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Decision Support for Collaboration of Carriers Based on Clustering, Swarm Intelligence and Shapley Value

Fu-Shiung Hsieh, Chaoyang University of Technology, Taichung City, Taiwan

ABSTRACT

Transportation costs constitute an important part in providing services and goods to customers. How to reduce transportation costs has a significant influence on competitive advantage of carriers. Although a lot of vehicle routing problems (VRP) and their variants have been extensively studied to reduce transportation costs via optimization of vehicle routes, little research focuses on how to achieve lower transportation costs through cooperation of carriers while fulfilling customer requests. This article aims to develop a decision support framework to facilitate cooperation of carriers to reduce transportation costs further based on information sharing, clustering requests, swarm intelligence, and the Shapley value cost allocation scheme. Two decision models for two carriers are compared: one reflecting the scenario without cooperation between the two carriers and the other one reflecting the scenario with cooperation between the two carriers. The simulation results indicate that the swarm intelligence and Shapley value based cooperative decision model outperforms that of the independent decision model.

KEYWORDS

Collaboration, Cost Allocation, Decision Support System, Information Sharing, Shapley Value, Swarm Intelligence

1. INTRODUCTION

Transportation is an important part of carriers as it imposes considerable cost on providing goods and has a significant influence on their competitive advantage. How to reduce transportation costs is an important issue in improving the profit of carriers. Vehicle routing is a critical factor in reducing transportation costs. Finding optimal vehicle routes offers great potential to efficiently manage fleets, reduce costs and improve service quality. An effective scheme to manage fleets and determine vehicle routes for delivering goods is important for carriers to survive. In the existing literature, a variety of vehicle routing problems (VRP) have been studied extensively. The classical VRP can be defined as the determination of an optimal set of routes for a fleet of vehicles to serve a set of customers (Dantzig & Ramser, 1959). VRP is NP-hard and therefore heuristic algorithms are required for tackling real-life instances (Toth, Vigo, 1998). Earlier surveys on VRP can be found in (Laporte et al. 2000) and (Christofides et al. 1979). Several methods to solve the classical VRP include the constructive heuristics proposed by Clarke and Wright (Clarke and

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Wright, 1964), generalized savings approach proposed by Mole and Jameson (Mole & Jamson, 1976), and the sweep algorithm proposed by Gillett and Miller (Gillett and Miller, 1974). Two earlier surveys for this very active research area are provided by Gendreau et al. (Gendreau et al. 1998) and by Golden et al. (Golden et al. 1998). Following the development of the classical VRP, several variants of VRP have been studied (Casco et al. 1988; Gendreau et al. 1996; Goetschalckx & Jacobs-Blecha, 1989; Kalantari et al. 1985; Vigo & Toth, 1997; Thangiah et al. 1996; Savelsbergh, 1985; Goksal et al. 2013; Chen & Wu, 2006; Salhi & Nagy 1999). For a recent survey of VRP, please refer to (Adewumi & Adeleke, 2016) and (Ritzinger et al. 2016). Although VRP has been extensively studied, most studies focus on VRP or its variants for one single carrier. How to cut down transportation cost through cooperation of carriers while fulfilling the customers' requests is an interesting and important issue.

There are several studies that address the issue on cooperation of freight carriers. In (Krajewska & Kopfer, 2006), Krajewska and Kopfer observed that increased competitiveness through cost reduction can be achieved if freight carriers cooperate in order to balance their request portfolios. They presented a model for collaboration among independent freight forwarding entities. Participation in such coalitions can benefit the entire coalition as well as each participant individually. The model for collaboration presented in (Krajewska & Kopfer, 2006) is based on theoretical foundations in the field of combinatorial auctions, operational research and game theory. The work presented in (Krajewska et al. 2008) combines features of routing and scheduling problems and cooperative game theory. A key question is how the total cost or savings should be distributed among the participants. Krajewska et al. analyze the profit margins resulting from horizontal cooperation among freight carriers and discussed the possibilities of sharing these profit margins fairly among the partners. In (Dahl & Derigs, 2011), Dahl and Derigs mentioned that for cooperation, the partners have to face two problems: (1) an optimization problem to achieve specific consolidation potentials through order exchange, and (2) the problem to find a fair cost/profit allocation schema for order exchanges. In (Juan et al. 2014), (Pérez-Bernabeu et al. 2014), Juan et al. studied how two or more companies can cooperate in horizontal cooperation in logistics to minimize global distribution costs including savings in routing costs and CO2 emissions costs. The topic of horizontal cooperation is gaining momentum in the transport and logistics sectors. Collaboration in transportation between two or more agents is becoming an important approach to find efficient solutions or plans. Cruijssen et al. presented a broad review of horizontal cooperation in transport and logistics (Cruijssen et al. 2007). Paper (Guajardoa and Ronnqvist, 2016) provides a survey on cost allocation methods found in the literature on collaborative transportation, including problems on planning, vehicle routing, traveling salesman, distribution, and inventory. In paper (Frisk 2010), the authors investigate a number of sharing mechanisms based on economic models and propose a new allocation method with the aim that relative profits of the participants are as equal as possible. Although the studies mentioned above have shed light on several research issues relevant to cooperation of carriers, there still lacks a study to support and evaluate the benefits of cooperation based on the distribution of depots and customers' requests.

Motivated by the deficiency of this research direction, this paper aims to study and evaluate the effectiveness of cooperation between carriers based on information sharing. The goal of this paper is to develop a framework and a solution algorithm to assess the benefits of cooperation between carriers, support their decisions and allocate cost reduction to carriers.

The remainder of this paper is organized as follows. Section 2 briefly introduces the background of this study. Section 3 introduces the two decision models. Section 4 describes the problem formulation for a single carrier and propose our problem formulation. Section 5 presents the discrete particle swarm optimization method. Section 6 details the clustering method and cost allocation scheme. Section 7 presents experiments based on numerical examples. Section 8 concludes this paper.