European Journal of Operational Research 000 (2016) 1–12

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Discrete Optimization

Adaptive large neighborhood search for the pickup and delivery problem with time windows, profits, and reserved requests

Yuan Li*, Haoxun Chen, Christian Prins

ICD-LOSI, UMR CNRS 6281, Université de Technologie de Troyes 12 rue Marie Curie, CS 42060, 10004 Troyes Cedex, France

ARTICLE INFO

Article history:
Received 27 August 2015
Accepted 16 December 2015
Available online xxx

Keywords:
Vehicle routing problem
Pickup and delivery problem
Time window
Profit
Adaptive large neighborhood search

ABSTRACT

This paper addresses the Pickup and Delivery Problem with Time Windows, Profits, and Reserved Requests (PDPTWPR), a new vehicle routing problem appeared in carrier collaboration realized through Combinatorial Auction (CA). In carrier collaboration, several carriers form an alliance and exchange some of their transportation requests. Each carrier has reserved requests, which will be served by itself, whereas its other requests called selective requests may be served by the other carriers. Each request is a pickup and delivery request associated with an origin, a destination, a quantity, two time windows, and a price for serving the request paid by its corresponding shipper. For each carrier in CA, it has to determine which selective requests to serve, in addition to its reserved requests, and builds feasible routes to maximize its total profit. A Mixed-Integer Linear Programming (MILP) model is formulated for the problem and an adaptive large neighborhood search (ALNS) approach is developed. The ALNS involves ad-hoc destroy/repair operators and a local search procedure. It runs in successive segments which change the behavior of operators and compute their own statistics to adapt selection probabilities of operators. The MILP model and the ALNS approach are evaluated on 54 randomly generated instances with 10–100 requests. The computational results indicate that the ALNS significantly outperforms the solver, not only in terms of solution quality but also in terms of CPU time.

1. Introduction

In recent years, the fierce competition in global markets, the introduction of products with shorter life cycles, the increasing fuel costs and labor prices, the growing transport legislation and the heightened expectations of customers have shrunk profit margins of shippers and carriers (Cruijssen, Cools, & Dullaert, 2007). Thus, as an effective way to cut empty backhauls and to increase vehicle utilization rate, Collaborative Logistics (CL) attracted a growing interest from industrial practitioners and academic research (Dai & Chen, 2009b). In CL, shippers, carriers, contractors and even competitors can be partners if their collaboration can create a win-win outcome.

The collaboration among small or medium sized enterprises (SME) plays a growing role in their daily operation/management. Participation in a network and collaboration with other enterprises has now become an inevitable strategy for them to gain competitive advantages in current severe environment. To achieve economies of scale, more and more SMEs have formed collaborative networks by sharing distribution tasks and resources, in order to reduce costs, improve responsiveness to the evolution of market demands, and capture more business opportunities.

In our study, we assume that several carriers form an alliance. This alliance aims at maximizing the total profit so as to generate more profit for each carrier. Inside this alliance, the carriers achieve collaboration by exchanging part of their transportation requests. We are developing a general two-step approach for carrier collaboration (*e.g.* Dai and Chen, 2009a; 2009b). The first step is reassignment/reallocation of requests among carriers, whereas the second aims at sharing the resulting profits among them (Dai & Chen, 2012, 2015). The task reassignment is realized through Combinatorial Auction (CA). In each iteration of CA, the auctioneer sets/updates a service price (revenue) for each request to be exchanged among carriers (Dai, Chen, & Yang, 2014), then each carrier determines which requests to bid for (to serve), in order to maximize its own profit. The latter problem is referred to Bid Generation Problem (BGP) (*e.g.* Wang and Xia, 2005; Lee, Kwon, and Ma, 2007; Buer, 2014; Triki, Oprea, Beraldi, and Crainic, 2014) for each carrier.

In this paper, we consider the BGP (or request selection problem) for each carrier in CA (Dai & Chen, 2011). It is assumed that each carrier has a set of *reserved requests* (*i.e.*, not proposed for

* Corresponding author. Tel.: +33 751610975.
E-mail addresses: yuan.li@utt.fr, yuan296103@gmail.com (Y. Li), haoxun.chen@utt.fr (H. Chen), christian.prins@utt.fr (C. Prins).

http://dx.doi.org/10.1016/j.ejor.2015.12.032
0377-2217/

exchange in CA) and can serve additional requests (*selective requests*) from other carriers. Each request is a pickup and delivery request associated with an origin, a destination, a quantity, two time windows, and a price (revenue) for serving the request paid by its corresponding shipper (a customer of the carrier). Two different decisions have to be simultaneously taken by the carrier: Which requests to bid for (to serve) and how to build routes for maximizing its own profit, equals to the sum of collected revenues minus the total cost of the routes. This raises a new Pickup and Delivery Problem (PDP) with Time Windows, Profits, and Reserved Requests (PDPTWPR). To the best of our knowledge, this problem was rarely studied in the literature.

The rest of the paper is organized as follows. A brief literature review on CL and Vehicle Routing Problems (VRP) with Profits (VRPP) is provided in Section 2. Section 3 defines the problem and provides a mathematical model. An adaptive large neighborhood search (ALNS) is developed in Section 4. Section 5 proposes a set of randomly generated instances and compares the results of our ALNS with the ones obtained by the CPLEX solver on the mathematical model. Finally, Section 6 provides a quick conclusion with some remarks for future research.

2. Literature review

Horizontal collaborative logistics refers to the collaboration among multiple actors at the same level in logistics operations such as the collaboration among shippers (manufacturers) and the collaboration among carriers. Two types of horizontal collaborative logistics are studied in the literature: shipper collaboration and carrier collaboration. Shipper collaboration considers a single carrier and multiple shippers. The collaboration among shippers is realized by consolidation of their transportation requests to be offered to carriers. Through collaboration, shippers are able to reduce "hidden costs" such as asset reposition costs (Ergun, Kuyzu, & Savelsbergh, 2007). However, more attention has been focused on carrier collaboration. Differing from shipper collaboration, carrier collaboration considers how to provide opportunities for LTL carriers to exploit synergies in operations (such as excess capacity), reduce costs associated with fleet operation, decrease lead times, increase asset utilization (power units), and enhance overall service levels (Esper & Williams, 2003; Hernández, Peeta, & Kalafatas, 2011).

Analyzing the existing scientific literature on carrier collaboration reveals that the majority of logistics cooperation research can be classified into two main categories according to the two ways of cooperation among carriers (Verdonck, Caris, Ramaekers, & Janssens, 2013). One way is to share resources, like vehicle capacities. The other is order sharing which is known to be able to improve efficiency and profitability owing to increment of capacity utilization and reduction of asset reposition by re-drafting the route planning (Dai & Chen, 2011). Verdonck et al. (2013) provide a detailed literature review of the two above carrier collaboration approaches.

Moreover, some interesting opportunities for CL are identified. Cruijssen et al. (2007) present the results of a large-scale survey on the potential benefits and impediments for horizontal cooperation and emphasize its importance. Krajewska and Kopfer (2009) apply a tabu search metaheuristic to solve an Integrated Operational Transportation Planning problem (IOTP) in which a carrier has the possibility of outsourcing its requests by involving subcontractors. Wang, Kopfer, and Gendreau (2014) use the ALNS framework proposed by Ropke and Pisinger (2006) and two other heuristics to solve the previous IOTP and its generalization to a centralized planning for all carriers. References (Krajewska & Kopfer, 2009) and (Wang et al., 2014) differ from our work, because, in addition to each request, complete routes can be subcontracted with either a payment per route or on a daily basis. Moreover, reserved requests are not considered.

Our problem is related to the Pickup and Delivery Problem with Time Windows (PDPTW), which itself is a generalization of the Vehicle Routing Problem with Time Windows (VRPTW). The PDPTW involves three main constraints: time window constraints, capacity constraints and coupling constraints (the delivery node of each request must be visited after its corresponding pickup node in the same route). The PDPTW has been well studied in the literature and due to its complexity, metaheuristic algorithms have become dominating methods for its resolution. Nanry and Wesley Barnes (2000) propose a reactive tabu search and test it on instances with up to 50 requests. Li and Lim (2003) create a set of benchmark instances and propose a hybrid metaheuristic. Hosny and Mumford (2012) compare sequential and parallel insertion heuristics to provide metaheuristics with high quality initial solutions. Bent and Hentenryck (2006) apply Variable Neighborhood Search (VNS) to the PDPTW and their computational results show promising performance of their algorithm, compared with the previous PDPTW metaheuristics. Ropke and Pisinger (2006) design an ALNS algorithm which is probably the most effective metaheuristic for the PDPTW so far, with results reported for up to 1000 locations.

Our PDPTWPR displays important differences with the PDPTW: i) serving all requests is not mandatory (provided all reserved requests are treated), ii) a profit is associated with each request, and iii) the objective function, to be maximized, is the sum of the revenues minus the routing costs. We found no reference on this problem in the literature, although a growing number of publications deals with Vehicle Routing Problems with Profits (VRPP) in general.

Single-vehicle problems with profits are surveyed in Feillet, Dejax, and Gendreau (2005). Tour costs and collected profits can be expressed in the objective function, by minimizing the travel costs minus the profits, giving the Profitable Tour Problem (PTP). The profits collected can be maximized, subject to a maximum tour length, which defines the Orienteering Problem (OP). Conversely, in the Prize-Collecting Traveling Salesman Problem (PCTSP) (Balas, 1989), the travel costs are minimized but the collected profits cannot be less than a given constant.

Among these problems, the PTP has the same objective function as our PDPTWPR. Only heuristics are available to solve it. Nguyen and Nguyen (2010) develop an approximation algorithm, based on the heuristic from Frieze, Galbiati, and Maffioli (1982) for the Asymmetric Traveling Salesman Problem (ATSP), and a method to round fractional solutions of a linear programming relaxation for the asymmetric PTP. Goemans and Bertsimas (1990) solve an undirected version of the PTP.

Routing problems with multiple vehicles and profits are much less studied. Butt and Cavalier (1994) define the Multiple Tour Maximum Collection Problem (MTMCP), a generalization of the OP where the same maximum tour length is applied to several vehicles. Chao, Golden, and Wasil (1996) study the same problem but introduce a nowadays standard name, the Team Orienteering Problem (TOP). A few recent papers have tackled the TOP with Time Windows (TOPTW), see for instance (Labadie, Mansini, Melechovsky, & Wolfler-Calvo, 2012) who develop a granular variable neighborhood search. The TOPTW is close to our PDPTWPR but does not distinguish between pickup and delivery nodes. A recent paper by Archetti, Corberan, Sanchis, Plana, and Speranza (2014) presents the Team Orienteering Arc Routing Problem (TOARP), but in a truckload (TL) context: since each vehicle can transport one request at a time, each request can be modeled by one arc, which leads to an Arc Routing Problem (ARP).

For more details on VRPPs, we refer readers to the technical report written by Archetti, Speranza, and Vigo (2013).

Please cite this article as: Y. Li et al., Adaptive large neighborhood search for the pickup and delivery problem with time windows, profits, and reserved requests, European Journal of Operational Research (2016), http://dx.doi.org/10.1016/j.ejor.2015.12.032