Workload equity for a dynamic multi-period routing problem in the context of medical transportation

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1 Introduction

The studied problem concerns the non-emergency transportation of patients. Some disabled or old patients cannot go back and forth to the hospital by their own to get cares. In this context, transport companies are involved to provide medical transportation of patients. In this work, we consider a single hospital and we assume that a single company is involved with a limited number of drivers.

Transportation requests are daily revealed on a time horizon of several days. In practice, there exists service provider platforms to help managing the schedule of such routes and the assignment of routes to drivers. Generally, these platforms use algorithms based on simple assignment rules (e.g. the FIFO rule "First In First Out"). These rules can be inefficient for large scale transportation systems or when the demand varies strongly. Another drawback of these rules is that they create inequities between drivers in terms of route cost (duration or distance) and/or painfulness of work. In this work we consider the latter.

Equity has gained interest in the VRP literature in the last two decades [1], [2]. The literature mainly focus on single period problems. In the rare papers where it is considered on a larger horizon, the demand is assumed to be completely known in advance, which is not realistic in many contexts. The originality of our problem is to consider equity on the "long" term (typically one month), with requests dynamically revealed. Compared to standard models, it gives the opportunity to accept unbalanced routes at some periods, as long as equity is preserved on the whole horizon. We investigate different solution approaches and evaluate computationally how addressing equity this way allows limiting its impact on routing costs.

2 Measure of equity and solution method

In our model, equity is required with regards to request painfulness. We measure the painfulness of a request i on period t as a value π_i^t defined taking into account the characteristics of patients : their age, their mobility and the type of residential building where they live. The more a request is painful, the higher π_i^t is. This metric is said constant-sum as for any feasible allocation of the workload, the sum of workload allocated is identical. The total painfulness of period t is denoted Π^t and painfulness assigned to driver m_k on period t is Π_k^t.

To deal with the multi-objective nature of our problem, instead of considering two explicit objectives, we consider cost minimization as the single objective, and set a limit to inequity. We then propose to manage equity with different solution approaches that are briefly described below :

— Routing First Equity Second (RFES) : for each period t, optimize vehicle routes without considering equity ; then, assign the most painful route to the driver with the least cumulative painfulness up to period $t-1$, the second most painful route to the driver with second least cumulative painfulness, and so on to balance the cumulative painfulness up to period t.

— Single Period Constant Equity (SPCE) : RFES with periodic equity constraints. For each driver m_k on period t, we limit the painfulness assigned to m_k. The limit is independent of the driver :

$$\Pi_k^t \leq \alpha \times \frac{\Pi^t}{K} \tag{1}$$

— Multi-Period Constant Equity (MPCE) : RFES with equity constraints depending on the driver, it takes into account the cumulative painfulness assigned to drivers up to period $t-1$:

$$\sum_{t'=1}^{t} \Pi_k^{t'} \leq \alpha \times \sum_{t'=1}^{t} \frac{\Pi^{t'}}{K} \tag{2}$$

— Multi-Period Adapted Equity (MPAE) : Similar to MPCE with a limit more and more restrictive over the time horizon (α^t decreasing uniformly from α_s to α_e).

$$\sum_{t'=1}^{t} \Pi_k^{t'} \leq \alpha^t \times \sum_{t'=1}^{t} \frac{\Pi^{t'}}{K} \tag{3}$$

The periodic problem is defined as a Multi-Trip Vehicle Routing Problem with Mixed Pickup and Delivery, and Release and Due dates and is solved with a specific Branch-and-Price algorithm. Its complete study is not the object of this work, instead we focus on the impact of adding the equity constraints (mentioned above) on the column generation algorithm.

3 Preliminary results and future experiments

Experiments are conducted on a benchmark of realistic instances extracted from the city of Aix-en-Provence, France. Obtained results on preliminary experiments show that the different proposed approaches offer equitable solutions without deteriorating drastically the total cost. RFES guarantees an optimal cost and equitable solutions on the long-term but inequitable routes on single periods. Adding equity constraints impacts slightly the routing cost (less than 1% increase) but offers more equitable routes on single periods.

Future experiments are planned to test more instances in different scenarios, that is, we plan to test different equity targets (managed with coefficients α, α_s and α_e). Also, we plan to test instances with some specific distribution of painfulness over the time horizon. An interesting perspective would be to consider a variable-sum metric such as the routing cost.

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Références

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