The Role of Collaborative Procurement of Transportation Services in Improving the Green Supply Chain Management

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***Abstract*—The lack of collaborative opportunities for the procurement of truckload transportation services can expose companies to high costs while transporting their goods. Moreover, carriers are forced to perform many movements with empty trucks for repositioning which represent a big environmental challenge. Our idea is to conduct e-procurement auctions in order to encourage the companies to diversify their channels for the transportation procurement. In this context, combinatorial auctions (CAs) represent an ideal tool to achieve this goal. In this new settings, new decisional policies should be defined by both the companies and the carriers. This work stands from the carrier's viewpoint who would be interested to collaborate with his competitors in order to achieve savings and to contribute for a green supply chain management. In this paper, we solve the problem of generating bids to be submitted to CAs in order to ensure loads for trucks that would travel otherwise empty. We discuss an decision support model and validate it through computational experiments.**

***Index Terms*—Green supply chain management, decision support model, transportation e-procurement, combinatorial auctions.**

I. Introduction

Electronic spot markets have shown to be an ideal tool for exchanging goods and services. Several E-markets, indeed, have been implemented and applied to different applications during the last decades even for improve green nature of supply chains.

The actors involved span from Business (B) to Consumers (C) till reaching Governments (G). Figure 1 shows the possible e-market combinations and gives an example for each alternative [1], [2]. Specifically, Internet-based CAs have shown to be very efficient in different sectors including public allocation problems that traditionally were managed through (often inefficient) regulatory orders [3], [4]. A first tentative in this direction appeared in the 80s of the last century when an auction mechanism has been proposed for allocating airport landing slots [5]. Even though this last study has proven that CAs can achieve more efficient outcomes with respect to non-combinatorial mechanism, real-life applications in this sector have been seen only two decades later [6]. Many other governmental-controlled sectors have got great benefit from the use of CAs. Examples include telephone service obligations [7], spectrum licenses [8], treasury bills [9] and deregulated electricity markets [10].

Things went differently in the field of truckload transportation services. Indeed, Anandalingam *et al*. pointed out in [6] that the governmental authorities were not fast enough to implement the challenges related to combinatorial nature of the auctions and, thus, B2B pioneers have led the innovation in this sector. A non-exhaustive list of companies (mostly installed in U.S.A.) that have applied successfully CAs to procure transportation services include Sears Logistics Services, The Home Depot, Walmart Stores, Compaq Computer Co., Staples Inc., The Limited Inc., Limited Logistics Services, Kmart Corporation, and Ford Motor Company [11], [12]. In many other regions of the world, however, private companies did not pioneered any alternative channel for procuring transportation services and, given the importance of the sector, those regions are failing to move towards more efficient green supply chains.

Moreover, the actors participating in CAs have to face the solution of complex decision support models in order to optimize their transportation network management. This work stands from the carrier's viewpoint who would be interested to achieve savings and to contribute for a green supply chain management. In this paper, we solve the problem of generating bids to be submitted to CAs in order to ensure loads for trucks that would travel otherwise empty. Scientific literature report example of the amount of money that can be saved using collaborative planning of transportation procurement; For example, the loss due to empty trucks movements in the case U.S.A. logistics market can be quantified in more than $165 billion [13].

The paper is organized in 5 sections. In Section II we introduce the problem and we summarize the literature review related to this topic. In Sections III we introduce the CAs, the specific problem to be solved and we describe our optimization model together with the solution approach. In Section IV we report some experimental experience in order to validate the model and discuss the results and, finally, we draw in Section V some concluding remarks.

	Government	Business	Consumer
Government	G2G e.g coordination	G2B e.g. information	G2C e.g. information
Business	B2G e.g E-procurement	B2B e.g. E-commerce	B2C e.g. e-commerce (Amazon.com)
Consumer	C2G e.g tax compliance	C2B e.g. price comparison	C2C e.g. e-markets (eBay.com)

Fig. 1. Internet-based markets [1].

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II. Problem Statement and Literature Review

Traditional auctions have been used since ancient times because of their efficiency as a business tool to exchange and price several kinds of goods. Recently, auctions organized via internet have received a lot of attention due to the growing popularity of electronic markets and to the efficiency and fairness characterizing these mechanisms.

ACs are multi-item auctions in which the bidders can define their own combinations of items and can submit bids consisting on bundles instead of on single items. This mechanism allows the bidders to take advantage of the complementarity effect that can characterize the different items to be auctioned and protect them against the so-called exposure problem.

In the context of transportation procurement, the auctioneer usually is the shipper who wants to buy long-haul full-truck transportation services in order to move a set of loads (called also lanes) from their pickup to their delivery locations. The bidders are interested carriers who have to submit bids on the transportation loads that they want to serve, not individually but grouped into bundles of loads.

CAs offer significant advantages for both shippers and carriers. Auctioneers, indeed, can achieve more economic efficiency and transportation cost savings of up to 15% while maintaining or increasing their service levels [11]. Bidders can take into account their economies of scope while expressing their preferences on the packages to be served. The Bid Generation Problem (BGP) interests the carriers that have to face the problem of constructing the bundles of loads to be submitted in the auction as bids. The BGP is a complex problem that bidders, traditionally, avoid to face by submitting singleton load bids. Its complexity derives from the necessity of evaluating an exponential number of potential bundles representing all the possible subsets that can be made out by the auctioned loads. Interested readers are directed to the following works: [14]-[22].

In this paper we focus on another complicating aspect of the BGP consisting in the stochastic aspect of the problem. Indeed, at the moment of submitting their bids to the auction the carriers cannot know the clearing price and have to take, thus, decisions under uncertain settings. Yet, only few contributions have targeted this important issue. Ergun et al. considered in [23] the price of a bundle as a decision variable and not as a parameter and considered the auction clearing price as a random variable. However, they simplified the study to the case of several single independent auctions that run simultaneously. The second work we are aware of is due to Triki et al. who have presented in [24] an accurate analysis of the BGP in a CAs for the full truckload transportation procurement. Their major scientific contribution consisted in developing a probabilistic mathematical model that integrates the bid generation and pricing problems together with the routing of the carrier's fleet.

This paper is inspired from the previous work, but it attempts to solve the problem exactly rather than relying on heuristic methods. We develop, indeed, a decision support tool based on an implementation of an optimization model that allows to find the optimal solution by using a well-known modeling language.

III. Risk Optimization Model and Solution Approach

Our optimization model has the goal of determining which set of bids to be submitted to the CA among all the possible bids (in total $2^n - 1$). Each bid will be constituted of a subset of the loads to be auctioned. The objective is to maximize the possible revenue deriving from serving the successful bids minus the routing cost. The optimization model has, thus, three sets of decisions to be taken as follows:

- X_b bid *b* to be submitted or not (binary)
- P_b price corresponding to bid *b* to be submitted
- Y_t routing of all the trucks that will satisfy all the successful loads in bid *b* (binary)

The optimization model can be represented as following:

$$\textit{Maximize} \quad \text{Profit} = P_b . X_b - C_t . Y_t$$

Subject to

$$\text{P rob}\left[P_b \geq \text{Competitors\_Lowest\_Price}\right] \leq \alpha$$

$$Y_t \in \text{Set\_of\_Feasible\_Tours}$$

$$X_b, Y_t : \text{Binary}, \quad P_b \geq 0$$

In this model the objective function represents, as mentioned above, the maximization of the carrier's profit. The probabilistic constraint will represent a measure of the exposure of the carrier to the risk of winning or not bid *b*. Indeed, any bid must satisfy, in order to be successful, the condition that the bid's price is less than the lowest price submitted by the competitors. However, this latter is not known in advance and represents thus a random variable that we face here by assuming a decision-maker threshold of the risk of not being successful. When the Risk threshold level" (a) increases then the carrier will be more aggressive by bidding in the auction even with bids that do not have big chance of success. In stochastic settings, this may be a fruitful policy that allows the carrier to express his aversion towards risk while participating in CAs. It is worth noting that the above model includes many other complicating features related to the actual definition of the "Set_of_Feasible_Tours" and to the transformation of the probabilistic constraint to a deterministically equivalent one.

The environmental and economic consequences of using the suggested model within CAs for the transportation procurement are obvious. The carriers will try to avoid having empty trucks travelling by filling the gaps with as many as possible loads auctioned in CAs. A wide use of this approach will reduce the number of trucks travelling empty over all the region and, consequently, will increase the utilization rate of the trucks and reduce the emission of gases, road jams, accidents, etc.

In this paper, we will solve the problem exactly in order to determine the optimal solution rather than using heuristics. We have, thus, developed a solution implementation that uses Lingo 13.0 as a modelling and solving environment. Our implementation involves all the complicating features related to both the routing aspects (nodes in-out balance, sub-tour eliminations, etc.) and the deterministically converted probabilistic constraint. Our preliminary computational experiments that validate the model are described in the following section.

IV. Illustrative Computational Example

In order to validate the optimization model we have carried out a computational experiment by considering a simple, yet significant, test problem, as represented in Figure 1. The test instance involve seven loads, four of them are already committed by the carrier (called booked loads: L1 and L2, L5 and L6) and the three others are auctioned ones (loads L3, L4 and L7) while connections AG, HE, CD and BE do not require any service but can be used for repositioning purpose. Moreover, we assume to have two trucks with enough capacity available at cities A and D respectively. The travel time for each load is chosen to be 1 day over a planning horizon of 5 days. The cost for serving each load depends only on the distance. In our example, having three auctioned loads, we can generate the following 7 different bids including all the loads combinations:

- 1-load bundles: {L3}, {L4}, {L7}
- 2-load bundles: {L3, L4}, {L3, L7}, {L4, L7}
- 3-load bundle: {L3, L4, L7}.

The results of the experimental study have shown that bid {L3, L4} is the optimum bundle that should be served since it ensures the maximum profit. Moreover, we get the following routing schedule:

- Truck K1 moves from city A to city B at the first day of the planning horizon then it continues to city C and finally goes back to city A;
- Truck K2 waits till day three to move from city D to city E then to city F then, it returns back to D.

These results show the validity of our model since it determines logical results. From the network depicted in Fig. 2 it seems clear, indeed, that load L7 was far away from the loops that the trucks can perform without causing excessive service cost.

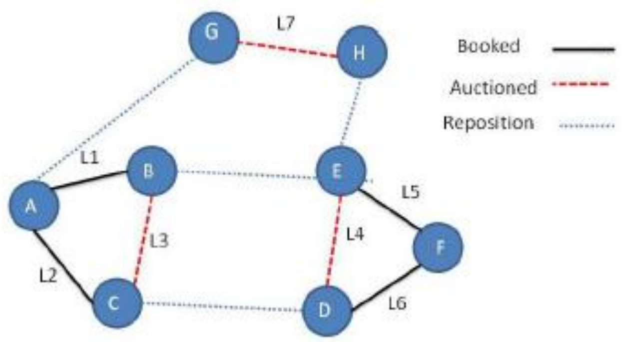

Fig. 2. Illustrative example test problem.

V. Conclusion

This work has the objective of proposing an environmental friendly collaborative approach that allows to reduce the routing of empty trucks in any national or regional transportation network. It consists on defining spot markets for transportation loads, based on CAs, that allow the shippers to procure efficiently their transportation needs and, in the same time, the carriers to increase the utilization rate of their trucks and reduce the emissions of harmful gasses. Achieving this goal will constitute a concrete contribution towards the improvement of green supply chains management. For this purpose, we propose an optimization model that supports carriers in generating the optimal bids to be submitted to the CAs. We solve exactly the formulation by using a well-known modeling language and we validate it while solving a simple test problem.

Possible research development in this direction can include considering a two-sided CAs in which every carrier can, in the same time, offer undesirable loads and bid on his favorite combination of bids. This scheme, even though more complex, will ensure remarkable advantages for all the actors involved in the transportation services and also to the society that can rely on a less environmental impact and more economic efficiency of its transportation network.

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