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Cooperative planning in express carrier networks — An empirical study on the effectiveness of a real-time Decision Support System

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ABSTRACT

For small transportation firms cooperation in a carrier network is a proper mean to overcome the inefficiencies from deadheading. To be successful, such a network has to secure two different but equally important aspects: the partners have to be aware of specific consolidation potentials through order exchange which is an optimization and communication problem, and, the partners have to experience incentives to contribute actively to the network which is the problem of finding a fair cost/profit allocation schema for order exchanges. In this paper we discuss the experience with the development of a Decision Support System for a specific express carrier network. We illustrate how the consolidation potentials in such a network with autonomously planning carriers can be exploited and cost effectiveness can be improved substantially through the use of a suitable distributed Decision Support System if the two success factors awareness and fairness are addressed properly.

1. Introduction

During the last years, transportation firms are faced with increasing cost pressure and revenue erosion at the same time. Large transportation companies are able to realize a high utilization of their vehicles and acceptable operational cost by consolidating and combining orders to efficient roundtrips. Small carriers serving ad-hoc one-way shipping orders only are faced with the problem of low volume of shipments with less than truckload trips as well as dead head trips due to an imbalance among locations. This leads to cost ineffective transportation plans and/or may result in non-competitive prices.

Such small-sized companies may compensate their competitive disadvantage by allying with partners to a cooperation network to establish a more profitable portfolio of orders. In such a network each partner plans his orders and his vehicle fleet independently with the option to exchange orders with partners. Partners charge their own customers based on a specific price function. The carrier operating an order for a partner receives a monetary compensation, which has been specified in a generally agreed upon compensation schema.

For such a network to be successful and sustainable there are a number of critical factors: on the strategical level the choice of the right set of partners yielding enough consolidation potential as well as mutual trust is a cardinal point. On the operational level awareness is essential, i.e. existing potentials have to be detected and communicated, a task which calls for the establishment of a proper information and communication system supporting cooperative planning. Another success factor is the establishment of a compensation schema which puts incentives to both partners involved in exchanging orders and which is considered to be fair by all network partners.

The issue of reducing transportation cost by collaboration and forming alliances has been investigated in the scientific literature with respect to different aspects like different transportation markets or modes i.e. airfreight [7], shipping [1], trucking [8], intermodal freight transportation [16], supply chain management [18] as well as decision level, i.e. from evaluating strategic aspects in alliance formation [2] to pricing/revenue management and allocation of cost benefits [4,10–12].

Most developments concern design questions and propose models which are based on theoretical foundations stemming from game theory, combinatorial auctions and network flow. Refs. [10,13] present approaches for a problem where intra-enterprise in and outsourcing decisions on bundles of logistic services i.e. bundles of transportation requests from customers in a profit center structured forwarding company have to be made. In both approaches the cost difference through exchanging requests is evaluated for numerous bundles of requests. Then the optimal distribution of the bundles among the profit centers is determined via a combinatorial auction. Both approaches propose mechanisms for sharing the resulting profit increase among the centers.

Our development was driven by the necessity to control cost effective transportation in an established collaborative network of independent express couriers on the operational level where decisions on the exchange of orders have to be made instantaneously. In our problem environment the situation is highly dynamic such that at no point in time planning of a fixed set of orders/requests is possible as it is

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assumed in Refs. [10,12]. Hence the focus was on implementing rational decision models which allow on-line algorithms within an effective Decision Support System.

In this paper we describe our experience with the development and maintenance of pool.tour, a distributed real-time internet-based collaborative Decision Support System (DSS) for a large express courier network, and we analyze the impact of this system on the success factors mentioned above. In a first development we implemented a system proposing order exchanges automatically which are profitable for both partners involved based on the established compensation schema. This technologically highly demanding system has been in use for about 2 years. Yet, the improvement over the formerly used approach where dispatchers had to assume potentials from their experience and to communicate proposals to partners over the phone was much lower than expected. An analysis of the business i.e. the order pool and the proposals generated showed that the system could only rarely find consolidations i.e. insertions of orders in existing trips which were profitable for the acquiring as well as the operating partner but was only able to propose exchanges which result in separate trips. This unsatisfactory behavior motivated us to analyze the contractual compensation schema, to propose an alternative schema and to compare the result with the existing schema. For that purpose we performed a simulation study on the logged order pool over a significant duration of several weeks. Our analysis showed that the rather poor performance could be clearly attributed to the compensation schema. Using a rather straightforward cost based compensation schema within the model base of pool.tour network wide transportation cost could be decreased significantly, even down to the level reachable by centralized planning. Also the distribution of the profit showed to be much fairer.

This paper is structured as follows. In Section 2 we give a short description of the transportation market and the specific carrier network underlying our development and study, in the following referred to as the Cooperative Logistic Network (CLN) or simply *network* for short. In Section 3 we introduce the planning problem and the established compensation schema. Then, in Section 4, we shortly describe our Decision Support System pool.tour. In Section 5 we describe the motivation and the design of our simulation study for evaluating the effectiveness of pool.tour and in Section 6 we report the central results of this experience.

2. The cooperative logistic network

In 2001 the market value of the courier/express/parcel segment in Europe was about 36 billion Euro, and 30% of this volume was realized in Germany. In Germany close to 10,000 courier firms are specialized on this kind of general freight transport, yet, this number contains many one-person businesses which operate as subcontractors for larger companies only. CLN was founded in 2001 by logistics professionals for logistics professionals to unite small and medium-sized courier companies under a strong brand. It was created by a consortium of independent courier companies with a more strategically oriented organization in mind than traditional partner-based systems. All twelve founding shareholders were professionals in international procurement logistics, i.e. all partner companies had long term expertise in national and international deliveries and offered procurement logistics, less than truckloads (LTL) and complete truckloads, transportation of dangerous goods and customs service. With the Europe-wide business partners CLN is able to offer pickup and delivery of shipments anywhere in Europe, with availability 24 h a day, 365 days a year and guaranteed pickup anywhere in Germany within 60 min.

The purpose of CLN – as the purpose of every cooperation of freight forwarding companies – is to realize a profitable equilibrium between customer demand and available transport resources by interchanging customer requests among partners. Being a member of CLN allows the forwarding company to choose between two modes of fulfillment for each task: To use own vehicles (self-fulfillment) or to use a partner carrier who will then receive a compensation for the request fulfillment.

The critical success factor for a freighter is the percentage of deadheads. According to experience this percentage had been up to 40% to 45% for the individual carriers before the cooperation, a number resulting from the high spatial diversity of the single requests and the inability to consolidate within the available time-frame, yet, a number much too high to allow competitive prices and sufficient profit. A rough analysis of the business within the first year of CLN's operation where cost reducing interchanges had been realized between the dispatchers occasionally via telephone conferencing had shown only a slight reduction of deadheads. Yet, expectation was that even with the full thrust of the cooperation, its mutual growth and coordination potential, the bottom line of deadheads would always remain around 30% due to the extreme short reaction time. All partners were aware of the fact that the two major make and break questions on the cooperation were constituted by the potential to bring the key performance indicator on deadheads closer to this bottom line and the discussion on how to split earnings among partners in a fair manner. This judgement on the key issues has led to the development of pool.tour, our DSS which supports cooperative planning as well as communication in this highly time-sensitive environment.

3. Modeling the planning situation

Let P be the set of partners in the network. Each partner $p \in P$ is located at a specific depot dep_p and operates a set of vehicles V_p. Each vehicle v is assigned to a vehicle class. Let VC be the set of vehicle classes and vc_v the vehicle class of vehicle v. All vehicles in a vehicle class $\text{vc} \in \text{VC}$ share common physical and technical transportation capabilities as for instance capacity Q_{vc}, average speed, cost rates for distance and time etc. The set of vehicle classes is assumed to be partially ordered with the semantic that a vehicle of a 'larger' class can always transport orders which require a 'smaller' vehicle class. Each partner $p \in P$ has acquired a set O_p of orders. Here, each order o is defined by its pickup location p_o, its delivery location d_o, its capacity requirement cap_o and a time window $[e_o, l_o]$, which specifies the earliest time for pickup and latest time for delivery, respectively. From the capacity requirement one can determine vc_o the minimum required vehicle class for the order. For each vehicle class $\text{vc} \in \text{VC}$ two rates apply: price_{vc} the transportation price per km for the customer and $\text{compCost}_{\text{vc}}$ an internal cost rate per km used for compensation. For two locations x and y let $l(x, y)$ denote their distance. Then the revenue $\text{rev}(p, o)$, which a partner p obtains from his customer after serving its order o, is calculated as follows:

$$\text{rev}(p,o) = \text{price}_{\text{vc}_o}\left[\max\left(0; l\left(\text{dep}_p, p_o\right) - l^{\text{fix}}\right) + l(p_o, d_o)\right]. \tag{1}$$

Thus, for picking up the order (pre haul leg) only the distance exceeding l^{fix} is charged. Note, that each vehicle can transport more than one order at a time, as long as the total capacity is not exceeded, and that it is the task of the dispatching systems of the partners to combine orders to tours.

Let us first assume the non-cooperative case, i.e. the special case of one partner p only. This problem of combining orders to tours is coined as *Pickup and Delivery Vehicle Routing Problem with Time Windows* (PDVRPTW) and well studied in the Operations Research literature. As a so-called rich variant of the classical *Vehicle Routing Problem* it is NP-complete and thus only heuristic methods are applicable for solving problem instances of practical size. Efficient heuristic algorithms have been proposed by Ref. [14] and Ref. [5]. Now, a solution to a vehicle routing problem, also called a schedule, consists of a partition of the orders into clusters/tours which are assigned to the vehicles and an ordering/routing of the orders within a