Combinatorial auction for LTL transportation service procurement with clusters of requests

Asma Ben Said¹, Haoxun Chen², Aziz Moukrim¹

¹Sorbonne universités, Université de technologie de Compiègne
CNRS, Heudiasyc UMR 7253, CS 60 319, 60 203 Compiègne cedex

²Laboratoire d’Optimisation des Systèmes Industriels
Institut Charles Delaunay, Université de Technologie de Troyes
asma.ben-said@hds.utc.fr, haoxun.chen@utt.fr, aziz.moukrim@hds.utc.fr

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Order delivery plays a critical role in e-commerce. To reduce transportation costs, multiple shippers (suppliers of goods) first consolidate their customer orders which correspond to pickup and delivery requests and then procure transportation services from one or multiple carriers to deliver these orders to customers. The consolidation of the customer orders is realized by solving a centralized transportation planning problem of all shippers involved, leading to a set of routes or in other words a set of request clusters. Each cluster of requests must be assigned to and served by a single carrier.

Transportation service procurement is usually realized by an auction ([1]). In the literature of auctions for transportation service procurement, it is assumed that all transportation requests involved are independent elements ([1]). In this study, we propose a combinatorial auction (CA) for the procurement of transportation services in less than truckload transportation environment with clusters of pickup and delivery requests. The CA is iterative and price-based. In each iteration (round), the auctioneer determines a price for serving each cluster of requests, and each carrier bids for a subset of request clusters to serve so as to maximize its profit based on the price information.

Two decision problems must be solved by the auctioneer and each carrier respectively in each iteration of the auction. One is the winner determination problem (WDP) which determines tentative winning carriers and bids, and the bid generation problem which determines which clusters of requests to bid and serve by each carrier. We consider a real situation where the pickup and delivery operations of each request must be performed within their pre-specified time windows. Moreover, each carrier may have reserved clusters of requests that must be served by the carrier itself, so a cluster can be reserved or selective depending on whether the service of its all requests is mandatory or not. Each cluster is associated with a profit that is collected only if all requests belonging to the cluster are served. The bid generation problem is thus a Clustered Pickup and Delivery Problem with Time Windows, Profits, and Reserved Requests (CPDPTWPR). This problem has not been studied yet in the literature to the best of our knowledge.

The objective of CPDPTWPR for each carrier is to select selective clusters to serve in addition to its reserved clusters and to design vehicle routes to serve all selected and reserved requests so as to maximize the total collected profit minus the travel cost of all vehicles used. The problem involves coupling, precedence, time windows and capacity constraints.
The CPDPTWPR can be decomposed into a master problem that seeks to determine a subset of selective clusters to serve and a routing sub-problem that seeks to design routes for serving all requests in the reserved clusters and the selected clusters. Based on this decomposition, we propose a bi-level iterative heuristic in which each level performs a different search strategy. The upper level treats the knapsack aspect of the problem and the lower level treats the routing sub-problem as a PDPTWPR ([2]) in order to minimize the travel cost. The key of the upper level is to find compatible clusters that can lead to feasible solutions with good quality. To that end, the proposed heuristic applies an adaptive iterative destruction/construction heuristic (AID/CH) to construct feasible solutions. The main component of our AID/CH is the adaptive construction heuristic based on a Best insertion algorithm (BIA). This algorithm tries to insert unserved clusters one by one in a solution. For each cluster, the requests are considered in a certain order and are inserted in the best position. The objective of BIA is to evaluate, in each iteration, all feasible insertions and then perform the best insertion. Within the iterative framework, we apply a series of construction/destruction procedures. In addition, many inter- and intra-route neighborhood operators are employed. Once the upper level terminates and returns a feasible solution, the method is switched to the lower level. In this lower level, the requests served in the feasible solution obtained by the upper level are considered, for which an AID/CH is applied to solve a PDPTWPR problem where all requests are reserved. The main difference of AID/CH procedures is that in the upper level the clusters are considered for insertion and destruction while in the lower level requests are considered for insertion and destruction. The two levels are repeatedly applied until a certain number of non-improving iterations is achieved.

To evaluate the performance of our proposed heuristic for CPDPTWPR, we first compare it with a state-of-art method proposed to solve PDPTWPR. Numerical experiments show that our algorithm can obtain best results for 48 instances over 54 instances and give 30 new best solutions with less computation time. We then generate a set of instances for CPDPTWPR. For small size instances in this set, our method can find the same optimal solutions as those found by solving a Mixed-Integer Linear Programming (MILP) model of CPDPTWPR.

Except for the algorithm to solve CPDPTWPR, we also provide a price-updating mechanism and a binary integer programming model of WDP for the CA. Preliminary numerical results show the effectiveness of the CA.

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References