Workload equity in vehicle routing with a medium-term perspective

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1 Problem description and measure of equity

In the vehicle routing literature, equity has gained a lot of interest in the last two decades, as acknowledged by the recent survey of [2]. Workload equity is indeed especially relevant in many practical situations, where drivers should be assigned distribution routes with comparable workloads. Equity for drivers is mostly considered on a daily basis while the perception that drivers may have of inequity is on a longer term. In this work, we consider a time horizon of a few weeks and a test-bed routing problem motivated by healthcare logistics. Having unbalanced routes at some periods (days) is accepted, but some degree of equity is imposed on the complete horizon.

The problem is dynamic in the sense that requests are revealed day by day. However, each daily routing problem is static as requests of a day t are all known before starting the day. Each day, two decisions have to be made, routing and assignment of routes to drivers. They can be treated separately because vehicles are identical and drivers work every day. The daily routing problem has been introduced in [1] and is called the Multi-Trip Vehicle Routing Problem with Mixed Pickup and Delivery, and Release and Due dates (MTMPD-RD).

In our problem, the equity metric concerns the difficulties that might be encountered by drivers at patient homes when they help patients moving to the vehicle or moving back home. We call it painfulness and denote it π_i^t. For a request i and a period t, π_i^t is assumed to be defined based on factors, like the patient ages, their number, their mobility and the type of residential building where they live. The more painful request i, the higher π_i^t. This equity metric is said constant-sum as the sum of workload assigned to drivers remains constant. The equity function that we use in our equity objective is the range, defined as the difference of painfulness between the drivers with the maximal and the minimal cumulative painfulness over the whole horizon.

2 Solution frameworks

We propose 5 solution frameworks aiming to achieve the best possible compromise between routing costs and equity. In all our frameworks, we follow the same principle. While optimizing daily routes, the objective is always to minimize travel cost. Inequity might be limited or not with a constraint, with techniques depending on the approach. When assigning routes to drivers, travel costs are known and the objective is always to minimize inequity which we manage using an assignment strategy that we proved to be optimal . We call it the Best Equity Assignment strategy (BEA). A dedicated branch-and-price algorithm is used to solve the daily routing problem [1] and is adapted for the different solution frameworks. So, the frameworks only differ in the way equity is considered when solving the daily routing problems. Below, we denote p_k^t the decision variable expressing the painfulness allocated to driver m_k (sum of painfulness of requests served in route of driver m_k) when solving the daily routing problem at period t. Also, the total painfulness of period t is denoted $\Pi^t = \sum_{i=1}^{n} \pi_i^t$. The total cumulative painfulness up to period t is denoted $\Pi^{1\to t} = \sum_{t'=1}^{t} \Pi^{t'}$. The painfulness assigned to a driver m_k on a past period t is Π_k^t. The cumulative painfulness assigned to driver m_k up to period t is denoted $\Pi_k^{1\to t} = \sum_{t'=1}^{t} \Pi_k^{t'}$.

The different solution approaches are briefly described below, where K denotes the number of drivers and where $\alpha > 1$, $\alpha_s > 1$ and $\alpha_e > 1$:

— Routing First Equity Second (RFES) : no equity constraints.

— Single-Period Constant Equity (SPCE) : When solving the daily routing problem at a period t, the average painfulness at that period is computed and routes are only allowed a limited upper deviation from this value :

$$p_k^t \leq \alpha \times \frac{\Pi^t}{K}, \forall m_k \in \mathcal{M} \tag{1}$$

— Multi-Period Constant Equity (MPCE) : This framework extends SPCE by taking account of the painfulness assigned to the drivers at the previous periods. At period t, the constraints imposed on variables p_k^t are :

$$p_k^t \leq \alpha \times \frac{\Pi^{1\to t}}{K} - \Pi_k^{1\to t-1}, \forall m_k \in \mathcal{M} \tag{2}$$

— Multi-Period Adapted Equity (MPAE) : This framework generalizes MPCE. It allows changing the deviation limit at the different periods :

$$p_k^t \leq \alpha_t \times \frac{\Pi^{1\to t}}{K} - \Pi_k^{1\to t-1}, \forall m_k \in \mathcal{M} \tag{3}$$

where α_t decreases uniformly from α_s at period 1 to α_e at period T :

$$\alpha_t = \alpha_s - (t-1) \times \frac{\alpha_s - \alpha_e}{T-1} \tag{4}$$

— Last-Period Adaptive Equity (LPAE) : framework RFES is applied for all periods except the last period, where the framework MPCE is applied.

3 Results and perspectives

Experiments are conducted on a benchmark of realistic instances extracted from the city of Aix-en-Provence, France. 30 instances are tested with all approaches combined to different parameters which gives a total of 750 runs. We compare the different frameworks through several measures : (i) feasibility, (ii) trade off between equity and cost, (iii) daily equity and evolution of equity along the time horizon, (iv) computing times. The results will largely be discussed at the conference.

Références

[1] Agius, Maxime and Absi, Nabil and Feillet, Dominique and Garaix, Thierry. A Branch-and-Price algorithm for a routing problem with inbound and outbound requests. *Computers & Operations Research*, 105896, 2022.

[2] Piotr Matl, Richard F. Hartl, and Thibaut Vidal. Workload Equity in Vehicle Routing Problems : A Survey and Analysis. *Transportation Science*, 52(2) :239–260, 2018.