13th AIMMS-MOPTA Optimization Modeling Competition

Home Service Assignment, Routing, and Scheduling with Stochastic Service Time, Travel time, and Cancellation

Introduction

Home services are the provision of providing services to people at their homes, e.g., home health care, home beauty care, banking service, appliance repair service, and more. The home service industry, especially home healthcare, has been rapidly growing worldwide due to emergent changes in family structures, work obligations, aging populations, and outspread of chronic and infectious diseases. In 2018, the global home service market was valued at $\sim$ \$282 Billion and is expected to grow by 18.91% annually from 2019-2026, reaching \$1,133.4 Billion by 2026 (Verified Market Research, 2019 [1]). Accordingly, the development of computationally efficient and implementable tools is essential to support decision-making in all areas of the home service industry.

Home services require professional service teams (or one operator) to travel for delivering the services to geographically distributed customers. Service providers often quote an appointment time (planned service start time) to each customer in advance to avoid delivery failure. Therefore, when home service providers plan for service, they need to decide: how many service teams to hire (i.e., sizing problem), how to assign service teams to the customers (i.e., an assignment problem), how to route service teams (i.e., a vehicle routing problem), and how to assign appointment times for the customers (i.e., appointment scheduling problem). This competition aims to address these specific critical operational decision problems in home service. Stochasticity is an intrinsic property of the *home service assignment, routing, and appointment scheduling* (H-SARA) problem. Here, we will focus on solving H-SARA under three key random factors: service duration, travel time, and customer cancellation. Your team's goal is to develop an efficient and implementable method to solve H-SARA, which will be used by home service providers.

Problem Description

In this competition, we consider a set of N geographically distributed customers on a connected graph who need to be served within a given day. Nodes $1,\ldots,N$ represent customers' locations, and node 0 represents the origin (e.g., service provider's office). Traveling time, $t_{i,i'}$, between each pair of nodes i and i' is random. Service time at each customer $i \in [N]$ is also random. On the day of service, customers may cancel their requested home service or appointment. The probability distribution of service durations, travel times, and the probability of cancellation are known.

Suppose that there are M homogeneous service teams (i.e., teams have the same skills and capabilities), and the fixed cost of assigning/hiring a service team $m \in [M]$ is f_m. Here, M is a sufficiently large number (since home service providers often have the option of hiring third-party services). Each assigned service team should start from the origin and ends at the origin (i.e., node 0) and visit customer nodes assigned to it exactly once before returning to the origin (your team is encouraged to consider returning to the origin, but we will accept and judge submissions that do not consider returning to the origin). Each service team has standard service hours [0, L] and cannot start service before the scheduled start time. Due to random service and travel times, and customers last minutes cancellations, one or multiple of the following scenarios may happen: (1) service team arrives at the customer before the scheduled service start time, and thus they remain idle until the scheduled start time, (2) service team arrives after the scheduled start time of service of a customer, and thus the customer incurs waiting, and (3) service team need additional time to finish serving all scheduled customers beyond L, and thus incur overtime.

Your team should develop an integrated and efficient optimization application for (1) determining the number of service teams to hire, (2) assigning the hired service teams to customers, (3) constructing routes for the service teams, and (4) determining the customers' appointment times. These decisions' quality is a function of fixed cost (i.e., assignment/hiring cost), customers waiting time, service team idle time and overtime costs, and traveling cost.

Case Study

Your team should solve H-SARA problem instances with $N = 20, 30, 40$ and 50 customers (again, all customers must be served and each exactly once by one service team). Assume that the origin node is at (0, 0) and the customers are distributed uniformly in a square of edge 50kilometers (km) with the origin at the center. For each instance, you should first generate N nodes (a_i, b_i) in this region then compute the distance $d_{i,i'} = \sqrt{(a_i - a_{i'})^2 + (b_i - b_{i'})^2}$ km between every pair (i, i') of customer nodes. The mean value of travel time equals to $\mu_{i,i'} = d_{i,i'}/v_{i,i'}$, where $v_{i,i'}$ represents the mean travel velocity between nodes i and j, and its value is equal to 1km/minute in all instance. Your team should generate the mean customer's service time μ from $U[30, 60]$ minutes, where $U[c, d]$ denotes the uniform distribution on $[c, d]$, and set the standard deviation of service time to 0.5μ.

We recommend the following settings for cost parameters, but teams are encouraged to propose and use other reasonable settings supported by appropriate references or a logical argument. Teams can generate customers unit waiting costs from $U[0, 10]$ and the unit idle cost from the set $U[0, 5]$. Teams should consider a positive overtime cost, e.g., at least 50% higher than the regular idling cost (e.g., 1.5 idle time cost). The unit travel time cost $\lambda \in \{0.5, 1, 2\}$, and the cost of assigning one service team should be $\geq$100. Teams should solve problem instances (i.e., a combination of N and M) with a cancellation rate of 1%, 5%, and 10%. Teams are free to choose appropriate probability distributions for service duration, travel time, and service cancellation.

Deliverables

Your team has to deliver a complete solution to H–SARA problem and the case study. Specifically, your submission should include:

- Develop an optimization model or algorithm that, in a reasonable time, finds the optimal or near-optimal solution to H–SARA for the given case study.
- A user interface for your model(s) that can be used to run different scenarios by a business unit. For visualization purposes, you can use Lehigh University's coordinates (40.36, -75.38) as the origin node.
- A report (max. 15 pages) describing the application and modeling approach backgrounds, 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.

Deadline and Questions

The **deadline** for submission is **May 21, 2021, 23:59 EDT**. If you have any question about the problem or the competition, please contact **MOPTA Competition Chair Dr. Karmel S. Shehadeh** at kshehadeh[AT]lehigh.edu; kas720[AT]lehigh.edu. Please start the subject line of your email with [MOPTA Competition 2021] (otherwise your email may be overlooked).

Software

You are free to use any software of your choice, but it is recommended to use AIMMS for your submission. All source code 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.

References

[1] Verified Market Research. Global home services market by deployment, by geographic scope and forecast to 2026., Published Date: April 2019.