Computers & Industrial Engineering 106 (2017) 182–191

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Heuristic methods for the periodic Shipper Lane Selection Problem in transportation auctions

Chefi Triki [a,b,*], Seyedmehdi Mirmohammadsadeghi [c], Sujan Piya [a]

[a] Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, AL-Khoud 123, Muscat, Oman
[b] Department of Engineering for Innovation, University of Salento, via per Monteroni, 73047 Lecce, Italy
[c] Young Researchers and Elite Club, Najafabad Branch, Islamic Azad University, Najafabad, Iran

ARTICLE INFO

Article history:
Received 30 June 2016
Received in revised form 29 January 2017
Accepted 6 February 2017
Available online 8 February 2017

Keywords:
Shipper Lane Selection Problem
Transportation procurement
Auctions
Synergy
Simulated annealing

ABSTRACT

In the Shipper Lane Selection Problem (SLSP) a set of lanes should be classified either to be serviced by the shipper's fleet or through auction. However, it is common in real-life problems that the same lane should be served multiple times during the planning horizon. In this study, the periodicity nature of the problem is incorporated into the SLSP. Thus, a novel variant of the problem, namely the Periodic SLSP (P-SLSP) is introduced. The aim is to achieve savings on the shipper transportation costs over the extended horizon. The problem is modeled as an integer programming formulation and solved first with a general purpose software. Subsequently, three different heuristic methods have been developed to overcome the limitation of the exact full-space method. The validity of the model as well as the efficiency of the heuristics have been tested by using a properly modified set of Solomon's benchmark problems. Intensive computational analysis indicates the appropriateness of the proposed heuristics and their relevance for solving large-scale P-SLSPs.

1. Introduction

An auction is "a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants" (McAfee & McMillan, 1987). An auction process involves the auctioneer, who wants to sell his goods or service, and the bidders, who will bid on the goods or service being offered. The goods/service will be assigned to the successful bidder determined by the auctioneer on the basis of his objective function. Since ancient times, traditional auctions have been employed due to their efficiency in business trading. With the advent of efficient information technologies, the traditional methods are being replaced by auctions that are run over internet. Electronic auctions help in reducing transaction and participation costs as compared to the traditional ones and ensure the access to a larger number of market participants (Yong, Li, & Zheng, 2011). In the last decades several such auctions have been introduced in different application fields covering business, retail consumers and governmental sectors as well.

Basically, traditional auctions focused on single items assuming that the items do not exhibit any complimentary effect from the bidders viewpoint. However, in reality, bidders often show preferences for certain sets of items and prefers to attempt to procure them within the same auction session. For this purpose, many other internet-based auction designs have been proposed such as simultaneous auctions (Kuyzu, Akyol, Ergun, & Savelsbergh, 2015), sequential auctions (Figliozzi, Mahmassani, & Jaillet, 2006) and combinatorial auctions (Triki, Oprea, Beraldi, & Crainic, 2014). The latter design has recently gained more attention in both academia as well as in industry due to their efficiency over the other auctions (Anandalingam, Day, & Raghavan, 2005; Kwon, Anandalingam, & Ungar, 2005). Several studies have shown how their employment in allocating different resources has produced efficient assignments (Ball, Donohue, & Hoffman, 2006; Beraldi, Conforti, Triki, & Violi, 2004; Brewer, 1999; Gunluk, Ladanyi, & De Vries, 2005; Menezes, 1995; Rassenti, Smith, & Bulfin, 1982; Triki, Beraldi, & Gross, 2005).

Even in the logistics sector, many literature studies have reported several experiences of companies that have successfully used auctions in order to procure their transportation needs. In the context of transportation procurement, the reverse auction has become an important tool for buyers to purchase goods or services (Teich, Wallenius, Wallenius, & Zaitsev, 2006). The reverse auction is based on the traditional auction in which one buyer solicits bids from multiple potential suppliers (Huang, Qian, Fang, & Wang, 2016). The buyer places a request for the desired good

* Corresponding author at: Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, AL-Khoud 123, Muscat, Oman.
E-mail address: chefi.triki@unisalento.it (C. Triki).

http://dx.doi.org/10.1016/j.cie.2017.02.005
0360-8352/

or service. The sellers then submit their bids for the amount that they expect to be paid for and, at the end, the buyer clears the auction and determines the winners.

In the transportation procurement, the buyer or auctioneer is the shipper who wants to buy transportation services in order to move a set of loads (lanes) from their pickup to their delivery locations. On the other hand, the bidders or sellers are the interested carriers who will submit bids to the auction on the lanes that they want to serve. According to Sheffi (2004) the use of auctions can help both shippers and carriers to achieve significant economic efficiency while maintaining or improving their service levels. Specifically, the shipper's concern is to find the best possible way to procure his needs such that the total service cost of all the lanes is minimized. Even though some papers have considered serving the entire set of lanes using only third party, other references have proven how the shipper can significantly reduce his costs for the same service level by outsourcing a subset of the lanes through auction (Kuyzu et al., 2015; Xu, Cheng, & Huang, 2015; Xu & Huang, 2013, 2014).

This study will focus on developing optimization methods to help the shipper in classifying the lanes between self-service and outsourcing. More specifically, the contributions of the this paper can be summarized as follows: (i) solve the SLSP over an extended time horizon (by defining a new variant of the problem, namely the P-SLSP) and model it as an integer programming formulation, (ii) develop three novel metaheuristic approaches, (iii) validate their performance with respect to both a general purpose solver and to the state-of-the-art model and finally (iv) perform some sensitivity analysis with respect to the most significant parameters of the problem and the heuristic methods as well.

The remainder of the paper is organized as follows. Section 2 reviews the studies that have been so far carried out in this area. Section 3 discusses the specific variant of the problem that this paper is addressing and develops a mathematical model for its solution. Section 4 describes the heuristic methods proposed to solve large-scale instances of the problem. Section 5 validates our model and methods through intensive computational experiments. The paper is concluded with some future research directions in Section 6.

2. Literature review

Companies often face many challenges while serving their customers. It is widely accepted that firms aiming to service customers that are scattered in a vast area should possess a servicing plan to save time and money. Freight transportation is considered as the largest logistics expense for a vast number of companies and it is the area where significant savings can be achieved (Ghiani, Laporte, & Musmanno, 2013). Large shippers usually cover part of their transportation needs by using either their own fleet or through forward contracts with third- and forth-party logistics providers. As stated by Potvin and Naud (2011), this happens when, for example, the demand exceeds the shipper's capacity or for economical convenience (see also Attanasio, Fuduli, Ghiani, & Triki, 2007). One alternative possible approach with this regard is to consider auctions as an option instead of relying only on the company's fleet or on forward contracts (Huang & Xu, 2013). The items auctioned off are transportation lanes. With the advances achieved in designing and running auctions through internet the shippers can also take advantage from the new trading mechanism.

A typical auction in transportation logistics consists of three phases. In the initial phase of auction the shipper will try to identify the transportation lanes that will be served by his own fleet and those to put into auction. Then, the shipper will invite carriers to bid on the auctioned lanes. This problem is known as the SLSP (Guastaroba, Mansini, & Speranza, 2009).

The second phase of the auction constitutes the Bid Generation Problem (BGP). In this phase the invited carriers will determine the bidding strategy in terms of defining the lanes on which they want to bid and their corresponding bidding prices (Chang, 2009; Kuyzu et al., 2015; Lee, Kwon, & Ma, 2007; Triki et al., 2014).

Finally, the last phase consists in solving the Winner Determination Problem (WDP) by the shipper just after the deadline of the bids submission. The WDP will select and assign the successful bids to the carriers on the basis of the cost minimization criteria. This problem has received considerable attention and has been extensively investigated in different application contexts (Caplice & Sheffi, 2006; Ignatius et al., 2014; Ma, Kwon, & Lee, 2010; Remli & Rekik, 2013).

From the above discussion it is evident that the SLSP has received very limited attention in academia even though it is one of the most important phases of transportation procurement in reverse auctions. To the best of our knowledge the SLSP has been subject to one single research work due to Guastaroba et al. (2009). The authors developed two different optimization models covering a single period horizon and compared their performance on limited-size problems generated from Solomon's instances (Solomon, 1987). Since the problem addressed is NP-hard in its strongest sense, there is a need to design efficient and effective heuristics to solve industrial size problems within a reasonable computational time.

Moreover, most of the problems related to the transportation procurement are characterized by the fact that most of the lanes need to be served for a specified number of times (r_l) within a T-day planning horizon rather than being served every day. According to Triki (2013) and Campbell and Wilson (2014) serving the lanes multiple times over an extended planning horizon may also produce substantial savings for the companies. Such a periodicity concept has received wide attention in Vehicle Routine Problem (VRP) due to its versatility coupled with the challenges it brings in solving the problem (Campbell & Wilson, 2014). The PVRP (P stands for Periodic) has been implemented successfully in broader applications such as delivery of products to the stores (Ronen & Goodhart, 2008), workforce planning (Smilowitz, Nowak, & Jiang, 2013), waste collection (Nuortio, Kytöjoki, Niska, & Bräysy, 2006), etc. Moreover, several solution methods have been developed to overcome the complexity related to the PVRP such as Tabu Search (Cordeau, Gendreau, & Laporte, 1997 and also Potvin & Naud, 2011) and local search methods (Vidal, Crainic, Gendreau, Lahrichi, & Rei, 2012). To the best of our knowledge, the concept of periodicity has never been used within the framework of transportation auctions where some of the lanes will be served by shipper's own fleet and the rest will be assigned to the successful bidders. The problem being addressed in PVRP is different from the P-SLSP in that PVRP deals with identifying the best routes that consolidate the optimal periodic combination for each customer. On the other hand, in the P-SLSP the shipper needs to identify, first, the set of lanes to be served by his fleet before defining the best routes while considering the lanes' periodicity. Therefore, in order to fill the gap of scarcity this context and to bring the problem closer to reality, the P-SLSP has been considered in this research. In this avenue, apart from the optimization model, three different heuristic methods have been proposed for solving large-scale P-SLSPs.

3. Optimization model

An extended planning horizon ($t = 1, \dots, T$) composed of T days has been considered during which a set of lanes (L) has to be served once or more times each during the planning horizon. Each lane is characterized by a source and a destination location. Given a complete bi-directed graph $G = (V, H)$ with V is the nodes set (including the depot) and H is the arcs set (with $L \subseteq$ H), the objective is to minimize the total transportation costs plus the costs of auctioning