The multi-vehicle profitable pick up and delivery routing problem with uncertain travel times

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Abstract

This paper addresses a variant of the well known selective pickup and delivery problem where travel times are considered uncertain. The goal is to find the solution that maximizes the net profit, expressed as the difference between the collected revenue, the route cost and the cost associated to the violation the time windows. This study introduces the problem and develops a solution approach to solve it. Very preliminary tests have been performed in order to show the efficiency of developed method.

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Peer-review under responsibility of the scientific committee of the 23rd EURO Working Group on Transportation Meeting.

\textit{Keywords:} Pick up and delivery; Profits; Expected tardiness; Expected earliness.

1. Introduction

The Pickup and Delivery Problem (PDP) is one of the most studied problem in the routing literature. It is a variant of the vehicle routing problem that uses a homogeneous capacitated and limited fleet of vehicles, parked at a single depot, in order to serve the customers’ pickup and delivery requests. Over the last decades, researchers have studied many variants of the PDP and they have used various algorithms to solve those variants (Berbeglia et al. (2009); Dumitrescu et al. (2010); Hernandez-Perez et al. (2017)). Very often, time windows are included in the considered problem, leading to the so-called Vehicle Routing with Time Windows (VRPDTW). When the constraint of visiting all the customers is relaxed, the problem becomes selective. This variant has received scant attention form the literature so far. Prive et al. (2006) developed a heuristic for a practical problem involving the delivery of soft-drinks and the collection of empty cans and bottles. Gribkovskaia and Laporte (2008) applied tabu search to the single vehicle pickup and delivery problem with selective pickups arising in the routing of supply vessels through offshore installations. For the single vehicle case a branch-and-cut algorithm was later proposed by Gutierrez et al. (2009, 2010). The multi-vehicle selective PDP has been studied in Qiu et al. (2014, 2017); Gansterer et al. (2017).
This paper studies the profitable Pickup and Delivery Problem (RSPDP) in which uncertain traveling times are modeled as random variables. Nodes can be visited at any order as long as the same route visits both the pickup and delivery nodes of a request provided that the pickup node is visited earlier (but not necessarily immediately before) than the delivery node (precedence relation). The available requests shall be served by a fleet of homogeneous vehicles that can consolidate different requests in the same trip as long as their load fit into the vehicle capacity. The fleet transports only profitable requests since is not mandatory to deliver all available requests. The profitability is evaluated as the net profit expressed as the revenue collected minus the traveling cost and the cost related to the possible violation of the time windows constraints. The motivation for focusing on the problem described in this paper is that, in real-life contexts, the compliance to time windows restrictions may become quite costly at the planning level, especially considering that vehicles often operate in traffic congested cities, leading to uncertain travel times. Since the travel times are random variables, also the arrival times are random variables (hereafter denoted by \( \bar{u}_i, \forall i \in V \)) and, as such, the tardiness and the earliness. A common approach under uncertainty is to consider a risk neutral viewpoint, notably implemented through the minimization of the expected value. The evaluation of these quantities, is in general not trivial, and depending on the particular distribution function used to model the travel times, can be a straightforward or a very complicates task Tas e tal. (2014). In fact, we note that \( \bar{u}_{i+1}^k \) depends on \( u_i^k \) and on the random travel time \( \bar{t}_{i+1} \) between \( i \) and \( i+1 \) , since we can rewrite \( \bar{u}_{i+1}^k = u_i^k + \bar{t}_{i+1} \). Hence, the arrival time at each node is the sum of the travel times associated to the links belonging to the route (\( \bar{t}_i^k \)) connecting the depot to the node \( i \). The calculation of the sum of of independent random variables is the convolution of their distribution and it can be quite complex based on the probability distributions of the random variables involved and their relationships. For a family of distributions closed under convolution, the task becomes easy, since the sum of random variables has the same distribution of the original variables. Within this family, the Gamma probability distribution has been be used to model travel times in routing problems, since is a good one to use for any skewed distribution. Assuming that travel times are distributed as Gamma random variables, we present a solution method to solve the problem defined above, based on graph search. Preliminary results show that the algorithm is able to find the optimal solution in a very limited amount of time for the smaller instances. On average the CPU time is around 3.5 second for wide time windows and less the 1 second for regular time windows. Surprisingly, the larger the time window are, the more difficult is the problem. This may be due to the fact that many solution with comparable objective function are generated and therefore, the search is not able to pruned inferior solutions in early stages of the algorithm. The the percentage deviation between the the objective function value of the problems with wide and narrow time windows is around 5.5%, meaning that decreasing the time windows range would lead to a decrease in the profit, related to the expected cost of the tardiness and earliness.

References


