Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/EU08.20250197
Published: July 2, 2025

Optimization of Electric Vehicle Charging Infrastructure: A Case Study in Jordan

Nader A. Al Theeb
Associate Professor of Industrial Engineering
Department of Industrial Engineering
Faculty of Engineering, Jordan University of Science and Technology
Irbid, Jordan
naaltheeb@just.edu.jo

Suliman Al Asmar and Abdallah Batayneh
Department of Industrial Engineering
Faculty of Engineering, Jordan University of Science and Technology
Irbid, Jordan

Abstract

As the adoption of electric vehicles (EVs) continues to rise in Jordan, particularly in the city of Irbid, a pressing issue has emerged the scarcity of Car Fast Chargers (DC) within gas stations. This challenge not only inconveniences electric car owners, but also contributes to extended waiting times at the limited available charging stations. In response to this issue, a collaborative initiative has been undertaken in partnership with a local company in Irbid, aiming to address the current shortcomings in the electric vehicle charging infrastructure. Optimization models are developed to determine where are the best gas stations to put the charging unit, and the best number of charging units in each station.

Keywords
Electrical Vehicles, Optimization, Charging Stations.

1. Introduction

The shortage of fast chargers poses a significant challenge in accommodating the growing number of electric vehicles, hindering the widespread adoption of this sustainable mode of transportation. As the demand for electric mobility rises, inadequate charging infrastructure can lead to inconvenience, long wait times, and restricted accessibility for EV users. Proposed solutions involve implementing mathematical models to strategically identify optimal charging station locations in cities like Irbid, ensuring comprehensive coverage and efficient use. Additionally, allocating budgets based on the importance of each station helps determine the optimal number of charges per location.

1.1 Objectives

This research tries to determine the ideal gas stations among 14 stations in Irbid for the installation of electric vehicle fast charging; through utilizing a mathematical model through Python software framework that considers a variety of criteria such as (coverage radius). Then, other mathematical model will be utilized to calculate the optimal number of fast chargers for each recognized station based on the importance of each station within a specific budget, ensuring a customized strategy that meets current and future requirements.

2. Literature Review

Many previous studies have dealt with EVs logistics frameworks. For example, Filote et. el. (2020) have assessed the impact of EVs stations on the environment; Bouguerra and Layeb (2019) have determined the best way to develop the charging station and applied their method on a case study in Tunesia. Similarly, Ullah et. el. (2023) have worked on finding the optimal deployment of fast charging stations, and Wang et. el. (2020) have utilized the multi-objective optimization to find the optimal locations for charging stations within specific coverage and accessibility constraints. In the other hand, some researchers have studied the layout of charging stations, as in Jiang et. el. (2023) and Hao et. el. (2021).

3. Development of the Optimization Models:

The first step to constructing the model is to find the distance (travel time) between the current stations.

3.1 Current Station Locations Identification and Distances

An important phase of this study is identifying potential candidate locations for future EVCS in the Irbid city. Locations were determined as in the Figure 1.

station	1	2	3	4	5	6
1	0	16.0913938	2.58510989	8.58219667	8.53787905	11.5036282
2	16.0913938	0	15.9013236	9.62316742	8.65956926	12.7758767
3	2.58510989	15.9013236	0	7.26061421	7.5992041	13.4050273
4	8.58219667	9.62316742	7.26061421	0	1.3227825	13.3158845
5	8.53787905	8.65956926	7.5992041	1.3227825	0	12.1291269
6	11.5036282	12.7758767	13.4050273	13.3158845	12.1291269	0

Figure 1. Station Location

Criteria for the selection are defined for the suitable station locations, with a primary focus on the coverage radius: The Cartesian distance on the neighborhood of each station is then derived and annotated as di,j (i, j V) representing the distance between locations i and j. Google Maps are used to pinpoint the longitude and latitude coordinates for each station. To calculate the distance between stations, the Haversian formula is utilized by using the Python programming language. The Haversian formula is commonly used in geospatial calculations, especially for calculating distances between latitude and longitude coordinates:

The haversine equation is given by:

$$a = sin^2\left(\frac{\Delta lat}{2}\right) + cos(lat_1) \times cos(lat_2) \times \ sin^2\left(\frac{\Delta long}{2}\right)$$
$$c = 2 \times atan^2\left(\sqrt{a}, \sqrt{1-a}\right)$$
$$d = R \times c$$

Where

- Δlat is the difference in latitude
- $\Delta long$ is the difference in longitude
- Lat_1 and Lat_2 are the latitudes of the two points
- R is the earth radius (mean radius = 6,371 km)
- $Atan^2$ is the arctangent function

The result *d,* is the distance between the two points along the surface of the sphere (Earth)
The resulted matrix of distances for the 14 candidates is a matrix of size of 14 by 14, the first 5 columns and 5 rows are shown in Table 1.

3.3 ILP Model for Location Decision in Python

Integer Linear Programming (ILP) models are developed and solved using the Python programming language to address location decisions, with a specific focus on the coverage radius. The coverage radius is defined for each potential location, denoted by *V,* , which comprises 14 potential charging stations.

For each location *i*, a binary variable *xi* is introduced that takes the value 1 if a charging station is installed at location *i* and *0* otherwise. . Mathematically, *xi* can be expressed as:

$$\begin{Bmatrix} 1\ if\ a\ charging\ station\ is\ installed\ at\ location\ 1 \\ 0\ \ otherwise \end{Bmatrix}$$

A binary constant *αi,j* is also defined that takes the value 1 if the distance *di,j* between locations *i* and *j* is less than or equal to a pre-fixed coverage radius *R*. This constant is crucial for determining whether the tolerable distance for Electric Vehicle users to travel in order to find an available charging station is satisfied. The mathematical representation of *αi,j* is as follows:

$$\begin{Bmatrix} 1\ if\ d_{ij}\ \leq R \\ 0\ \ otherwise \end{Bmatrix}$$

di,j denotes the distance between locations *i* and *j*. Additionally, the model may include parameters such as the maximum coverage radius *R*, the number of potential charging stations *V*, and the distances *di,j* between all pairs of locations.

The Model 1 can be formulated:

$$M_1: Minimize \sum_{i \in V} X_i \qquad (1)$$

Subject to:

$$\sum_{i \in v} a_{i,j} x_i \geq 1\ \forall j \in V \qquad (2)$$

$$\sum\nolimits_{i \in Region_k} x_i \geq \frac{1}{|Region_k|} \times \sum_{i \in v} x_i, \forall k \qquad (3)$$

$$x_i \in \{0,1\}, \forall i \in v \qquad (4)$$

This first model minimizes the objective function (1) representing the total number of installed stations. Constraint (2) asserts the coverage radius for EV users' accessibility. Constraint (3) Region ***k*** represents a specific region or neighborhood, and Region$_k$ is the number of potential charging station locations in that region. The constraint is applied for each region (***k***). The left side of the equation calculates the total number of installed charging stations within a specific region Regionk by summing up the binary variables ***xi*** for each location in that region.

The right side of the equation calculates the expected minimum number of charging stations in each region, which is the total number of charging stations divided by the total number of potential locations. The constraint ensures that the number of installed charging stations in each region is greater than or equal to the expected minimum, promoting equitable distribution. This constraint helps avoid scenarios where charging stations are concentrated in certain areas, ensuring that users across different regions have similar access to charging infrastructure.
Where:

k1 = [1, 2, 4, 5, 6, 13, 14]

k2 = [3, 7, 8, 9, 10, 11, 12]

Constraint (4) expresses binary restrictions imposed on **x** variables.

3.4 Output of the first model

Different value of R are used to figure out the expected number of stations versus each value of R.
According on the model 1 results: It is assumed that a coverage distance of **2 km** seems practicable and appropriate for EV users. Total Charging Stations = 8 Total Charging Stations in Region k1: 4 Total Charging Stations in Region k2: 4 (Table 1). Locations of electric vehicle charging stations after expected implementation are shown in Figure 2.

Table 1. Impact of Coverage Radius on Result

R (KM)	Installed Charging Station
0	14
1	14
1.2	13
1.3	12
1.4	10
1.5	10
1.6	9
1.7	8
1.8	8
1.9	8
2	8
2.1	8

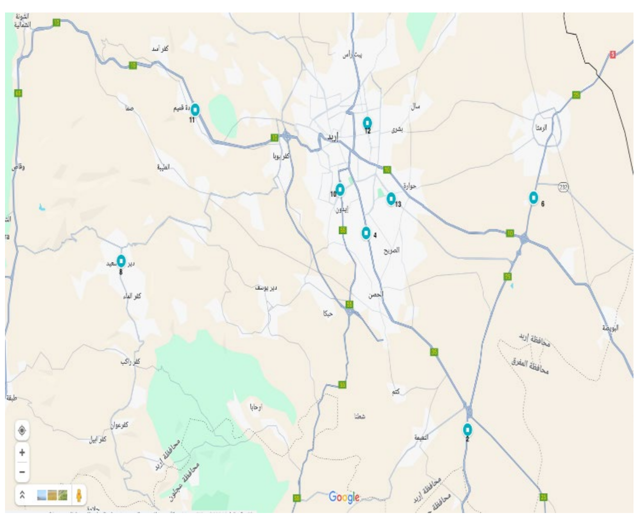

Figure 2. Model 1 Selected Location

3.5 MODEL two for sizing decision using Python

Results of Model 1 are used to solve the second model which concerns about determining the optimal number of charging units in each station.

3.6 Capacity of Each Station

In Model 2 When determining the number of EV chargers at charging stations, it is important to take into account the capacity of each station. This means making sure that the number of chargers installed doesn't go beyond what the station can handle. By following this principle, we ensure a safe and pleasant experience for electric car users, avoiding overcrowding. This careful planning contributes to the upkeep of an effective charging infrastructure that matches the demand and usage patterns, ultimately enhancing the overall satisfaction of users.

Decision variables: There is only one decision variable set; x_i which represents the number of chargers at gas station *i*.

Parameters:

- C_{max} is the maximum number of chargers allowed at any station.
- *B* is the budget constraint for the total cost of chargers.
- C_p is the cost per charger.
- $Importantce_i$ is the importance score of station i.
- $\sum_{j=1}^{8} importance_j$ is the sum of importance scores for all stations.

Objective function:

$$Maximize \sum_{i=1}^{8} x_i \qquad (1)$$

Constraints:

$$x_i \leq C_{max} \forall i \quad Capacity\ Constraint \qquad (2)$$

$$\sum_{i=1}^{8} c_p . x_i \leq B \quad Budget\ Constraint \qquad (3)$$

$$x_i \geq round\left(\frac{Importance_i . \left(B/_{c_p}\right)}{\sum_{i=1}^{8} Importance_j}\right)$$

This second model maximizes the objective function (1), which represents the sum of the number of chargers at each station. The stated objective function reflects a strategic approach to enhance the electric vehicle charging infrastructure by strategically increasing the number of chargers at gas stations. The ultimate goal is to meet user demand, improve user satisfaction, and contribute to the overall growth and adoption of electric vehicles.

Model 2 is solved for one scenario of budget of 100,000 JD and capacity of 7; the next figure shows the results of this model which can be taken by the decision makers. However, changing the capacity and budget can change these results (Figure 3).

```
Gas Station 1: Number of Chargers = 7
Gas Station 2: Number of Chargers = 6
Gas Station 3: Number of Chargers = 7
Gas Station 4: Number of Chargers = 6
Gas Station 5: Number of Chargers = 7
Gas Station 6: Number of Chargers = 5
Gas Station 7: Number of Chargers = 5
Gas Station 8: Number of Chargers = 6
```

Figure 3. Scenario 1 Result

6. Conclusion

Utilizing a linear mathematical model, we identified eight optimal charger locations based on radius coverage. A second model, taking into account station importance and capacity restrictions across various budget scenarios, resulted in a strategic allocation of chargers at each of the identified locations.

Thorough facility planning was undertaken to prioritize user comfort and prevent overcrowding. Environmental and economic impact assessments were conducted, further confirming the viability and sustainability of this electric car charging infrastructure project. The findings highlight its potential to meet the growing demand for electric vehicles in Irbid while minimizing adverse effects. This research provides a solid foundation for improving service delivery and advancing eco-friendly transportation in the region.

References

Bouguerra, S., & Layeb, S. B., Determining optimal deployment of electric vehicles charging stations: Case of Tunis City, Tunisia. *Case Studies on Transport Policy*, *7*(3), 628–642. 2019. https://doi.org/10.1016/j.cstp.2019.06.003

Filote, C., Felseghi, R., Răboaca, M. S., & Aşchilean, I., Environmental impact assessment of green energy systems for power supply of electric vehicle charging station. International Journal of Energy Research, 44(13), 10471–10494. 2020, https://doi.org/10.1002/er.5678

Filote, C., Felseghi, R., Răboaca, M. S., & Aşchilean, I., Environmental impact assessment of green energy systems for power supply of electric vehicle charging station. *International Journal of Energy Research*, *44*(13), 10471–10494. 2020. https://doi.org/10.1002/er.5678

Hao, H., Cheng, X., Liu, Z., & Zhao, F., Optimal deployment of electric vehicle charging infrastructure based on multi-criteria decision analysis. Energy Policy, 150, 112062. 2021.

Jiang, Z. K., Han, J., Li, Y., Chen, X., Peng, T., Xiong, J., & Shu, Z., Charging station layout planning for electric vehicles based on power system flexibility requirements. *Energy*, *283*, 128983. 2023. https://doi.org/10.1016/j.energy.2023.128983

Ullah, I., Liu, K., Layeb, S. B., Severino, A., & Jamal, A., Optimal deployment of electric vehicles' Fast-Charging stations. *Journal of Advanced Transportation*, *2023*, 1–14. 2023. https://doi.org/10.1155/2023/6103796

Wang, H., & Lin, X., Multi-objective optimization model for the location of electric vehicle charging stations considering service coverage and accessibility. Applied Energy, 262, 114823, 2020.

Biographies

Nader A. Al Theeb received his BS in Industrial Engineering from the Jordan University of Science and Technology, Irbid, Jordan in 2005 and MS in Industrial Engineering from the University of Jordan, Amman, Jordan in 2009. He also has an MISE in Industrial and Systems Engineering from the Auburn University, Auburn, AL in 2012. He received his PhD in Industrial and Systems Engineering from the Auburn University. His current research interests include operations research and its applications in the optimisation of logistics and routing systems, lean systems, and quality control.

Suliman Al Asmar and Abdallah Batayneh are undergraduate students in the industrial engineering department at Jordan University of Science and Technology.
.