shown in Table 4. Alternative point 10 (A10) is the most preferable shopping mall because it has the highest priority value. Alternative point 3 (A3) is the least preferable place because it has the lowest priority value. The value of inconsistency ratio is 0.04830 which gives reliable results.

Table 5. Comparison of Alternatives with respect to Traffic Convenience

C3	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Priority
A1	1.0	5	5	4	5	4	4	1.0	3	2	0.230
A2	0.2	1.0	5	3	5	0.33	3	0.5	0.25	0.5	0.089
A3	0.2	0.2	1.0	0.2	1.0	0.5	0.2	0.25	0.5	0.16	0.026
A4	0.25	0.33	5.0	1.0	3	0.33	1.0	0.33	3	0.5	0.073
A5	0.2	0.2	1.0	0.33	1.0	0.33	0.25	0.25	0.5	0.33	0.028
A6	0.25	3.0	2.0	3.0	3.0	1.0	3	0.5	2	0.5	0.113
A7	0.25	0.33	5.0	1.0	4.0	0.33	1.0	0.33	1.0	0.33	0.060
A8	1.0	2.0	4.0	3.0	4.0	2.0	3.0	1.0	3	1.0	0.157
A9	0.33	4.0	2.0	0.33	2.0	0.5	1.0	0.33	1.0	0.33	0.076
A10	0.5	2.0	6.0	2.0	3.0	2.0	3.0	1.0	3.0	1.0	0.143

The comparison of alternatives with respect to traffic convenience is illustrated in Table 5. Alternative point 1 (A1) is the most preferable shopping mall according to priority value which is 0.230. Alternative point 3 (A3) is the least preferable place with the value of 0.026. The value of inconsistency ratio is 0.09990 which means it yields reliable results.

The overall weight is obtained by the product of the weight and priority vector (Table 6).

Table 6. Overall composite weight of the alternatives

	C1	C2	C3	Composite Weight
Weight	0.319	0.558	0.121	
A1	0.075	0.085	0.230	0.0998
A2	0.0563	0.071	0.089	0.0690
A3	0.023	0.028	0.026	0.0270
A4	0.226	0.121	0.073	0.1491
A5	0.025	0.033	0.028	0.0301
A6	0.049	0.055	0.113	0.0605
A7	0.256	0.114	0.060	0.1530
A8	0.063	0.139	0.157	0.1175
A9	0.165	0.066	0.076	0.0995
A10	0.059	0.282	0.143	0.1942

4.3. Proposed Mathematical Programming Approach

In our model, we aim to find the optimal number of charging stations by maximizing drivers' utility. We consider various factors and constraints:

<u>Indexes:</u>
i: Index of charging stations, {i = 1,2,..,10}

<u>Parameters:</u>
C_i: cost of charging station to build in location i (cost includes EVSE unit cost, installation cost, operation and maintenance costs),
W_i: weight factor for location i,
B: available budget to build charging station,
K_i: the capacity of the station at site i,

<u>Decision Variales:</u>
X_i: number of charging station to be located

<u>Mathematical Model:</u>

Maximize $$\sum_{i=1}^{10} W_i X_i \quad (5)$$

Objective function (5) aims to maximize the user utility by considering weights (w_j) of each alternative point. The weight of each alternative is obtained by the evaluation of users.

Subject to $$\sum_{i=1}^{10} C_i X_i \leq B \quad (6)$$

The budget constraint set (6) provides the number of charging station to install. We can buy a certain number of charging station under a budget limit. For this reason, a budget is allocated to determine how many station to install. We consider costs as EVSE unit cost, installation cost, operation and maintenance costs.

$$\sum_{i=1}^{10} X_i \leq K_i, \forall i \quad (7)$$

The constraint set (7) ensures that each alternative location has a certain capacity to install EVCS.

$$X_i \geq 0 \;\; , \forall i \quad (8)$$

Constraint (8) ensures that the number of charging station to locate is equal or greater than 0.

4.3.1. Data Set:

We obtained weights for each shopping mall by AHP calculations (Table 6. Overall composite weight of the alternatives). We considered electric vehicle supply equipment EVSE unit cost, installation cost, operation and maintenance costs for each shopping mall. We took average EVSE unit cost for Level II is as $3,209. Operation and maintenance cost and installation cost which includes trenching, supplying electrical service to charging station, charter price to locate EVCS, differ for each shopping mall. We asked each utility for these data and we considered related Projects feasibility reports. According to this study we get the cost results as shown in Table 7.

Table 7. Data Set

I	Weight	Cost ($)	Capacity
A1	0.0998	7,450	4
A2	0.0690	6,985	3
A3	0.0270	6,970	2
A4	0.1491	8,450	5
A5	0.0301	7,180	2
A6	0.0605	7,150	4
A7	0.1530	8,120	4
A8	0.1175	8,050	5
A9	0.0995	8,550	5
A10	0.1942	7,450	4

The model was solved in LINGO 17.0 Solver optimization tool. According to LINGO results we obtained optimal number of charging stations as illustrated in Table 8.

Table 8. Number of Charging Station to be located to each shopping mall

I	Number of charging stations to be located (X_i)
A1	4
A2	1
A3	0
A4	5
A5	0
A6	0
A7	4
A8	5
A9	4
A10	4

5 Conclusion

In this paper, we address the problem of where to locate charging stations in districts of Istanbul. The problem of where to locate electric vehicle charging station can be grouped as a decision making problems because of including many criteria and alternatives that have to be considered simultaneously. Therefore, we identified 10 alternative locations in Kadikoy and Ataşehir, two districts of Istanbul. We formed three main criteria from the literature review to compare these alternative locations with each other. AHP methodology is used to obtain composite weight of each alternative locations and to rank these alternative locations. Then we used these weights as an input for mathematical model to obtain optimal number of charging station to locate for each alternative locations. Because the installation of EVCS is costly and we have a limited budget to buy EVCS, considering the weights that we obtained from AHP methodology is significant. That is why AHP methodology was integrated with mathematical model.

In the literature, there are studies based on MCDM methods and optimization models upon locating EVCS, however; on the basis of Turkey, neither MCDM based method nor mathematical model have been used together in a study which is about EVCS location. However, because EVs are new technology in Turkey and the number of EV drivers are few, the range of criteria we defined is few and so evaluation of them can be difficult. This problem will be solved as the number of vehicles increases over years.

For further studies, proposed methodology may be extended and applied to all districts of Istanbul by adding more constraints and crtiteria. Other integrated methodologies may be developed and applied for EVCS location problem.

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