IOWA STATE UNIVERSITY
Department of Civil, Construction and Environment Engineering

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Optimal Electric Vehicle Charger Placement Problem: A Time-of-Day Parking Activity-Based Approach

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Abstract

Replacing conventional vehicle by battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) has the potential to reduce petroleum use and greenhouse gas emissions. Installing charging stations is considered an effective measure to extend the driving range and encourage the adoption of electric vehicles. This study optimizes public charging station placement to minimize the installation cost and unmet charging demand. A mixed integer programming is used to solve the proposed problem. The spatial and temporal distributed charging demands are derived from parking activities of GPS-tracked vehicles in Seattle Metropolitan area.

Motivation

- ❖ Promote Plug-in Electric Vehicle technologies.
- ❖ BEV and range anxiety.
- ❖ PHEV and all-electric miles
- ❖ Charging infrastructure planning

Assumptions

- ❖ We assume 10% of the vehicle population is replaced by PEVs.
- ❖ Candidate public charging station locations (home charger placement is not considered).
- ❖ Charge when dwelling time is over 30 minutes.
- ❖ All chargers stalled at candidate node are level 2 chargers.

Methodology

- ❖ Use R to process the GPS-tracked travel survey data, based on the above-mentioned assumptions.
- ❖ Formulate the MIP problem.
- ❖ Solve the problem using CPLEX.
- ❖ Check sensitivity of some parameter.

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Formulation

Minimize total cost (Installation and Operation)

$$\min J(x) = C\sum_{i=1}^{N} y_i + V\sum_{i=1}^{N} x_i + w\sum_{i=1}^{N}\sum_{t=1}^{T} r_{it}$$

Subject to:

Binary Variable	$y_i = 0,1$;	(1)
Unserved demand	$d_{it} - x_i \le r_{it}$;	(2)
Big M	$x_i \le y_i M$;	(3)
Unmet	$r_{it} \ge 0$;	(4);

- n is number of node;
- C is Fixed cost;
- V is unit cost; w is weighting factor of unmet demand,
- M is big M (1,000,000);
- d_{it} number of vehicles parked at node *i* during time *t*;
- x_i number of chargers installed at node *i*;
- r_{it} unmet demand;
- y_i install a charging station at node i (y_i = 1, if x_i >0).

Numerical Example

Solve the problem using a 4-node network.

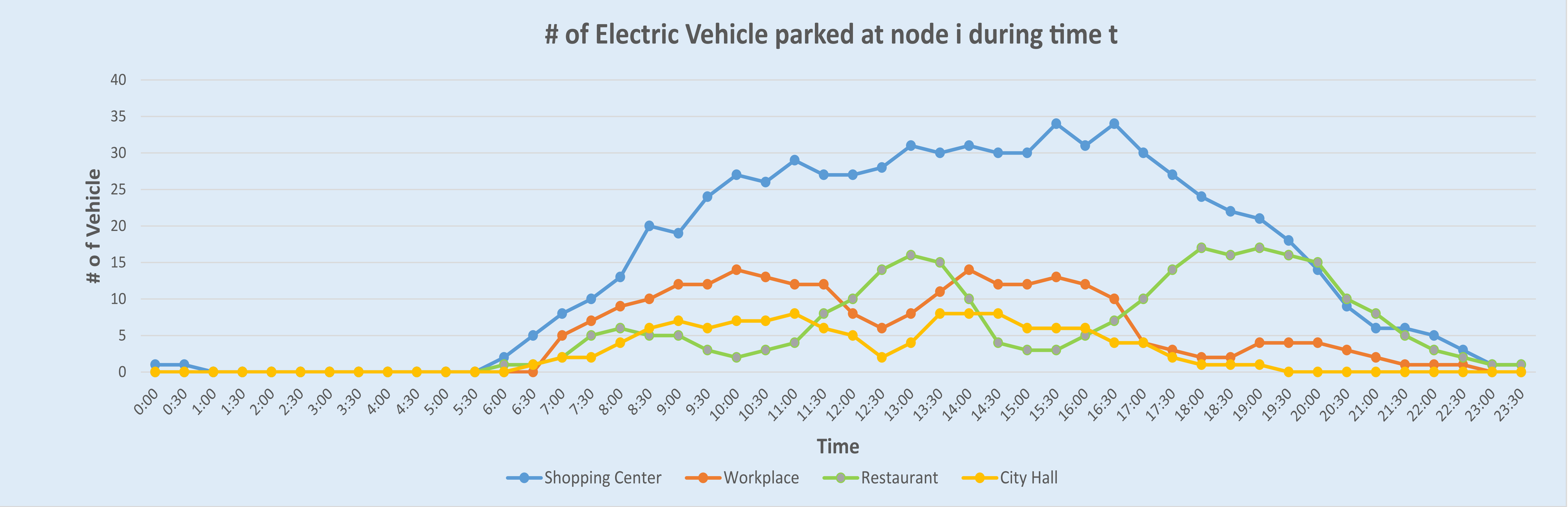


Figure 1. Input data for Numerical Example

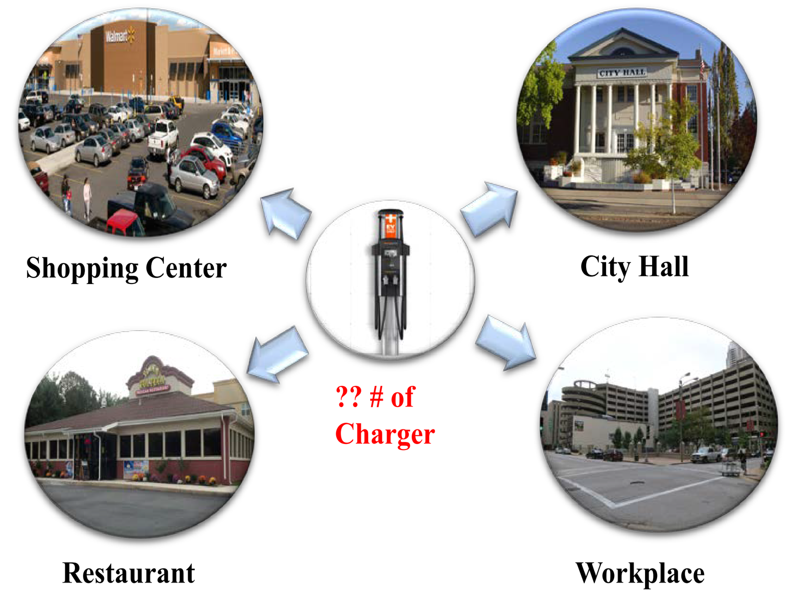


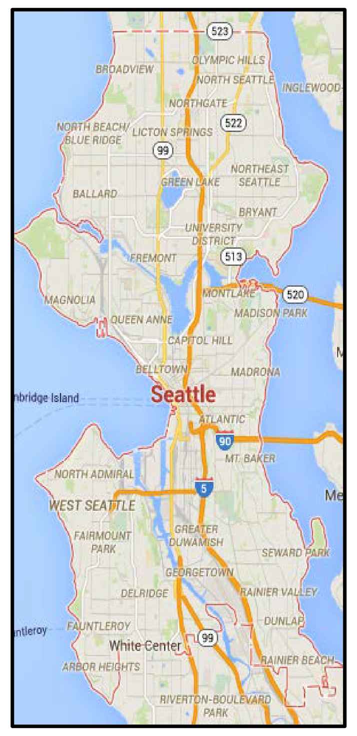
Figure 2. Numerical Example-weight (weight factor, w, 100)

```
int n=...; // number of node
int m=...; // period of time

range node=1..n;
range period=0..m;
```

Results of Numerical Example:
Shopping Center: 29;
Workplace: 12;
Restaurant: 10;
City hall: 6.

Application-Seattle Metropolitan Area

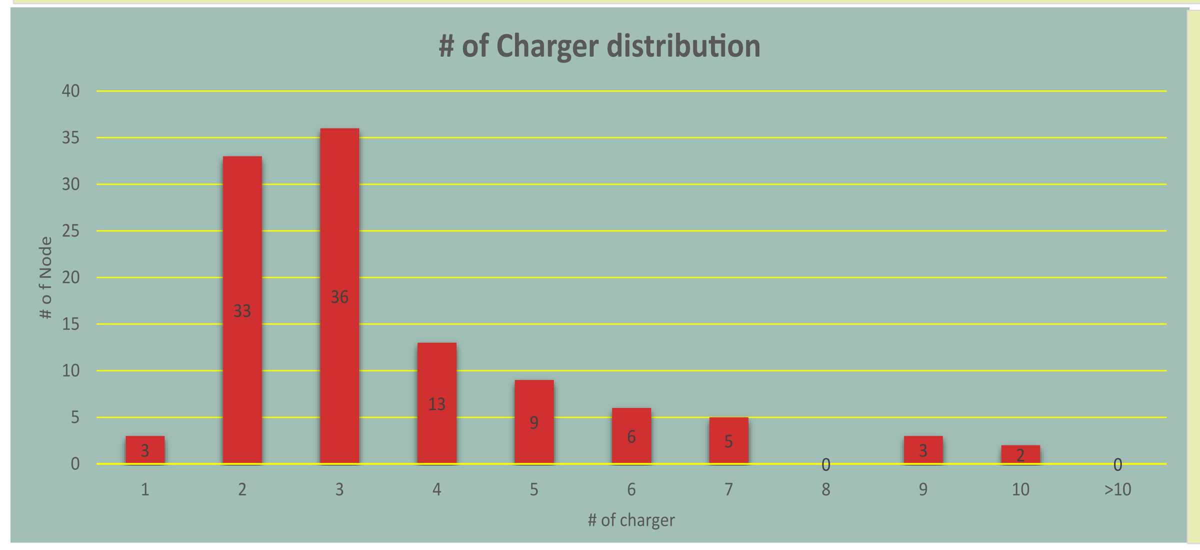


Node	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00	8:30	9:00
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4. Seattle data analysis by using R. (Data Source: GPS tracked travel survey, from Traffic Choices Study (PSRC, 2008))

Figure 3. Seattle on Google map

Result of Seattle Metropolitan Area charger distribution is following:



Number of charging stations: 110 (out of 3261 nodes)
Total Number of charger: 392

Figure 5. Number of chargers per charging station

Sensitivity Analysis- Weighting Factor, w

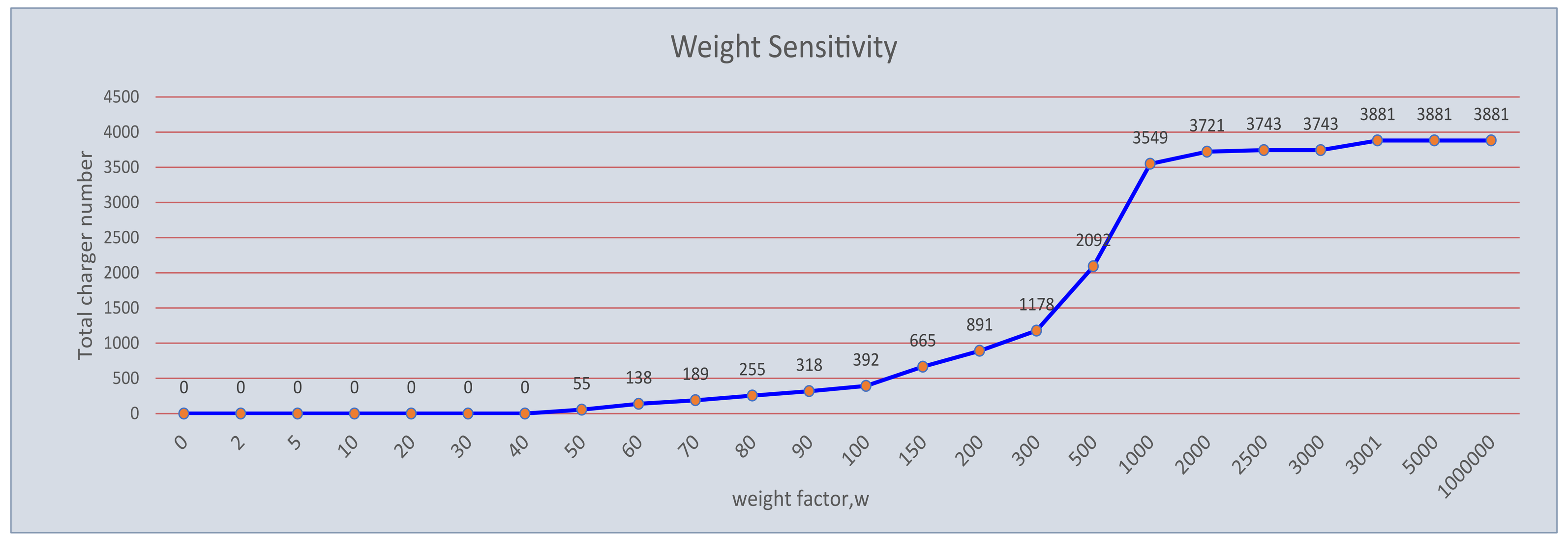


Figure 6. Weight factor, w, Sensitivity

Conclusions

- ❖ This study optimizes charger placement to minimize the total installation cost, and the unmet charging demand using a MIP.
- ❖ The solution is found to be sensitive to the weighting factor that combines the two objectives.

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