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A vehicle routing problem with backhauls and time windows: a guided local search solution

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Abstract

This paper presents a guided local search heuristic to solve a vehicle routing problem with backhauls and time windows. The VRPBTW with and without customer precedence are both considered. Customer precedence requires that all linehaul customers be visited before any backhaul customer. The basic approach is to construct an initial infeasible solution and then use a guided local search to improve the solution feasibility and quality. A new technique—section planning—is used to enhance the feasibility. Computational results show that the new heuristic can solve problems in which customers are distributed normally or in clusters. Some of the results are better than the best solutions that have appeared in the literature.

Keywords: Vehicle routing; Time windows; Metaheuristic

1. Introduction

The Vehicle Routing Problem with Backhauls and Time Windows (VRPBTW) can be stated as follows: A set of customers with deterministic demand, deterministic time windows, and certain types of service requirements (pick up and/or delivery) must be served by a homogeneous fleet of vehicles with fixed capacity starting from and ending at a central depot, which also has a certain time horizon. For each service requirement (pickup or delivery), each customer must be assigned exactly once to a vehicle. The customers are classified into two groups: linehaul customers whose

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demand needs to be delivered, and backhaul customers whose demand needs to be picked up (if a customer requires both pickup and delivery, it is modeled as two separate customers). In this paper, a vehicle is allowed to arrive at a customer before the relevant time window, but cannot service the customer until the time window opens. The VRPBTW has two objectives: minimize the number of routes and minimize the sum total distance of all the routes. The VRPBTW can be classified into two cases. In the VRPBTW with customer precedence, all of the linehaul customers must be served before any backhaul customers in each route. In the VRPBTW without customer precedence, linehaul and backhaul customers can be interspersed on a given route.

This research develops a heuristic approach to the VRPBTW. Optimal methods are not appropriate since the traditional VRP is an NP-hard problem and, in general, adding time windows and backhauls does not simplify the problem. The new heuristic is a cluster-first, route-second algorithm, with most effort spent on routing. The two phases are

- *Phase 1*—Use an adapted sweep algorithm (Fisher and Jaikumar, 1981) to generate an initial infeasible solution. Use GLSA, a guided local search heuristic (based partly on Voudouris and Tsang, 1999) to manage 2-opt, 1-move, and 1-exchange (a new method) to improve the initial solution.
- *Phase 2*—Enhance feasibility using a new technique called section planning. This technique inserts new routes until feasibility is attained, and arranges customers within routes to reduce travel distance. This phase is iterative with feasibility constraints being "soft" in early iterations and "hard" in later iterations.

The new heuristic was originally developed for the VRPBTW without customer precedence. After promising results for problems without customer precedence, we extended the heuristic to consider the VRPBTW with customer precedence.

2. Literature review

A comprehensive review of the VRP can be found in Bodin et al. (1983) and Ball et al. (1995). Useful techniques for the general VRP are outlined in Golden and Assad (1988) and Aarts and Lenstra (1997). Reeves (1993) covers modern techniques such as simulated annealing, tabu search, and genetic algorithms. Various heuristic methods may be found in the literature for both the VRPTW (Potvin et al., 1996b; Potvin and Bengio, 1996; Russell, 1995; Chiang and Russell, 1997) and the VRPB (Casco et al., 1988; Deif and Bodin, 1984; Golden et al., 1985; Goetschalckx and Jacobs-Blecha, 1989; Jacobs-Blecha and Goetschalckx, 1993; Toth and Vigo, 1996).

Several papers deal specifically with the VRPBTW. Gelinas et al. (1995) propose a new branching strategy for branch-and-bound approaches based on column generation. This algorithm finds optimal solutions to different test problems with up to 100 customers. Potvin et al. (1996a) design a genetic algorithm to identify an ordering of customers that produces good routes. Duhamel et al. (1997) design a tabu search heuristic for the VRPBTW with customer precedence. First a feasible solution is constructed by an adapted version of Solomon's (1987) insertion heuristic. Then tabu search and local search and improvement algorithms are used to improve the solution. All three of these papers detail experiments on problems with customers distributed