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Risk and Logistics

Homework Assignment 1

February 3, 2023

Instructions

1. For this assignment, you will have to write a report and produce some Xpress code.
2. You should attempt all questions.
3. The total marks for this assignment are: 15.
4. Explain in your report what you have been doing in a concise and reproducible way. Write full sentences, not just the final results. The style in which you present your answers is part of the marking.
5. Structure your code, include comments, and avoid unnecessary loops, conditions, and calculations. The style in which you write your code is also part of the marking.
6. You don't have to do everything by the book. **Use your imagination!**

   If you have an idea for a new method or one that helps you to improve the efficiency or effectiveness (or both!) of an existing method, without deteriorating the other too much, then please go ahead. The questions are kept deliberately vague to allow you that freedom (it would be boring – both for you and me – if I'd tell you exactly what to do and what not).

   I am happy with any method that is reasonable and does the job, but I expect you to properly explain and motivate why you think this is a good idea - and, ideally, back it up with some empirical results. Marks will be awarded for clever ideas (to some degree, independent of whether they work or not), and the overall efficiency, i.e. runtime, and effectiveness, i.e. solution quality, of your heuristics.
7. The strict deadline for handing-in your assignment is **16:00 on Thursday, 16 February 2023**.

   Please upload a PDF of your report and your Xpress code and data files on Learn. Please compress all Mosel and data files into a single zip file and upload just the zip file.

Preliminaries

I have uploaded on Learn

- *CaseStudyData.txt*: a file containing the data of the case study in Xpress format,
- *CaseStudyDataAggregated.txt*: a file containing the data of the case study in Xpress format where postal districts have been aggregated into a total of 100 cluster, and
- *CaseStudy.mos*: a Mosel template that already includes all variable declarations and routines for reading data which you can use as a starting point.

Setting the Scene

In this assignment you are asked to develop a heuristic to help *Tartan Trade* set up their supply chain. In the following, I call the postcode districts the "customers". While *Tartan Trade* is aiming at winning over 5% of all people living in Scotland as customers, it is highly unlikely that they will reach this target within the first year, or even within the first five years. Instead, they anticipate that their customer base will be fairly small in the first year, but then – hopefully – keep on growing over about 8-10 years, reaching the 5% target at the end of Year 10, at the latest. All data given and all decisions taken in the basic Warehouse Location Problem refer to one generic time period, e.g. 10 years. Hence, constructing all warehouses at the start will result in many warehouses being (heavily) underutilized in the first few years and others being, possibly, overutilized in later years. Instead, it would be more appropriate to build up the supply chain step-by-step over the years as customer demand increases. That is, we would not only decide where to build warehouses, but also when to build them. The goal of this exercise to solve the 3-echelon model for the WLP allowing for a gradual build-up of the supply chain over time. The three echelons are the suppliers, warehouses, and customers.

To start with, we divide the planning horizon into 10 periods, one for each year. The customer demands in the files are given per product group and per year. For simplicity, we assume that the transportation costs remain the same over the next ten years. The cost for building a warehouse at a location is given as usual and independent of time. However, having more than one time period, the building cost now only accounts for the cost of actually constructing the warehouse. The cost of running a warehouse at each location is given as operating costs (the cost is independent of the amount of goods handled by the warehouse). Once a warehouse has been built, it remains in operation until the end of the planning horizon and, accordingly, we have to pay the operating costs until the end. Each warehouse can serve a different set of customer in each time period and each customer can be served by a different warehouse in each period.

For simplicity, we assume that a warehouse can be constructed instantaneously, i.e. if we decide to build a warehouse in period t, then the warehouse is ready to serve demands already in period t. While this is obviously unrealistic, it is straight-forward to adapt the model to starting construction one or more periods earlier, and this adaptation doesn't change the nature of the formulation, it only messes up the indexing of the variables. Moreover, we assume that **both warehouses and suppliers are uncapacitated**, i.e. each supplier can send an unlimited amount of goods of their respective product group to the warehouses.

The task is now to determine where to build warehouses and in which time period, which warehouse is to supply which customer in each period and which supplier is to provide goods for which warehouse such that all customer demand is served at minimal cost (= setup plus operating plus transportation cost).

Further Information

- The demand in the data files (`CustomerDemand`) is given for each district, product group, and year and is specified in kilograms per year.

- All customer locations are potential locations for building warehouses.

- The setup and operating costs for the warehouses in the data file (`SetupWarehouses` and `OperatingWarehouses`) are independent of time, i.e. they are the same for each year. The costs are in £. They are estimates and the higher the more densely populated the region is.

- Each supplier can provide goods for only one product group. This information is included in the vector `SupplierProductGroup` in the data file. Its entries stand for the four product groups.

  All deliveries from warehouses to customers must be carried out using 3.5t vans. Suppliers that are located in a remote part of the country and/or have a low capacity must be served by 7.5t trucks. All other suppliers can be served by 18t trucks. Whether a supplier can be served by an 18t truck or not is given in the data file in the field `SupplierVehicleType`. A "1" means that an 18t truck can be used, a "2" that a 7.5t truck must be used.

  In the data file, the distance matrix between any pair of potential locations and customers is given under `DistanceLocationCustomer`. The distance matrix between any potential location and postcode district is given under `DistanceLocationSupplier`. Each entry gives the distance in miles between the two points.

  The transportation cost is based on a diesel price of £1.60 per litre.

  The Mosel template already contains code for correctly computing transportation costs.

Questions

1. Given a vector $Y \in \mathbb{Z}^m_{0+}$ of selected locations for warehouses, implement an Xpress function `computeTotalCost` that computes the total cost of this solution. This includes the setup, operating, and transportation costs.

   The vector Y hereby denotes for each potential location $j \in J$ the time period it was built, e.g., $Y(5) = 3$ means that a warehouse is built at location 5 in period 3. If no warehouse is built a location j, we set $Y(j) = 0$.

   Briefly describe the function in your report.

   Run your function for both data sets on a solution with the following warehouse locations:

   $$Y(\text{DG1}) = 1, Y(\text{G12}) = 3, Y(\text{IV36}),$$

   and $Y(j) = 11$ for all other locations. Include the cost of the solution in your report.

   [3 marks]

2. Develop and implement a construction heuristic for the case study. I leave the choice of heuristic to you.

   Describe your construction heuristic in the report.

   Run your heuristic for both data sets and include in your report the final set of selected locations, the periods they are built, the total cost of this solution, and the runtime of your heuristic.

   [5 marks]

3. Develop and implement an interchange heuristic for the case study.

   I leave it up to you how you define your neighbourhood(s), how you explore them, and how you check whether or not you found a better solution.

   Describe your improvement heuristic in the report.

   Run your heuristic on both data sets for the following two starting solutions

   - the solution you obtained from your construction heuristic, and
   - a solution with the following warehouse locations:

     $$Y(\text{DG1}) = 1, Y(\text{G12}) = 3, Y(\text{IV36}) = 5, Y(\text{ML8}) = 7, Y(\text{PH17}) = 9,$$

     and $Y(j) = 0$ for all other lo locations.

   Include in your report for each starting solution the final set of selected locations, the periods they are built, the total cost of this solution, and the runtime of your heuristic.

   Compare the final solutions with the starting solutions.

   [7 marks]