MAS 632 Management Science

Electricity Vehicle Charging Station Layout Optimal

Bingqing Wang, Jiaqi Wang, Lei Chen

Business Analytics, Miami Herbert Business School

MIAMI HERBERT BUSINESS SCHOOL

Introduction

Motivation

- An increasing number of people use electric vehicles as their travel tools because they are more environment-friendly and more affordable.
- Short endurance is a common problem for electric vehicles. The solution is to increase the number of charging stations. How to reasonably allocate them based on cost and utilization rate has become a hot topic.

Importance

- The current charging station layout in Coral Gables is not optimally arranged. They are concentrated in a few locations, which may result in wasted resources and incomplete coverage.

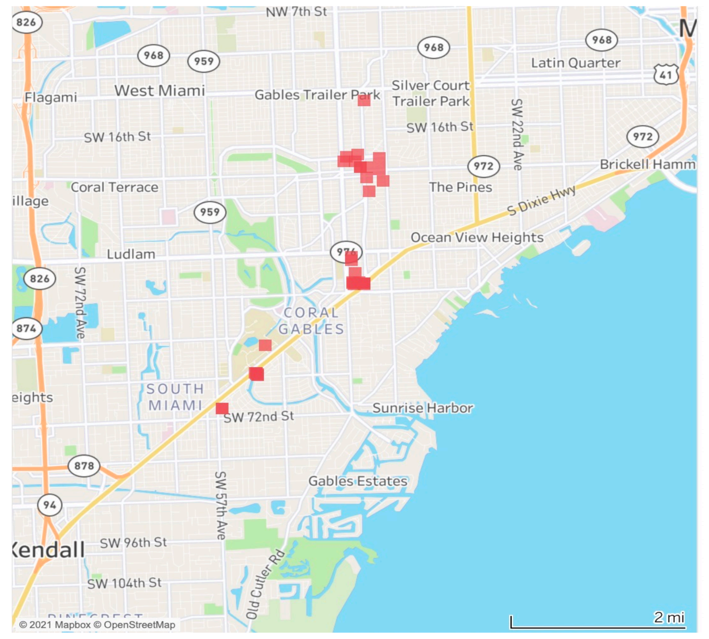


Figure 1. Coral Gables Charging Stations layout

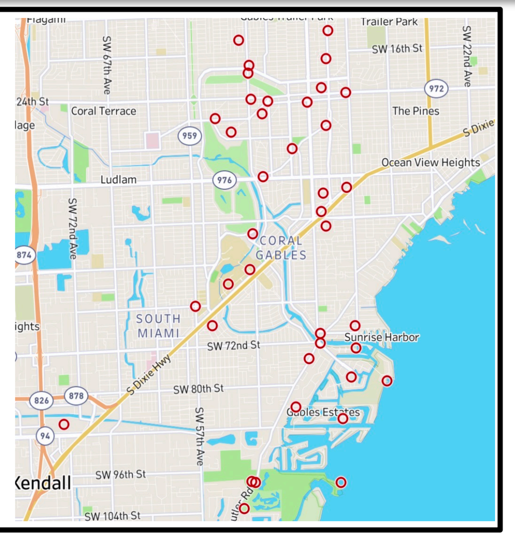
Objective

Enhance the efficiency of the charging stations in Coral Gables

- Minimize the number of charging stations to cover all the area
- Minimize the cost of the optimized charging stations combination
- Maximize the number of points covered by a limited number of charging stations

Methodology

- Use Coral Gables as the research object
- Collect 40 places with dense crowds on Google Map
- Obtain the distance between each point



Take the minimum number of charging stations and the minimum cost as the objective function

Use linear programming and greedy algorithm to obtain the multiple sets of charging stations combination

Introduce cost factor to quantitatively evaluate the cost of the layout combination and select the best combination

- This article also studied how to cover the most areas with the least cost with a limited number of charging stations.

Model

Step 1

Identify the potential station location Combination

Decision variables:

$$x_i = \begin{cases} 1, \text{the charing station } i \text{ is selected} \\ 0, \quad \text{otherwise} \end{cases}$$

Auxiliary Variables :

$$y_{ij} = \begin{cases} 1, \text{distance between point } i \text{ and point } j \ \le R \\ 0, \quad \text{otherwise} \end{cases}$$

Objective:

$$\min \sum_{i=1}^{40} x_i$$

Constraints:

$\sum_{i=1}^{40} x_i y_{ij} \ge 1$ *(Every point needs to be covered)*

$x_i\ y_{ij}$ *binary for* $i = 1,2,3 \ldots 40; j = 1,2,3 \ldots 40$

Step 2

Add cost factor and pick out the best Combination

Decision variables:

$$C_i = \frac{\sum_{i=1}^{40} \lambda_i E_{ik}}{N_i}$$

Objectives:

$$\min \sum_{i=1}^{n} C_i$$

n is number of combinations from step 1

1) N_i *is the number of points that station i can cover*
2) E_{ik} *is the cost k of station i,* λ_{ik} *is the weight of cost j (We will simulate* E_{ik} *and* λ_{ik} *as normally distributed matrix)*

Step 3

Identify the best combination with a limited number of charging stations

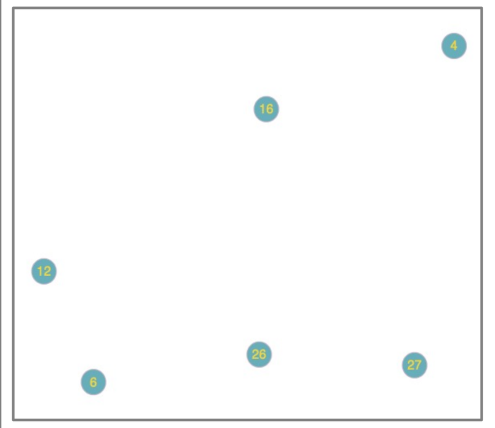
Result

Step 1

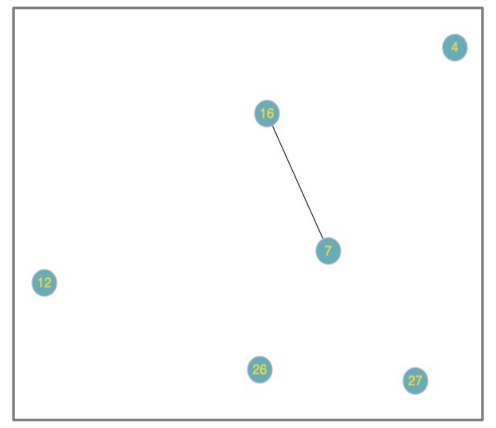
R (the distance an EV can travel after a low battery warning / the radius a charging station can cover) = 2

Binary algorithm

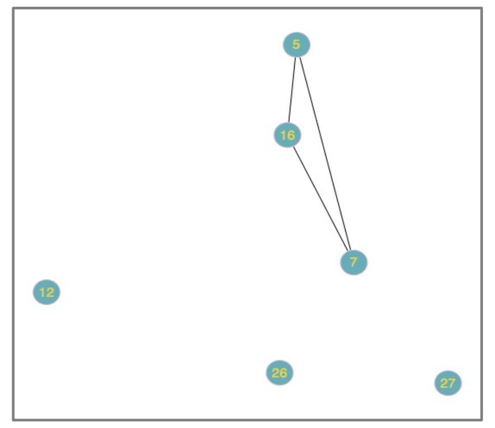
4-6-12-16-26-27



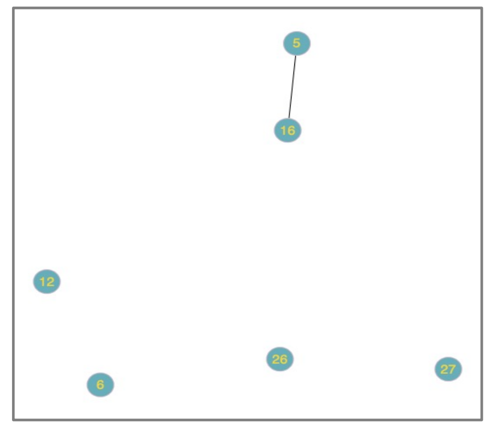
4-7-12-16-26-27



5-7-12-16-26-27

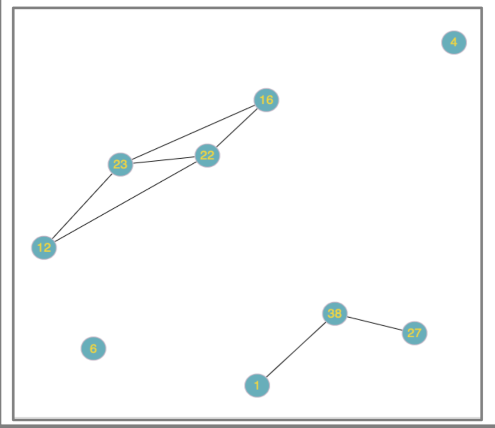


5-6-12-16-26-27

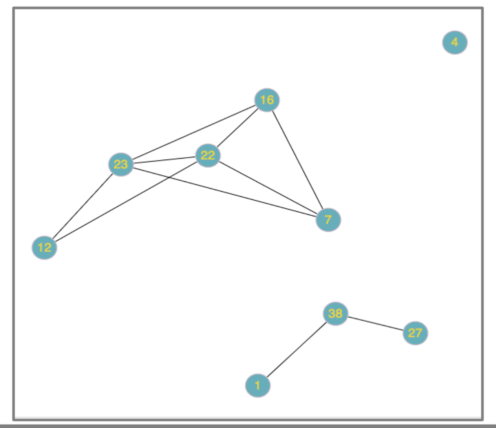


Greedy algorithm

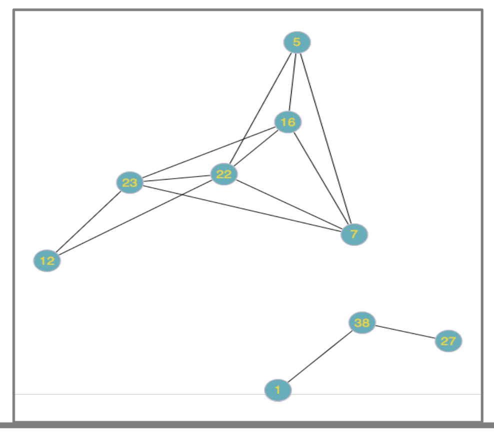
4-6-1-12-16-22-23-27-38



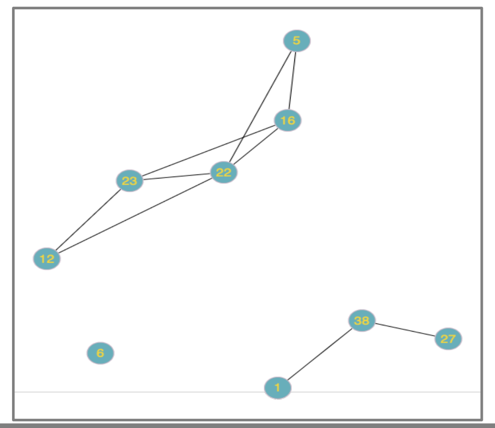
4-7-1-12-16-22-23-27-38



5-7-1-12-16-22-23-27-38



5-6-1-12-16-22-23-27-38



Result

Step 2

Cost factor

Land price : 0.33 ; Management fee : 0.36 ; Electricity cost : 0.31

Binary algorithm	**Greedy algorithm**
Combination 1: 105.5585	**Combination 1: 103.9082**
Combination 2: 71.2637	**Combination 2: 69.6134**
Combination 3: 71.4614	**Combination 3: 69.8110**
Combination 4: 37.1665	**Combination 4: 35.5163**

Based on the results, we use Combination 4 (5-12-16-26-27) from Binary algorithm as our best combination.

Step 3

what is the maximum number of locations we can cover with a certain number of charging points limited?

- Limit the number of charging points to 4
- 2-16-25-29
- 38 points at most can be covered

Conclusion

- This paper addresses the problem of low utilization and high cost of charging stations and proposes a cost control aggregate coverage model based on comprehensive coverage of the area and the lowest cost of combinations.
- According to the Binary algorithm and greedy algorithm, we finally get the combination that can cover all charging points (5-6-12-16-26-27), and the combination is also the most cost-effective one.
- With the limitation of only 4 charging stations is available, we can cover 38 points at most, the combination is 2-16-25-29.
- The result of Binary algorithm and Greedy algorithm differs because of different solving ideas. In this problem, Binary algorithm performs better.
- We hope to provide a contribution to the goal of energy-saving and carbon reduction by the optimization of the charging station layout.

Reference

https://www.cbsnews.com/news/why-is-it-so-hard-to-find-chargers-for-electric-cars-utility-regulations-are-partly-to-blame/