Supply Chain Analytics (42380)
Project Assignment 2

Deadline Monday, April 22 at 23:59.

Hand-in format Detailed report in PDF addressing all questions thoroughly, plus the Excel and Julia (or other programming language) files used to obtain your solutions. The report should be self-contained and explanatory (including graphs, figures, tables, etc.) without the supplementary files and have a maximum length of 8 pages. The Excel and Julia files are used for checking, documenting, and reproducing the calculations.

Group format The assignment is to be completed in the same group of 3 students as in the first project assignment, and a single hand-in should be made per group. The assignment report has to be personalized, meaning that it should be clear which student(s) were responsible for each part of the assignment. Note that general statements like "all students contributed equally to the report" are *not* sufficient.

Questions Questions about the assignment can be asked during the lectures and exercise sessions. If it is not possible to ask questions during these sessions, you can also ask questions by mail through `rowho@dtu.dk`.

Introduction

Comma Computing is a distributor of computer hardware in Switzerland. Its main distribution center is located in Zürich, and it currently has a few smaller corporate service centers throughout the country. The distribution center provides parts to both private and corporate customers and is also responsible for restocking the service centers. The service centers provide in-house services to (local) corporate customers, meaning that technicians drive out to the customers to provide these services.

The network of service centers has grown organically at Comma Computing as the company itself grew. Moreover, transportation plans are currently made manually at Comma Computing. The company would now like to redesign these plans using more advanced methods to increase competitiveness within the Swiss market. They have asked you to help with this. You start by analyzing the general transportation structure in the supply chain of Comma Computing:

1. Describe the main differences between truckload and less-than-truckload transportation. How do these concepts likely relate to the distribution of goods to service centers from the (central) distribution center? And for the distribution of goods directly from the (central) distribution center to customers?

Facility Location for Service Centers

First, Comma Computing is interested in redesigning its network of service centers. To do so, the company has collected information about the customers it services throughout the country from these service centers, as well as the number of visits made to these customers on a yearly basis. Moreover, Comma Computing has made available a set of possible facility locations, including both the existing service centers and a number of potential new service centers. A closing cost is given for each existing facility, while an opening cost is given for each potential new facility (both in Swiss francs and discounted to a yearly basis). The data is provided to you in the `Customers` and `Facilities` sheets of the file `facilityData.xlsx`.

As the service provided to corporate customers is often relatively complex, technicians drive directly from the service center to the customer. Moreover, to make the calculations easier, Comma Computing tells you that you can assume that the distance from a service center to a customer is equal to the great circle distance between the locations (hint: see page 271 in the book on how to compute the great circle distance). In addition, Comma Computing uses a per kilometer transportation cost of 10 Swiss francs.

2. Solve the capacitated fixed-charge location problem using the data in the provided data file. Report the optimal objective value and make a visualization of the opened facilities.

3. Describe how the newly found set of facilities differs from the ones originally used by Comma Computing.

As the number of visits to customers per year can vary quite strongly, Comma Computing is also interested to see if better facility location plans can be found for the service centers when explicitly taking into account this uncertainty. To look into this problem, Comma Computing has made available a set of scenarios, which can be found in the `Scenarios` sheet in the `facilityData.xlsx` data file. Each scenario gives the demand of each customer under that scenario. Moreover, also the capacity of the different facilities deviates in the scenarios due to differences that can occur in the staffing level at the facilities. Assume that each scenario occurs with equal probability and that the transportation cost is the same as in the deterministic setting, i.e., is not dependent on the scenarios.

4. Give a mathematical formulation of the stochastic fixed-charge location problem described above. Clearly explain all parameters, variables, constraints, and the objective function.

5. Solve the formulated stochastic fixed-charge location problem using the provided set of scenarios. Report the found objective and visualize the opened facilities.

6. Describe how the chosen facilities differ from the ones you found for the deterministic facility location model, i.e., the facilities you found in question 2.

7. Based on your findings for both the deterministic and stochastic facility location model, give managerial advice to Comma Computing on how to improve their facility design for service centers. Make sure to motivate your advice clearly and to use appropriate wording that can be understood by general management.

Routing Technicians within Zürich

Next to its existing service to corporate customers, Comma Computing has also just started offering a new repair service to private customers in the city area of Zürich. In this repair service, a technician in a van goes out from the central distribution center to the customers and provides service at their home locations. As these repairs generally take considerably shorter than those at corporate customers, a single technician can service multiple customers within a single day without visiting the distribution center in between. Moreover, as only small IT parts are needed for the customers, the capacity of a van is not restrictive. However, a maximum working time of each technician should be respected, meaning that the total duration of the repairs should be no longer than 6 hours (exclusive of driving time). Comma Computing is interested in determining which routes the technicians should drive, given all repair visits that need to be executed on a given day and their corresponding duration.

8. Explain why the above-defined problem can be modeled as a (traditional) vehicle routing problem (VRP). Clearly explain how the repair time and maximum repair duration per technician are taken into account.

To determine the routes for technicians, Comma Computing is interested in determining the best solution method to use for solving their instances of the VRP. To evaluate this, they have made available an instance of this problem for a single historical day. The corresponding transportation cost matrix (in kilometers of distance) and expected duration of the repair per customer for this instance are given in the `distances` and `repairTimes` sheets of the file `vrpData.xlsx`. In this file, node 0 indicates the distribution center (depot). Moreover, consider a maximum of 10 available technicians, each of which has its own van available. You decide to try out both an exact formulation and heuristic as taught in class.

9. Use the load constraint formulation to solve the provided instance using an appropriate time limit. Report the found objective value, the optimality gap (if the time limit is reached) and the found routes.

10. Apply the location-based heuristic such that a maximum of 1 vehicle is used per cluster, i.e., $\gamma = 1$. Report the found objective value and found routes. Compare the routes to the ones you found in question 9.

11. Based on your results from the previous two questions, give managerial advice on which of these two methods seems most suitable for Comma Computing.

After running the new service to customers for some time, Comma Computing notices that customers would prefer to have a time window directly when booking a service visit. However, making this possible would also require changing the allocation of customers to routes, as these time windows now have to be considered in the VRP. Comma Computing ask you for help in implementing this and provide a set of time windows for the previously considered instance in the `times` sheet of the `vrpData.xlsx` file. Moreover, you can assume that traveling one kilometer costs 2.5 minutes. As you believe that solving an exact formulation will be too time-consuming to provide good solutions for this vehicle routing problem with time windows, you decide to use the Clarke-Wright savings heuristic as a starting point.

12. Describe how you would adjust the Clarke-Wright savings heuristic to provide solutions that respect the customer time windows.

13. Implement the algorithm that you described in question 12 for the data provided in `vrpData.xlsx`. Report the found objective value and describe how the found routes differ compared to the ones you found in the previous questions, where you did not consider the time windows. [1]

Hints

Here are some small (programming) hints that might help you in completing this project assignment:

- To read data from the provided data files in Julia, you can make use of the `XLSX` Julia package, see `https://docs.juliahub.com/XLSX/gPxqz/0.10.1/`.
- To set a time limit for a solver in JuMP, you can use the code

  ```
  set_time_limit_sec(model, x)
  ```

  where `x` is the time limit in seconds that you want to set.
- For calculating the great circle distance, you might want to use the `surface_distance` function in the Geodesics package in Julia. See `https://juliapackages.com/p/geodesics` for further details.

[1] Note: if you believe that using your adjusted algorithm for the full instance is too time-consuming, you can solve the instance considering just the first 15 customers. In that case, consider a maximum working time of 4 hours per technician. Moreover, make sure to recompute the solution you obtained in the previous questions for this smaller instance when comparing the found routes.