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Electronic Notes in DISCRETE MATHEMATICS

Electronic Notes in Discrete Mathematics 64 (2018) 155–164 www.elsevier.com/locate/endm

Column Generation Based Approaches for Combined Routing and Scheduling

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Abstract

The multi-trip location routing problem is usually applied in the logistics and transportation field. The multi-trip location routing problem is an integrated problem that combines two important and difficult optimization problems: the facility location problem and the multi-trip vehicle routing problem. In the facility location problem, one has to determine the set of facilities that can be used to serve the clients. To fulfill the clients needs, we generate a set of routes by solving a multi-trip vehicle routing problem which allows the assignment of more than one single-trip to a vehicle along the planning horizon. To solve the multi-trip location routing problem, we propose a column generation approach that integrates these two problems. In practice, both the facility location problem and the multi-trip vehicle routing problem are solved simultaneously. This approach leads to better solutions than those achieved by solving the two problems separately. Computational results are described at the end of the paper to illustrate the potential of this approach.

Keywords: Location routing, Elementary shortest path, Multi-trip, Integer Programming, Column generation, Parallelization

[1] The work of Bruna Ramos is supported by a doctoral FCT grant SFRH/BD/90558/2012.
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https://doi.org/10.1016/j.endm.2018.01.017

1 Introduction

The multi-trip location routing problem (MLRP) is a difficult optimization problem that integrates the facility location problem (FLP) and the multi-trip vehicle routing problem (MVRP). The routing problem allows the determination of a set of optimal routes such that the demands of multiple clients are fulfilled. In the location problem, one has to determine the location of a set of depots to be used. The integration of these two problems has as main objective the minimization of the total cost of the system, thereby allowing the reduction of unnecessary costs. A review of methods for the location and vehicle routing problems and their variants has been proposed by Nagy and Salhi [10], Prodhon and Prins [11], and Drexl and Schneider [5]. Most of the proposed methods are purely heuristic approaches. The number of exact approaches to variants of this problem is still very low [2,3,4]. Belenguer et al. [3] describe a branch-and-cut algorithm for instances of the problem with capacity constraints in depots. Akca et al. [2] propose a branch-and-price algorithm combined with heuristics for solving the column generation sub-problem. Another branch-and-price algorithm has been proposed by Berger [4] to solve a version of the problem without capacity constraints on depots and constraints on the distances travelled.

In [8] the authors propose a variant of a vehicle routing problem where a vehicle may perform more than one single-trip per workday. The MLRP is a variant rarely discussed in the literature nevertheless it has been previously addressed in [7], where Lin and Kwok discuss a multi-objective case combining cost minimization with the minimization of the imbalance among vehicles.

2 Problem Description

The MLRP consists in the selection of the depots that should be opened and the single-trips or multi-trips that should be performed to serve the clients at minimum cost. The multi-trip variant considers the possibility of a vehicle to perform more than one single-trip during the planning period. Hence, it is typically applied to cases in which the routes are performed within a small geographic area that involves, for example, the transportation of perishable goods which must be delivered in a short period of time. As a consequence, the inherent complexity of the problem increases since now it is necessary to determine the route that should be assigned to a vehicle.

A route r is composed by an ordered set of clients to be served. A route is a broader term that may be a single-trip (r_2 in Figure 1) or a multi-trip (r_1