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Innovative Applications of O.R.

Operational transportation planning of freight forwarding companies in horizontal coalitions

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ABSTRACT

In order to improve profitability, freight forwarding companies try to organize their operational transportation planning systematically, considering not only their own fleet but also external resources. Such external resources include vehicles from closely related subcontractors in vertical cooperations, autonomous common carriers on the transportation market, and cooperating partners in horizontal coalitions. In this paper, the transportation planning process of forwarders is studied and the benefit of including external resources is analyzed. By introducing subcontracting, the conventional routing of own vehicles is extended to an integrated operational transportation planning, which simultaneously constructs fulfillment plans with overall lowest costs using the own fleet and subcontractors' vehicles. This is then combined with planning strategies, which intend to increase the profitability by exchanging requests among members in horizontal coalitions. Computational results show considerable cost reductions using the proposed planning approach.

1. Introduction

The increasing pressure on modern freight forwarding companies to improve profitability has strongly influenced their fleet management and transportation planning strategies. In order to utilize resources more efficiently, it is no longer sufficient for forwarders to optimize the usage of their internal resources, but they also have to improve the management of external relations with other carriers. Forwarders can fulfill their acquired customer requests by applying the following options: (1) keeping the execution in-house using their own fleet (self-fulfillment), (2) forwarding requests to other carriers (subcontracting), and (3) exchanging requests with partners in horizontal cooperations (collaborative planning). Using all three options may result in considerable cost-savings. However, due to the high heterogeneity of these different options, forwarders have to apply new planning schemes to realize the embedded potential. In this paper, we study the operational transportation planning under consideration of all three fulfillment options.

Besides self-fulfillment, forwarders can subcontract some requests to subcontractors in vertical cooperations and to common carriers to reduce their fleet size. Due to the high fixed costs of vehicles, many forwarders strongly downsize their own fleet. This enables them to do "cherry-picking", i.e., assigning the most profitable tours to their own vehicles and filling the gap between the own fleet capacity and customer demand by using capacities of other carriers. As a consequence, the process of forwarding requests to subcontractors has to be integrated into the traditional vehicle routing and scheduling. Krajewska and Kopfer (2009) refer to this extension as the integrated operational transportation planning (IOTP).

In addition to subcontracting, the operational efficiency can be improved further by building up horizontal coalitions enabling collaborative planning. According to Stadtler (2009), collaborative planning can be understood as a joint decision making process for aligning plans of individual coalition members with the aim of achieving coordination in light of information asymmetry. Wang and Kopfer (2014) refer to the joint decision making process for fulfilling transportation requests in a horizontal coalition as collaborative transportation planning (CTP). CTP aims to reach a reallocation of requests among the coalition members through request exchange, with total costs less than the sum the partners' individual costs would be without cooperation.

The main differences between the cooperations in IOTP and CTP is that CTP is performed on the basis of an equal partnership, while in IOTP the players are in a hierarchical relation with the forwarder being the client of carriers acting as subcontractors. In IOTP,

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forwarders plan independently for their internal and external capacities without explicitly coordinating with their subcontractors. In CTP, all partners plan for themselves (i.e., for their own fleet and, if applicable, for their subcontractors either) and try to harmonize their plans with those of other coalition members.

Although both approaches, IOTP and CTP, have been investigated in literature, a systematical integration of both approaches into vehicle routing strategies has not been discussed yet. In this paper, we study how the operational planning of the forwarders should be performed taking subcontracting and collaborative request exchange into account. The purpose is to develop an appropriate mechanism to realize the cost-saving potential at the highest level, which is embedded in the integration of IOTP and CTP.

The remainder of this paper is organized as follows. Related literature is reviewed in Section 2. Different planning strategies are formally described in Section 3. The solution approaches for the IOTP problem are presented in Section 4 and integrated into a collaborative planning framework in Section 5. Section 6 shows the computational results. Section 7 concludes this paper.

2. Literature review

2.1. Combining vehicle routing and subcontracting

The idea of using external resources for the fulfillment of transportation requests is not new in transportation planning. Due to the high fixed costs related to trucks and the low profit margin, forwarders have to keep a very high utilization rate of their own fleet to generate acceptable profits. Introducing subcontracting enables forwarders to do "cherry-picking" for their reduced fleet and thus, to ensure a high utilization rate of own vehicles, even in case of strongly fluctuating demands for transportation volume.

"Cherry-picking" is often performed by forwarders in practice, in spite of the fact that it implements a sequential planning approach, which may lead to inferior solutions regarding the total fulfillment costs. Thus, simultaneous planning approaches have been proposed in transportation planning literature. The resulting planning problems, i.e., variations of the IOTP, have attracted interest of researchers for some decades.

Ball, Golden, Assad, and Bodin (1983) investigate the problem of simultaneously generating routes for own vehicles and subcontracting single requests to common carriers. The underlying routing problem can be seen as a multi-depot full-truckload (FTL) pickup and delivery problem (PDP). Klincewicz, Luss, and Pilcher (1990) study a variation of the IOTP which is based on the vehicle routing problem (VRP) with stochastic customer demands. The whole area to be served is divided into several sectors assigned either to an own vehicle route or to common carriers. A static version of this problem on the operational level is proposed and solved many years later by Chu (2005), who discusses the problem where only a fixed number of heterogeneous trucks with limited capacity are available in the own fleet and the demands of customers are known. After that, this problem and its variation with a homogeneous fleet are investigated in Bolduc, Renaud, and Boctor (2007), Bolduc, Renaud, Boctor, and Laporte (2008), and Côté and Potvin (2009). Based on the analysis of a German mid-sized freight forwarder, Krajewska and Kopfer (2009) introduce a variation of the IOTP while considering several different tariff structures for freight charges, and propose a tabu search heuristic to solve this problem.

2.2. Integrating collaborative transportation planning

Small and mid-sized forwarders face greater difficulties in taking advantage of both economy of scope and economies of scale, due to their relatively limited business size. The commonly estimated achievable cost reduction through CTP amounts to 5–15% (Cruijssen & Salomon, 2004; Krajewska, Kopfer, Laporte, Ropke, & Zaccour, 2008). The attained cost-savings represent the joint benefits of the coalition that cannot be achieved individually. They can then be shared among the coalition members.

In order to exploit the cost-saving potential embedded in CTP, appropriate request exchange mechanisms, which are simple and implementable, yet effective in terms of generating high joint benefits have to be developed. Such mechanisms must be able to deal with distributed information and decision-making competences Wang and Kopfer (2014). Some approaches have been proposed in literature to tackle this challenging task. These approaches differ not only in the solution methodologies but also in the scenarios (e.g. underlying routing problems) to which CTP is applied.

Krajewska and Kopfer (2006) propose a request exchange mechanism using a combinatorial auction (CA), which is based on the idealized assumption that the fulfillment costs for any bundle of requests can be exactly evaluated. Schwind, Gujo, and Vykoukal (2009) propose two auction mechanisms for a scenario with several warehouses supplying single commodity goods to customers, which can be modeled as the VRP with time windows (VRPTW) (Cordeau, Desaulniers, Desrosiers, Solomon, & Soumis, 2002). Due to the characteristics of the VRP, only requests located between neighboring profit centers are exchanged. For the PDP however, it is impossible to simply choose candidate requests for exchange on the basis of their geographical locations. Berger and Bierwirth (2010) deal with the CTP of a coalition, where each member has to solve a PDP without capacity restriction. Schönberger (2005) proposes a CA-based approach for a similar problem, in which also time windows of requests have been considered. Özener, Ergun, and Savelsbergh (2011) solve the CTP problem by using bilateral exchanges for forwarders doing FTL business. Wang and Kopfer (2014) propose a route-based request exchange mechanism for the exchange of less-than-truckload (LTL) requests. The basic routing problem is the pickup and delivery problem with time windows (PDPTW) with a fixed homogeneous fleet.

The approaches proposed by Berger and Bierwirth (2010) and Özener et al. (2011) depend on the calculation of the marginal costs for single requests. The basic idea is to choose those requests with the highest marginal costs and offer them for exchange. If an exchange resulting in a better solution for all parties is found, it will be accepted and the exchange process continues. Otherwise the process ends. This idea suffers from the fact that the underlying process resembles a hill-climbing strategy, which does not accept any declined solution and thus cannot escape from local optima. The mechanisms in Berger and Bierwirth (2010) realize an average cost-saving potential of 18.2–64.8% for different test sets, and the approach in Özener et al. (2011) of 30% in the test setting relevant for CTP as discussed in this paper.

Schönberger (2005) and Wang and Kopfer (2014) solve the CTP problem by following the decomposition principle proposed by Dantzig and Wolfe (1960). This decomposition scheme is suitable for decentralized decision making (with distributed information) since each member decides for his part without regard to whether it is feasible for any other part (Dantzig & Wolfe, 1960), and without having to expose private information. In both approaches, the CTP problems are decomposed into several subproblems reflecting the routing decisions of single participants and a coordinating problem. Schönberger (2005) assumes an extremely high price level for forwarding requests to common carriers and tries to increase the degree of self-fulfillment. Wang and Kopfer (2014) use an iterative route generation process and realize almost the complete cost-saving potential which is determined by solving the centralized problem using effective heuristics for vehicle routing.