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A branch-and-price based heuristic for the stochastic vehicle routing problem with hard time windows

G. Andreatta [1], M. Casula [2], C. De Francesco [3], L. De Giovanni [4]

Dipartimento di Matematica
Università degli Studi di Padova
Padova, Italy

Abstract

In the Vehicle Routing Problem with Hard Time Windows and Stochastic travel times, a disruption occurs if, due to stochastic events, a vehicle arrives too late at a customer. In this case a recourse action is required such that the service starts within the time window, and a relevant penalty cost is incurred. Despite the problem has been inspired by a real-life application in airport ground handling optimization, it has never been addressed before in literature, to the best of our knowledge. We discuss how the expected penalty cost can be evaluated and how this computation can be integrated in a branch-and-price procedure to obtain heuristic solutions. Preliminary tests on literature instances show the effectiveness of the approach.

Keywords: Vehicle routing, Hard time windows, Stochastic travel times, Branch-and-price

[1] Email: giovanni.andreatta@unipd.it
[2] Email: casula.marco@gmail.com
[3] Email: carla@math.unipd.it
[4] Email: luigi@math.unipd.it

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1 Introduction

The Vehicle Routing Problem (VRP) is a well known network optimization problem where a set of customers is located at the nodes of a graph and a set of node-disjoint routes have to be determined in order to visit all the customers. Routes have to start and end at a same node called depot and travel distances between nodes, as well as node service times, are given. The objective is to minimize the total cost, normally related to the total distance traveled (see [13], among others). One of the possible extensions of this problem is the VRP with time windows (VRPTW), where the service of each customer has to start within a specific time interval. Time windows may be soft (they can be violated at some penalty cost), or hard (early vehicles have to wait at no additional cost, while late vehicles are prohibited to serve). Real-life applications often require that uncertainty is taken into account so that stochastic variants of the VRP have been introduced (see e.g. [9] for a review).

We consider the VRP with Hard Time Windows and Stochastic travel and service times (S-VRPHTW). Due to the uncertainty, a customer originally included in a route may be reached after the end of its time window: we call *disruption* this event, and we assume that a recourse action is taken such that the customer is served within its time window and a large fixed penalty cost is incurred. As a consequence, the objective is to minimize a weighted sum of the total distance traveled and the expected number of disruptions.

The study of the S-VRPHTW has been inspired by a real application related to the optimization of ground handling operations in airport aprons, where the customers are the aircraft that need specific operations before/after departure/landing, and the vehicles are the specific Ground Service Equipment (GSE) required by the same operations (see [3]). If a GSE cannot serve an aircraft on time (for example because the previous aircraft is late, or the delay cumulated along the service route is sufficiently large, or because of a breakdown or other unforeseen events), a recourse GSE takes its place in the originally planned route, causing an additional relevant penalty cost.

Among the stochastic variants of the VRP, the ones involving stochastic travel times are less studied and literature is concerned with soft time windows: we cite some heuristic approaches based on genetic algorithms or tabu search (see [2,10] among others), and an exact algorithm based on branch-and-price [12]. Also the method proposed in [6] for the VRP with stochastic demands may be adapted to soft time windows, under suitable restrictions on delay distributions. The S-VRPHTW is concerned with hard time windows and, to the best of our knowledge, it has not been yet considered in literature.