15th AIMMS-MOPTA Optimization Modeling Competition

Planning Electric Vehicle Charging Stations

Introduction

Electric vehicles (EVs) are becoming increasingly popular due to their environmental and economic benefits. They offer a viable alternative to petrol and diesel vehicles, and generate fewer total greenhouse gas emissions than fossil fuel vehicles. They are becoming more affordable, efficient, and powerful, with advances in battery technology and improved charging infrastructure. EVs can now travel longer distances, faster, and with greater efficiency than ever before. The Biden administration has recently introduced an electric vehicle incentive that provides consumers with a tax credit when they purchase or lease a new electric vehicle. This incentive is part of the administration's plan to reduce emissions and combat climate change. It is anticipated that this incentive will encourage more people to switch to electric vehicles, helping to reduce emissions and save money on fuel costs.

While most electric vehicle charging occurs at home, there is an increasing trend of commercial electric vehicle charging stations being built across the country. These charging stations provide a safe and convenient way for electric vehicle owners to charge their vehicles. They are typically located near public places such as shopping malls, hotels, and other popular locations. The construction of these charging stations can help electric vehicle owners maximize their vehicle's capabilities and decrease range anxiety for potential buyers. Hence, it can make electric vehicles more accessible and encourage more people to make the switch to electric vehicles.

Problem Description

This competition considers planning electric vehicle charging stations in Pennsylvania (PA). The goal is to identify optimal locations for constructing charging stations as well as the number of chargers at each station to minimize the total cost. The cost consists of three parts as follows.

- Construction and maintenance cost of the station. Assume the annualized construction investment of a charger is \$5,000, and the maintenance fee of each charger is \$500. Each station has at least 1 charger and at most 8 chargers.
- Cost of driving to the charging station. The cost of driving is \$0.041 per mile.
- Cost of charging. Each EV will charge to its full range at the station. Assume that the full range is 250 miles. The cost of charging is \$0.0388 per mile.

The charging demand in PA is modelled as follows.

- The geometry of PA is simplified as a rectangle (290 miles $\times$ 150 miles) and the left lower corner is the origin. The locations of EVs that may need to go to charging stations are provided in `MOPTA2023_car_locations.csv`. In this file, 1,079 locations are provided, and each location represents 10 EVs, i.e., we consider 10,790 EVs in total.
- The range of an EV (in miles) is described by a truncated normal distribution generated by truncating a normal distribution $N(100, 50^2)$ with lower bound 20 and upper bound 250 (then normalizing the probability distribution function). An illustrative MATLAB code of generating samples from this truncated normal distribution is `MOPTA2023_car_range_dist.m`.
- The probability that an EV wants to go a charging station is $\exp(-\lambda^2(x-20)^2)$, where x is the range of the EV and $\lambda = 0.012$. Assume all EVs are independent when they decide whether to go to a charging station.
- Each charging station may have a queue with size up to the total number of chargers when all chargers are occupied. For example, a station with 3 chargers may have a waiting line with at most 3 EVs.

Case Study

Your team is expected to consider the following two scenarios.

1. A plan of constructing 600 charging stations to minimize the total cost. Please specify the location of each station and the number of chargers at each station.
2. Decide the optimal number of charging stations as well as the number of chargers at each station to minimize the total cost. Specify the location of each station.

Use appropriate optimization as well as statistics terminology to present your results. For example, for the minimum total cost, you may report the mean value, confidence interval, quantile, etc. It is helpful to include sensitivity analysis in the study. For example, the effect of the cost of charger maintenance, charging cost, number of stations, maximum number of chargers at each station, etc. For a more comprehensive study, you may also investigate the probability of rare events. For example, the probability of a rare case that the planned stations are not sufficient to satisfy the charging demand.

Deliverables

Your team is expected to deliver a complete solution to the case study problems. Specifically, your submission should include:

- The development of an optimization model and corresponding solution approach that, in a reasonable time, finds the optimal or near-optimal solution for the given case study.
- A user interface for your model(s) that can be used to run different scenarios in order to visualize results and make scheduling decisions.
- A report (max. 15 pages) describing the application and modeling approach, the solution techniques used, the results and insights obtained, and your team's final recommendations. **In order to judge your numerical results, it is key that all mathematical programming, and algorithms you used are clearly presented in the report.** The 15 pages limit includes references.

You are allowed and strongly encouraged to use related literature. Please cite properly all information sources and references used and carefully distinguish your ideas from ideas found in the literature.

Strongly encouraged: mathematical curiosity, passion for learning, and enthusiasm for applying optimization techniques.

Deadline and Questions

The **deadline** for submission is **May 31, 2023, 23:59 EDT**. If you have any question about the problem or the competition, please contact **MOPTA Competition Chairs Dr. Xiu Yang** (xiy518[AT]lehigh.edu) and **Dr. Tommaso Giovannelli** (tog220[AT]lehigh.edu). Please start the subject line of your email with [MOPTA Competition 2023] (otherwise your email may be overlooked) and send it to both Dr. Yang and Dr. Giovannelli.

Software & Data

You are free to use any software of your choice, but it is recommended to use AIMMS for your submission. **All source code and data must be included, properly documented, and results must be reproducible.**

About AIMMS: AIMMS is an industry leading rapid model building and deployment platform perfected for over 30 years. AIMMS is an enjoyable and robust way to not only build optimization models but to deploy them as optimization applications to be used by business professionals. You can develop analytical models and highly interactive end user interfaces all within the same environment. Learn more and request the free academic license from here: AIMMS Academic License.