Solving the Mixed Backhauling Vehicle Routing Problem with Ants

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ABSTRACT

The mixed vehicle routing problem with backhauls is investigated using ant system heuristic. This distribution problem seems to suffer from a lack of published work even though it has immense practical applicability especially within logistic systems. Some enhancements to the basic ant system algorithm are embedded into the search. In particular a focus is on the choice in the placement of ants, the use of site-dependent candidate list, the introduction of a look ahead-based visibility, and appropriate strategies for updating local and global trails. Encouraging computational results are reported when tested on benchmark data sets.

Keywords: Ant System Metaheuristic, Ants, Mixed Backhauling, Vehicle Routing, Vehicle Scheduling

1. INTRODUCTION

The vehicle routing problem with backhauls (VRPB) is an extension to the vehicle routing problem (VRP) where two different types of customers exist. The first type consists of linehaul customers, also known as delivery customers, who require a given quantity of product to be delivered. The second type are the backhaul customers, also known as pickup customers, who require a quantity of goods to be picked up and sent back to the depot. Hence, the VRPP is also known as the vehicle routing problem with pickups and deliveries. The goods are transported to or from a single depot by a fleet of homogeneous vehicles. The

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objective is to find a set of routes with the least cost where all customer demands are satisfied, each customer is visited exactly once, all routes begin and end at the depot, and finally the load on the vehicle at any arc along the route does not exceed the vehicle capacity.

The VRPB models in the literature either restrict backhauls to be visited once all linehauls have been served, the classical VRPB, or allow a mix of linehaul and backhaul customers along the routes, the mixed VRPB. The latter problem is also known as the vehicle routing problem with mixed pickups and deliveries, and is closely related to the problem of vehicle routing with simultaneous pickups and deliveries, where each customer can have both a pickup and a delivery load. The focus of our paper is on the mixed VRPB. In the classical VRPB it is only necessary to check that the total linehaul load and the total backhaul load do not separately exceed the total vehicle capacity. In the mixed VRPB it is necessary to check that the vehicle capacity is not exceeded at any arc along the route, since in this problem the vehicle load can either decrease or increase at each customer site depending on whether the customer is a linehaul or a backhaul. The classical case is often solved by matching two partial routes: one containing linehauls and the other backhauls. The mixed case is typically solved by inserting backhauls into linehaul routes. The mixed classical VRPB has not received as much attention in the literature as its counterpart the classical VRPB. This has some practical justification given that many vehicles are rear-loaded and that linehaul customers usually prefer early deliveries while backhaul ones may not object to late deliveries. However, the improved design of vehicles, in particular vehicles that permit side loading, mean that mixed routes are now a much more practical option and therefore worth investigating. Such a motivation is obviously also of interest to the case of simultaneous VRPB. In other words, in the mixed VRPB we are allowed to mix linehaul and backhaul customers within a given route as long as feasibility, in terms of vehicle capacity and time restriction, are not violated. Though such flexibility may provide cheaper scheduling costs, it adds extra difficulties in the checking of the vehicle capacity as the load will now fluctuate along the route.

Toth and Vigo (2002), Berbeglia, Cordeau, Gribkovskaia and Laporte (2007) and Parragh, Doerner and Hartl (2008) present detailed reviews of the VRPB. Hence, we give here a brief review of the most recent papers. Dethloff (2001), Tang and Galvão (2006) and Chen and Wu (2006) treat only the simultaneous case, while Osman and Wassan (2002) and Wassan (2007) deal with the classical VRPB. Henceforth, we focus only on papers solving the mixed case. Dethloff (2002) applies a methodology designed for the simultaneous problem (see Dethloff, 2001) to the mixed case. This is an insertion-based method using the concept of “residual capacities”. The author notes that the two problem cases, although related, are not equivalent and it may be misleading to compare results. Wade and Salhi (2002) introduce a generalised backhauling problem. Their model suggests a compromise between the classical and the mixed cases. A mixture of linehauls and backhauls is permitted on routes, but subject to a restriction on having some space on the vehicle to allow manoeuvring the loads. An insertion-based procedure is presented, allowing either a single backhaul or a pair of backhauls to be inserted into route. Wade and Salhi (2003) proposed an initial implementation of an ant system heuristic for the mixed case and present some initial results. We aim to make this approach more accessible to readers by slightly extending it and by providing the complete set of results for the mixed VRPB. An exact method, based on a flow formulation and branch-and-cut, was given by Baldacci, Hadjiconstantinou and Mingozzi (2003). Nagy and Salhi (2005) developed a composite heuristic approach for the simultaneous VRPB that is also applicable to the mixed VRPB and can also cater for multiple depots. Crispim and Brandão (2005) present the first metaheuristic approach for the simultaneous and mixed VRPB. Their method is a hybrid of tabu search and variable neighbourhood search. Initial solutions are generated using a sweep method. If any route
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