Filtrec S.p.A. milk-run logistics

Difficulty level: advanced

Keywords

- Mathematical modelling
- Mixed Integer Linear Programming
- Python+PuLP

Introduction

Filtrec S.p.A. is a company with two offices in Italy, one in Telgate (Bergamo, headquarters) and one in Villimpenta (Mantova), plus twelve branches worldwide. The main products manufactured by Filtrec are filters of various kinds, used in different application sectors, such as agriculture, renewable energy, transport, or the maritime industry.
To carry out its operational activities, Filtrec relies on a network of suppliers and contractors, located in several Italian regions, both to obtain products from them and to sell its own. Many times a week, Filtrec visits suppliers and contractors to deliver and/or collect pallets of filters. To do this, Filtrec relies on an external logistics company to rent the needed vehicles (the cost incurred by Filtrec also includes the drivers' fees). Typically, a supplier/contractor notifies Filtrec by phone or email when they are ready to be visited. Then, as soon as possible, a courier hired by Filtrec will visit it.
To try to optimize these operations, Filtrec wants to resort to the so-called **milk-run** logistics, a mode of transport which follows the deliveries made by a milkman visiting house to house (hence, "milk run"). For each milk run:

- the routes and visiting times for each vehicle at each supplier/contractor are defined;
- the constraints of availability of materials, vehicle size, usable loading or unloading areas based on the size of the vehicle, and more, are taken into consideration;
- historical data relating to past orders from suppliers/contractors are taken into account.

The main purpose is to make the delivery more efficient. Once defined and tested, this management mode requires few resources dedicated to transport planning. But, first, the company has to decide which suppliers/contractors to visit with a specific vehicle, on which day and at which time of the day, how often per week, etc..

`Filtrec-M1`: the milk-run problem simplified to one day

Consider:

- a time horizon of one day;
- only one warehouse (the Telgate office), point of departure/return for couriers;
- a subset of Filtrec contractors, each with an average quantity of pallets delivered by a courier during a visit (assuming that there are no pallets to collect and service times are negligible);
- a set of homogeneous vehicles, having the same characteristics in terms of capacity, maximum circulation time, departure/return point, and fixed daily cost.

Given the fixed daily cost of each vehicle, the goal is to spend as little as possible, using as few vehicles as possible to serve all the contractors on a given day.

`Filtrec-M2`: the milk-run problem simplified to one working week

Extension of the `Filtrec-M1` problem over the whole working week. Consider:

- a time horizon of five days (Monday to Friday);
- the other hypotheses of the `Filtrec-M1` problem;
- a *minimum weekly visit frequency* for each contractor.

Given the fixed daily cost of each vehicle, the goal is to use as few vehicles as possible to serve all contractors a number of times at least equal to their minimum weekly frequency.

Project objectives

The teaching methodology adopted to tackle the project is a combination of collaboration and cooperation. The students are divided into five groups.

Basic objectives:

1. Formulation of the mathematical model of the `Filtrec-M1` problem (with one day as time horizon).
2. Implementation and resolution of the mathematical model `Filtrec-M1` with Python+PuLP.
3. Addition of the following constraints to the `Filtrec-M1` problem to get the `Filtrec-M1-bis` problem:

3.1. **Group 1**: if two contractors are indicated as "different", they must be served by different vehicles;

3.2. **Group 2**: some "neighbor" contractors must be visited from the same vehicle;

3.3. **Group 3**: the number of contractors assigned to each vehicle cannot exceed half of the total number of contractors;

3.4. **Group 4**: some "neighbor" contractors, visited by the same vehicle, have precedence over others;

3.5. **Group 5**: the number of kilometers traveled by each vehicle cannot exceed its maximum permitted distance.

The information needed to model the additional constraints is already all in the `Filtrec-M1.txt` instance.

Advanced objectives:

4. Formulation of the mathematical model of the `Filtrec-M2` problem (with one working week as time horizon).

5. Implementation and resolution of the `Filtrec-M2` mathematical model with Python+PuLP applied to the `Filtrec-M2.txt` instance.

Instructions

- **Objectives 1 and 2** will be achieved **together with the tutors** during the last lesson.
- As for **objective 3**, each group X will have to formulate its own 3.X constraint and implement it in Python **within two weeks**, sending the proposed solution to the tutors via email.
- The tutors will merge all the constraints formulated and implemented by the groups to obtain the mathematical model of the `Filtrec-M1-bis` problem, which will be sent to the groups.
- **Objectives 4 and 5 are optional**: when a group X sends its 3.X constraint, it can also send the formulation and/or implementation in Python+PuLP of the `Filtrec-M2` problem, also done in consultation with other groups.

Return to Filtrec: report and presentation

Within each group, the following roles have be assigned:

- *modeller*, i.e., who deals with the formulation of the mathematical model;
- *programmer*, i.e., the person who implements the mathematical model in Python+PuLP;

- *shoulder of the programmer*, i.e., who offers support for the implementation;
- *slide creator*, i.e., who takes care of the graphics and contents of the final presentation;
- *presenter*, i.e., who deals with the communication and talks during the final presentation.

All groups will have to write a **collective class report**, which must contain at least:

- the description of the real problem;
- the analysis carried out to arrive at the mathematical models of the `Filtrec-M1` and `Filtrec-M1-bis` problems;
- the description of the Python+PuLP implementation;
- the analysis and interpretation of the results of the Python+PuLP resolution;
- conclusions and future developments (possible extensions).

The draft of the class report must be delivered to the tutors, who will send any corrections. The final version of the class report must be delivered to Filtrec contact person **by the agreed date**.

The project will end with a 30-minute **presentation** at Filtrec headquarters in Telgate, in which at least two members of each group will have to participate: the *presenter* and the *slide creator* (the former will have to talk more than the latter, being, in fact, the person in charge of presenting). The remaining modalities of the presentation are free.