (Demand cannot be negative) [14,21,22,23]:

di = u * fi represents the charge demand for cell I, u = 0.10 Daily usage rate is determined as 10%. It is the average of the charging station planned to be established for the fi i cell.

Profitability Account:

$$(cr\_j[j] + ce\_j[j] + ci\_j[j] + 0.1 * ce\_j[j] + 0.1 * ci\_j[j]) * n[j] \backslash + pe * alpha * q[j] \quad (5)$$

cr_j= 30 # Parking fee

ce_j = 1100 # Charge unit price

Creating the Optimization Problem[14,21,22,23]: The problem for which a solution is sought for the research is to maximize the 10 locations to be selected from among the many locations where charging stations are planned to be established. The optimization problem is used to bring the maximized solution.

Parameters for the Optimization Problem[14,21,22,23]; n is the number of charging stations planned to be installed, q is the number of requests remaining after the locations determined for a fixed number of stations planned to be installed. c is the total cost for the fee planned to be installed will increase according to the parameters, x is the usage status of the candidate locations planned to be established (0 or 1) and r is the distance of the planned charging station to the existing charging station (0 or 1)

All constraints explained as[14,21,22,23]: Constraint 1 ;Remaining below the demand according to the number of daily recharges determined at the charging stations planned to be established

$$q - n * m <= 0 \quad (6)$$

m=2 (Daily charging is fixed as 2)

Constraint 2; The situation where the distance of the candidate locations to the charging demand points is more than 500 meters

$$q[j] - lpSum(r[i][j] * dr[i]\ for\ i\ in\ demand\_lc) <= 0 \quad (7)$$

Constraint 3; Use cases during the determination of candidate locations (whether the location is selected or not)

$$lpSum(x[j] * r[i][j]\ for\ j\ in\ chg\_lc) - 1 <= 0 \quad (8)$$

Constraint 4; Failure to reach the target number after installations

$$probe += n[j] - x[j] >= 0 \quad (9)$$

Constraint 5; Not reaching the maximum number at the specified location

$$n[j] - lj * x[j] <= 0 \quad (10)$$

Constraint 6; Not reaching the number of locations planned to be selected

$$lpSum(x[j]\ for\ j\ in\ chg\_lc) == N \quad (11)$$

In the study, firstly, a function that generates populations is created by using the charge demand positions and ISPARK positions with the genetic algorithm. Then, in order to determine the service area for each population, a parameter that takes a value of 0 if the distance of the charging demand point to the potential ISPARK is greater than 500 m, and 1 if it is not, has been added.

A function that includes all parameters and calculates the fulfillment of the charging demand by the existing electric vehicle charging stations for each cell on the grid and rates the charging demand is used. The state of meeting the charging demand was calculated over the GIS system using the existing electric vehicle charging stations located on the grid.

Finally, it is formulated with the Mixed Integer Linear problem consisting of variables and constraints. Optimization function aimed with; is to maximize the profit to be obtained from the stations by subtracting the capital and operating costs required for the installation of the charging station. The situation used as a constraint in the problem is that the station capacity and the charged car are less than the charging demand, the need is met at the charging demand point, and a maximum of 5 charging units are installed in a location.

3. RESULTS AND DISCUSSION

As a result of the study, when the traffic data of the province of Istanbul is examined, among the candidate locations for the charging station to be established according to the rate of meeting the charging demand in the regions where the highest charging demand occurs, the parking lots closest to the charging demand point have been determined first. Being close to the charging demand point is limited to 500m.

Table 4 shows 10 locations obtained by optimization problem solving. All the data collected on the grid were solved with the genetic algorithm created and the efficient 10 locations were determined.

Table 4. Ten locations which are obtained by optimization algorithm

	Park Name	Latitude	Longitude	District
1	Bosna Bulvarı 4	29.0844743 26843	41.024938 615784	Ümraniye
2	Ataşehir Bulvarı 5	29.1253191 232681	40.992844 048405	Ataşehir
3	Ataşehir Bulvarı Taksi Durağı	29.1267067 463254	40.992571 9800085	Ataşehir
4	Kanlıca Barış Manço Caddesi 1	29.0662089 71994	41.100121 8927195	Beykoz
5	Eski Büyükdere Caddesi 1	29.0062693 981217	41.088122 2691293	Kağıthane
6	Haliç Sosyal Tesisleri Otoparkı	29.0062693 981217	41.088122 2691293	Fatih
7	Avni Akyol Bulvarı	26.6854883 15175	41.070025 875213	Başakşehir
8	Poyrazlı Sokak 1	28.8886640 444539	41.009281 7416347	Güngören
9	Abide-i Hürriyet Caddesi 2	28.9875766 28333	41.063402 364554	Şişli
10	Haznedar Yer Altı Otoparkı	28.8729094 095495	41.008344 2312323	Güngören

Figure 8 shows the optimization function result, 10 efficient locations were determined among 223 İSPARKs in the dataset of candidate locations. According to the results obtained, İSPARKs located in Ümraniye, Ataşehir, Beykoz, Kağıthane, Fatih, Başakşehir, Şişli and Güngören districts of Istanbul were determined as the efficient location.

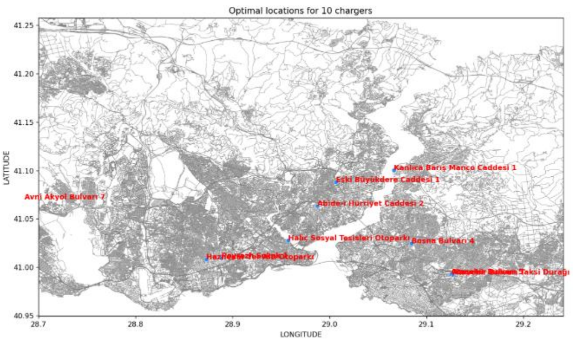


Figure 8. Display of 10 İSPARK points selected according to the results of the optimization function on the map (Python)

4. CONCLUSION

One of the critical issues in increasing the use of electric vehicles is the correct positioning of charging stations. While aiming to increase charging stations; It is very important for both service buyers and service providers to be able to use electric vehicle users without disrupting their travel planning, creating long queues and keeping charging stations empty. For this reason, in this study to determine the efficient location at charging stations, the set of possibilities was examined by genetic algorithm using existing charging stations, traffic density and candidate location data; with Mixed Integer Linear Programming, which is one of the optimization techniques, the most reasonable solution among the possibilities has been reached. Using the GIS, the province of Istanbul was partitioned with a grid structure and the city was scanned in units of 500 square meters. In the study, the charging demand points of the city were determined on the grid and the rate of meeting this demand was calculated by giving a certain charging rate to the existing charging stations. In future studies, periodic charging time of each station, amount of energy consumption, usage intensity; it is aimed to increase the sensitivity of efficient location determination by using AC-DC comparison data.

ACKNOWLEDGMENT

This work has been supported by Üçay Mühendislik A.Ş.

REFERENCES

[1] M.Z. Saeed, Akbari, T. "A Mixed-integer Linear Programming Model for the Plug-in Electric Vehicle Charging Problem in Unbalanced Low Voltage Electrical Distribution Systems Considering Neutral Conductor" *Electric Power Systems Research*, 209, 32-38, 2022.

[2] K.C. Arayıcı, G. Poyrazoğlu, "Elektrikli Araç Şarj İstasyonu Doğru Konumlandırılması", **Güç Sistemleri Konferansı, Ankara**, 1-4, Kasım, 2018.

[3] A. Zubiria, A., Menendez, H-J., Grande, P., Meneses, G., Fernandez, "Multi-Criteria Decision-Making Problem for Energy Storage Technology Selection for Different Grid Applications" *Energies*, 1(2), 16, 2022.

[4] M.S.K, Asnaz,. B. Özdemir, "Elektrikli araç şarj istasyonlarının çok kriterli karar verme yöntemleri ile optimal konumlandırması". *Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi*, 4(2), 175-187, 2021.

[5] S.S., Bilgilioğlu, "Coğrafi bilgi sistemleri ve bulanık analitik hiyerarşi süreci ile elektrikli araç şarj istasyonu yer seçimi", *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, 22(1), 165-174, 2022.

[6] D. Güler, T. Yomralioğlu, "Açık Kaynak Kodlu CBS Yazılımı ve Bulanık Analitik Hiyerarşi Yöntemini İçeren Elektrikli Araç Şarj İstasyonu Yer Seçimi Önerisi", *Harita Dergisi*, 163, 17-28, 2020.

[7] D Savran, G Tuna, F Macit, R Daş "Coğrafi bilgi sistemleri kullanılarak taşınmaz kültür envanterinin hazılanması: Kırklareli ili örneği" *Dicle Üniversitesi, Mühendislik Fakültesi, Mühendislik Dergisi*, 8 (1), 147-158

[8] C., Li, et al., "Robust model of electric vehicle charging station location considering renewable energy and storage equipment". *Energy*, 238, 121713, 2022.

[9] G., Zhou, Z. Zhu, S. Luo, "Location optimization of electric vehicle charging stations: Based on cost model and genetic algorithm", Energy, 247, 123437, 2022.

[10] R., Luo, et al. "Deep Learning Approach for Long-Term Prediction of Electric Vehicle (EV) Charging Station Availability". **IEEE International Intelligent Transportation Systems Conference (ITSC)**, Indianapolis, 8-15, 2021.

[11] C., Bian, et al., "Finding the optimal location for public charging stations–a GIS-based MILP approach", *Energy Procedia*, 158, 6582-6588, 2019.

[12] Q., Zhang, H., Li, L., P.E., Zhu Campana, H., Lu, F., Q., Wallin Sun " Factors influencing the economics of public charging infrastructures for EV–A review", *Renewable and Sustainable Energy Reviews*, 94, 36-38, 2018.

[13] S., Erdoğan, et al., "Establishing a statewide electric vehicle charging station network in Maryland: A corridor-based station location problem", *Socio-Economic Planning Sciences*, 79, 101127, 2022.

[14] Internet: O. Sims, Where should we be placing ev charging stations using qgis and pulp, https://towardsdatascience.com/where-should-we-be-placing-ev-charging-stations-using-qgis-and-pulp-d2bb7b664a55, 11.05.2022.

[15] Internet: IBB, Ocak 2020 Trafik Yoğunluk Verisi, https://data.ibb.gov.tr/dataset/hourly-traffic-density-data-set/resource/db9c7fb3-e7f9-435a-92f4-1b917e357821, 16.03.2022.

[16] Internet: IBB, ISPARK Otopark Bilgileri, https://data.ibb.gov.tr/dataset/ispark-otopark-bilgileri, 16.05.2022.

[17] Internet: IBB, Trafik Yoğunluk Haritası, https://uym.ibb.gov.tr/yharita6/, 17.03.2022.

[18] Internet:Wikipedia,İstanbul. https://en.wikipedia.org/wiki/Istanbul, 16.06.2022.

[19] O. Engin, **Akış tipi çizelgeleme problemlerinin genetik algoritma ile çözüm performansının artırılmasında parametre optimizasyonu**, Doktora Tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, 2001.

[20] R Daş, I Türkoğlu, M Poyraz "Genetik algoritma yöntemiyle internet erişim kayıtlarından bilgi çıkarılması ", *Sakarya Üniversitesi, Fen Bilimleri Enstitüsü Dergisi* 10 (2), 67-72

[21] J., Islam, et al., "A holistic review on artificial intelligence techniques for well placement optimization problem". *Advances in Engineering Software*, 141, 102767, 2020. Transportation Research Part C: *Emerging Technologies*, 132, 103376, 2021.

[22] M. Karaköse, H. Yetiş, T. Müezzinoğlu "Optimizasyon Tabanlı Adaptif Görüntü Mozaikleme Algoritması". *Bilişim Teknolojileri Dergisi*, 10(4), 389-400, 2017.

[23] Y. Pochet, A.W. Laurance, **Production Planning by Mixed Integer Programming**. NY, Springer New York: 77-113, New York, 2006.

[24] K. Buyukozdemir, K. Yildiz, A. Bas, B.C. Uslu, "A Review of Heuristic Approaches to Vehicle Routing Problems". **IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)**, Australia, 2022.

[25] Internet Wikipedia, Geographic information system. https://en.wikipedia.org/wiki/Geographic_information_system, 16.06.2023.