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Request selection and exchange approach for carrier collaboration based on auction of a single request

Junsong Li [a,b], Gang Rong [a,*], Yiping Feng [a]

[a] State Key Laboratory of Industrial Control Technology, Department of Control Science and Engineering, Zhejiang University, Hangzhou 310027, China
[b] College of Information Science and Technology, Zhejiang Sci-Tech University, Hangzhou 310018, China

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ABSTRACT

This paper addresses the request selection and exchange problem in the carrier collaboration process with limited sharing of carrier's request information. A framework including two decision makers, carrier and coordinator, is constructed and its collaboration process is described. In this framework, two request selection models for the carriers are established. In addition, a request exchange method for the coordinator is proposed and four profit allocation strategies are discussed. Compared with other four approaches, simulation results show that the proposed approach is effective and efficient.

1. Introduction

With the fast economic development, transportation demands between various nodes in the supply chain are growing gradually. These bring a lot of opportunities to the carriers. On the other hand, along with the high cost of unit transportation and the intensive competition in the transport market, carriers, especially the small and medium-sized carriers, are suffering considerable pressure to survive. The general solution is to optimize the internal vehicle routing to reduce the cost. However, this solution has limited room for profit improvement as it can only optimize resource allocation within an individual carrier.

Recently, researchers pay more attention to the collaborative transportation in order to increase market share and improve profits for carriers. The collaborative transportation mode has been studied from several aspects. From the supply chain perspective, the Voluntary Inter-industry Commerce Solutions Association (VICS) logistics committee developed Collaborative Transportation Management (CTM). CTM can enhance the interaction and collaboration between three principal parties: shipper, carrier and receiver, as well as secondary participants such as third-party logistics (3PLs) service providers to eliminate inefficiencies in the supply chain (Committee, 2004). The collaboration between different transport participants, such as the cooperation between shippers and a 3PL, is called vertical collaboration by Cruijssen et al. (2007a). Meanwhile, this reference analyzed the collaboration between the same transport participants which is called the horizontal collaboration and indicated that the collaboration can improve their profits and service qualities. Song and Regan (2003) proposed an auction approach based Collaborative Carrier Network (CCN) for the collaboration among carriers. Their analysis shows that the system is Pareto efficient in which no participants are harmed and many are better off.

* Corresponding author. Tel.: +86 571 87953145.
E-mail address: grong@iipc.zju.edu.cn (G. Rong).

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CCN can also be described as one kind of collaborative transportation alliance, briefly called alliance. The primary objective of CCN is to make the alliance obtain maximum profits along with more profits for participants of the alliance. An alliance is commonly composed of multi-carriers who provide identical transportation service in a fixed geographic area. They exchange self-owned transportation requests to increase the profit and optimize the transportation resource. The formation of alliance is largely dynamic and randomness. Small and medium-sized carriers or relatively independent departments in large-scale transportation companies can form an alliance voluntarily according to the requirement at any time. Generally, carriers own limited number of fleet. Before participating in the alliance, most of the carriers can serve a certain amount of transportation requests from customers (such as shippers) by the route optimization based on their transport capacity in a transportation cycle (such as one day). Therefore, the alliance possesses a certain amount of transportation resource including transportation tools and requests. The process of collaboration can be regarded as an optimization for the resource reallocation in an alliance. Several problems/issues need to be addressed in the construction process. Firstly, carriers in the alliance have not only synergic but competitive relationship that will make carriers not want to share their private information (such as request information, fleet information) completely. Secondly, carriers need to consider how to select requests for outsourcing and purchasing before request exchange. Thirdly, how to exchange request, namely which kind of mechanism for request exchange, can optimize the transportation resource reallocation in the alliance. Finally, how to allocate the increased profits in the alliance also needs to be addressed.

The following researches are performed to address the above-described problems/issues in the carrier collaboration with single request auction mode. First, a framework of operational process for carrier collaboration with two types of decision makers, the carrier and the coordinator, is constructed. This framework extends traditional local collaboration, namely CCN, to a larger range. In the meantime, the most private information is isolated within carriers. In this framework, we establish an Outsourcing Request Selection Model (ORSM) and a Sourcing Request Selection Model (SRSM) for carriers based on marginal profits. These models allow for better independent decision-making abilities of carriers. Second, the Maximum Profit Increase (MPI), a request exchange approach based on the auction of a single request, is proposed for the coordinator. This approach makes the alliance acquire maximal profit when a single request is exchanged with limited sharing of carrier's request information. Third, four profit allocation strategies are discussed for MPI. Finally, a set of simulations are performed to compare the performance of the approach proposed in this paper with that of other four approaches. The results show that the proposed approach is effectiveness and efficiency.

The rest of this paper is organized as follows. In the next Section, we briefly review the literature on the carrier collaborative transportation. In Section 3, the framework, the scope of carrier collaborative transportation and the notations are described. Two mathematical models of the request selection are presented in Section 4. In Section 5, we discuss the optimization process of the request exchange and the profit distribution. In Section 6, the computer simulation is demonstrated and the computational results are analyzed. The conclusion and future research directions are given in Section 7.

2. Literature review

According to the definition for CTM by VICS, the collaboration transportation involves a variety of different transportation-related elements such as different transport participants and different transport modes. Accordingly, researchers have carried out comprehensive researches for collaboration involving carriers in the horizontal coordination level. The horizontal collaboration mainly focus on the collaborations between transport participants at the same level (European Union, 2001). Cruijssen et al. (2007b) summarized some features of horizontal collaboration from many perspectives, e.g. horizontal relationships and types of cooperation. Groothedde et al. (2005) discussed the intermodal hub network. The collaboration between different modes of transports is achieved by the design of many-to-many hub networks from the perspective of collaboration structure. The case study in logistics networks shows that economies of scale and scope can be achieved through this network. Ergun et al. (2007) developed several solution algorithms for the shipper collaboration. Their goal is to identify a set of route that can be submitted to the carrier as a bundle to acquire more favorable rates. In addition, for the carrier collaboration, a classic problem called Multi-Depot Vehicle Routing Problem (MDVRP) has been widely studied. For example, Escobar et al. (2014), Liu et al. (2010a), Yu et al. (2011) developed a variety of different heuristic algorithms under different constraints to improve the efficiency of MDVRP solving process. The essence of these solutions is to solve collaborative optimization between carriers through a centralized control approach.

Some literature discussed carrier collaboration with different collaborative processes and manners. Chu (2005) considered the usage of outside carriers when the total demand is beyond the transport capacity of the carrier. At the same time, a mathematical model and a heuristic algorithm are constructed for this collaborative process based on node requests subcontracted to outside carriers. Following Chu's studies, Bolduc et al. (2007, 2008) further improved the mathematical model of this collaborative method and proposed the better heuristic algorithms. Liu et al. (2010b) extended this collaborative manner: not only internal requests can be subcontracted from carriers to external carriers, but also external requests can be subcontracted from external carriers to carriers. The collaborative process is discussed based on the arc routing problem. This kind of carrier collaboration has two major features: first, the collaboration only occurs between the private vehicles and the external carriers; second, the value of the subcontracted request is a fixed value determined by the transport market. For the collaborative process between multiple carriers, Kopfer and Pankratz (1999) and Krajewska et al. (2008) studied a groupage system which exchanges information and manages capacity balance by the cooperation between several independent