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Fair profit contract for a carrier collaboration framework in a green hub network under soft time-windows: Dual lexicographic max–min approach

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ABSTRACT

This paper models a novel and practical bi-objective hub-location problem under a centralized carrier collaboration framework between one holding company and multiple carriers. The holding company first establishes a hub-and-spoke network in order to locate *p* hubs and to assign the center nodes to the located hubs. Then, it allocates the transportation routes of the hub network to the carriers. In contrast, the carriers should select an appropriate vehicle type to serve the transportation requests in a green hub network. The carriers are also able to meet the transportation requests within a certain time-window based on a soft time-window mechanism. Moreover, aiming to emphasize green transportation, a vehicle emission model is used to take into account CO_2 emissions of the vehicles where the fuel consumption is a function of speed level. Aiming to identify a win–win deal between the holding company and the carriers, a dual lexicographic max–min (LMM) approach is used in order to optimize their profits in a fair way. Finally, some numerical experiments are presented to demonstrate the applicability of the proposed methodology. The computational results show that not only the holding company and the carriers can better generate a fair profit contract among themselves using the LMM approach, but also both can obtain more profit in the worst case for their businesses rather than using the max–min approach. In addition, sensitivity analyses show that increasing the size of the soft time-window leads to a reduction in the delivery schedule violations, while results in raising the total profit. Moreover, the tax cost of fuel consumption as well as the number of potential vehicles has a substantial impact on both the fuel consumption and carrier's profit.

1. Introduction and literature review

Hub-and-spoke networks play a significant role in the performance of transportation companies. According to UNCTAD (2012), approximately 80% of global trade by volume and 70% by value is transported through sea and is mainly accomplished by hub ports worldwide. Furthermore, as governments impose more tax regulations promoting the so-called environment-friendly policies in transportation activities, investment in such networks became even more important. A hub network is defined as a fully connected network with material/information flow between any two nodes being

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processed at a small number of hub nodes and moved through inter-hub links. Therefore, the hubs serve as transshipment or switching points for flows of the goods between the origin and destination center nodes (non-hub nodes), instead of generating direct links between them (Kratica et al., 2007). Hence, as the hubs consolidate and collect the flows, less operating cost can significantly be achieved because of the economies of scale concept.

In real world, the locations of hubs and the allocations of center nodes (i.e. *spokes*) to hubs is one of the most important issues in hub-and-spoke network problems. That is why the hub location problem (HLP) has recently received a widespread attention of both researchers and practitioners, where several models of hub-and-spoke networks are utilized in almost all modes of transport such as airline and railway. In this regard, Rotterdam and Hamburg in Europe, Singapore and Hong Kong in Asia, and Long Beach in the U.S.A. are instances of the world's major hub ports (Gelareh et al., 2015). In addition, Hong Kong and Singapore in Asia and Atlanta, Frankfurt and Paris in Europe, and Chicago in the U.S. are the other instances of the world's major airports. To give an insight on the hub network, an example of the hub airport location between 37 cities taken from the Iranian aviation dataset (IAD) is displayed in Fig. 1, in which Tehran and Kerman are active airports acting as the hubs (Karimi and Bashiri, 2011).

The work of O'Kelly and Bryan (1998) was a pioneer in HLP with the economies of scale on the trunk lines in an un-capacitated network. A HLP with stochastic time and service-level constraints is proposed by Sim et al. (2009) using mutually independent normal random variables for the travel times. Ge et al. (2010) developed a tree pruning algorithm for a capacitated HLP on the air transportation system using data on passenger flows between the top 20 Chinese cities. Stanimirović (2010) proposed a genetic algorithm to solve a HLP to minimize the total transportation cost. Yang et al. (2011) studied a HLP with discrete random travel times to minimize the efficient total travel time point. In addition, Yaman and Elloumi (2012) proposed an HLP model in a two-level star networks with regard to service quality considerations in order to minimize the total routing costs. Rabbani et al. (2013) described an HLP with a combined cost including fixed, health, safety, environmental, energy, and personnel costs. In addition, two mixed-integer programming for an HLP were introduced by Yang et al. (2013). They solved the problem using an improved hybrid particle-swarm optimization algorithm by combining genetic operators and local search. However, they did not take into account the capacity restrictions of the hubs. Furthermore, Bashiri et al. (2013) proposed a hybrid approach for an HLP using both qualitative and quantitative parameters to minimize the longest travel time. They utilized a fuzzy VIKOR in combination with a genetic algorithm to provide a hybrid solution.

Lüer-Villagra and Marianov (2013) presented a nonlinear programming formulation for a competitive HLP including the optimal pricing decision and a discrete choice of customers. They solved the problem using a genetic algorithm. Besides, Sasaki et al. (2014) introduced a general discrete Stackelberg HLP using the multiple allocation hub arc location model under a competitive environment. Mohammadi et al. (2014) developed a sustainable hub location-allocation problem using a mixed possibilistic-stochastic programming approach. They incorporated two environmental-based cost functions for the

Fig. 1. An instance of a hub-and-spoke network in Iranian aviation dataset.