Assignment I: The Multi-Depot Homogeneous-Fleet Vehicle Routing Problem

Assigned on Thursday, March 31, 2022
Due electronically via course site (Canvas) on Tuesday, April 12, 2022, 23:59 pm EST

Assignment is to be completed individually, no group-work.

Required Reading

For this assignment, please first read the following paper, which you can find on the course site:

> Salhi, S., Imran, A., & Wassan, N. A. (2014). The multi-depot vehicle routing problem with heterogeneous vehicle fleet: Formulation and a variable neighborhood search implementation. Computers & Operations Research, 52, 315-325. https://doi.org/10.1016/j.cor.2013.05.011

In particular, for this assignment, focus on Section 2 of the paper.

Please note:

- In Equation (23) on page 318 of the paper, there is a mistake in the notation. The domains of the indices should be $i, j = 1, \dots, n$ instead of be $i \neq j = 1, \dots, n$.
- There is a constraint missing in the sets of constraints (22) through (28) that is required for properly enforcing a route length constraint:

$$T_{ijd} \leq TD \sum_{k=1}^{K} X_{ijkd}, \quad i, j = 1, \dots, n+m; d = n+1, \dots, n+m$$

Introduction

You are analyzing the last mile delivery operations of a CPC company who serves the daily demand of its commercial customers in Manhattan out of two local depots using conventional combustion engine delivery vehicles (e.g., vans).

The company is looking to find the optimal setup of its delivery operations under current conditions as well as in consideration of alternative vehicle technologies and urban freight regulations that are on the horizon.

The following assignment consist of four parts, some of which have sub-sections.

Data

On the course site you will find the following three datasets:

- "**SCM293_assignment01_30customers_NYC.csv**":
  A demand data set containing all relevant information for 30 customers in Manhattan:
  - Customer ID
  - Customer location
  - Customer order size in units
  - Customer service time in hours

- "**SCM293_assignment01_2depots_NYC.csv**":
  The locations of two depots to be available as starting points of your routes.

- "**SCM293_assignment01_vehicles.csv**"
  A dataset containing all relevant base case parameters for the vehicle types you are going to include in your analyses:
  - Fixed cost per route
  - Distance cost per km
  - Hourly cost while on route
  - Speed in km/hour
  - Carrying capacity in units
  - Maximum travel range in km
  - Maximum duration of a route in hours (initialized as a very large number)
  - Maximum number of vehicles available (initialized as a very large number)

Moreover, you will find a basic code structure, similar to the ones discussed in class that should serve as a starting point for your implementation:

- "**SCM293 - Assignment I - MDHFVRP in NYC - starter.ipynb**"

Note: Please ensure that you implement and execute your code in a Jupyter notebook running on Python 3.6.

Deliverables

Please work on this assignment individually.

Please hand in before the submission deadline:

- An executable **iPython notebook** with your model implementation
- A quick **Word / PDF write-up** summarizing the answers to the following questions based on the results you obtained from your model

<u>Part 1a: Analysis of the Status Quo (25 Points)</u>

In its current operations, the company can operate routes out of one or both of its Manhattan depots. There is no limit to the number of routes, number of customers, or total demand to be served out of either of the two depots. The only constraining factor is the carrying capacity of the vehicles. Each vehicle can only be dispatched one per day. Each route incurs a fixed set-up cost as well as a variable cost per travel distance (mainly due to fuel consumption, maintenance, wear and tear) and a variable cost per duration of the route (mainly due to driver wage).

Please implement a mixed integer linear programming model using Gurobi in Python to minimize the total cost incurred by the current operations of the company, using <u>only conventional delivery vehicles</u>. That is, determine which customers should be served from which depot, and which customers should be served on a common route and in which sequence.

Furthermore, please determine the following key performance indicators of the current operations after your optimization:

- The total cost of operations
- The number of routes starting from each depot
- The length, duration, and cost of each route
- The average route length, duration, and cost per depot
- The capacity utilization of each vehicle
- The average vehicle capacity utilization per depot

<u>Note</u>: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 1% is reached

Part 1b: Working hour restrictions (15 Points)

The driver union negotiates with your company that from now on, all delivery routes may not last longer than 8 hours and that this limit needs to be strictly enforced in your operational planning.

Extend your model to account for this maximum route duration and repeat the analysis conducted in Part 1a. Does the maximum route duration have an impact on your optimized operations?

<u>Note</u>: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 4% is reached

Part 2: Fleet replacement with light electric freight vehicles (LEFVs) (20 Points)

In an effort to become more environmentally friendly, the company is exploring the use of light electric freight vehicles (LEFVs). In a first step you are asked to repeat the analysis from Part 1 for the case of LEFVs being the only available vehicle type, i.e., a complete replacement of the current fleet with LEFVs.

Keep in mind that LEFVs are constrained by their maximum travel distance, due to a limited battery capacity.

The maximum route duration introduced in Part 1b remains in place.

Would you recommend a complete fleet replacement with LEFVs?

Note: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 2.5% is reached

Part 3a: Optimal fleet composition (15 Points)

The management of the company wants to know if for some routes the conventional delivery vehicles might be more cost efficient while for other routes LEFVs are more economical.

Extend your model (if necessary) and rerun the previous analysis allowing for two types of vehicles to be employed: conventional delivery vehicles and LEFVs. What is the optimal fleet mix?

Specifically, please provide the following KPIs:

- The total cost of operations
- The number of routes per vehicle type starting from each depot
- The length, duration, and cost of each route
- The average route length, duration, and cost per depot per vehicle type
- The capacity utilization of each vehicle
- The average vehicle capacity utilization per depot per vehicle type

The maximum route duration introduced in Part 1b remains in place.

Briefly discuss your results.

Note: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 3.5% is reached

Part 3b: Supplier issues (10 Points)

The supplier of the LEFVs has difficulties keeping up with demand. In the short term, the company can only acquire a total of 4 LEFVs. How does this affect your operations, fleet mix and performance?

Extend your model to incorporate this new constraint and repeat your analysis from Part 3a.

The maximum route duration introduced in Part 1b remains in place.

Briefly discuss your results.

Note: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 4% is reached

Part 4: Time-based access restrictions for commercial vehicles (15 Points)

The city of New York announces its plans to restrict the access to Manhattan for conventional delivery vehicles during commute times. In the future, convention al vehicles will only be allowed to operate in Manhattan between 9 am and 4 pm. How does this affect your operations, fleet mix, and performance?

Extend your model to incorporate this additional constraint. Please rerun your analyses from Part 3a and Part 3b and interpret your results.

Note: To limit your runtime, please set the Gurobi numerical solver to terminate one an optimality gap of 2.5% is reached