European Journal of Operational Research 250 (2016) 590–601

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Decision Support

Pricing and timing of consolidated deliveries in the presence of an express alternative: Financial and environmental analysis

Peter Berling[a,b], Fredrik Eng-Larsson[c,*]

[a] Department of Industrial Management and Logistics, Lund University, PO Box 118, Lund 221 00, Sweden
[b] Linnaeus University, Sweden
[c] MIT Center for Transportation & Logistics, Massachusetts Institute of Technology, Cambridge, U.S.A.

ARTICLE INFO

Article history:
Received 14 October 2014
Accepted 22 September 2015
Available online 9 October 2015

Keywords:
OR in environment and climate change
Shipment consolidation
Incentives
Supply chain management

ABSTRACT

Shipment consolidation has been advocated by researchers and politicians as a means to reduce cost and improve environmental performance of logistics activities. This paper investigates consolidated transport solutions with a common shipment frequency. When a service provider designs such a solution for its customers, she faces a trade-off: to have the most time-sensitive customers join the consolidated solution, the frequency must be high, which makes it difficult to gather enough demand to reach the scale economies of the solution; but by not having the most time-sensitive customers join, there will be less demand per time unit, which also makes it difficult to reach the scale economies. In this paper we investigate the service provider's pricing and timing problem and the environmental implications of the optimal policy. The service provider is responsible for multiple customers' transports, and offers all customers two long-term contracts at two different prices: direct express delivery with immediate dispatch at full cost, or consolidated delivery at a given frequency at a reduced cost. It is shown that the optimal policy is largely driven by customer heterogeneity: limited heterogeneity in customers' costs leads to very different optimal policies compared to large heterogeneity. We argue that the reason so many consolidation projects fail may be due to a strategic mismatch between heterogeneity and consolidation policy. We also show that even if the consolidated solution is implemented, it may lead to a larger environmental impact than direct deliveries due to inventory build-up or a higher-than-optimal frequency of the consolidated transport.

1. Introduction

Freight transportation is, on the operational level, characterized by strong economies of scale: larger shipment volumes lead to significantly lower transport costs per unit. However, for an individual shipper it is costly to realize these scale economies. Normally, two options exist: either, the shipper can purchase a less-than-truckload service (LTL), with longer transit time due to terminal handling; or he can purchase a full truck load service (FTL), but at a lower frequency. In both cases, the reduced flexibility leads to higher inventory costs. Since those costs are generally higher than the savings in transportation costs, scale economies often go unrealized, leading to operational and environmental inefficiencies. For instance, the EEA (2006) reports that the average vehicle load factor in Europe is below 50 percent.

Globally, freight transports account for approximately 8 percent of all energy-related GHG-emissions (IPCC, 2014). By increasing the vehicle load factor, the external costs associated with these emissions can be significantly reduced. Consequently, researchers and politicians have advocated different consolidation schemes, where shipments from several shippers are consolidated without the time consuming terminal handling of LTL-transports (see e.g. Arvidsson, 2013). In this paper we investigate one type of efforts: those where a common shipment frequency is used for all shippers who use the consolidated transport alternative. There are several examples of consolidation efforts where this is the case. Co-loading with set "sailing dates" (Taherian, 2014), time-based consolidation in distribution systems (Marklund, 2011), and intermodal truck-train transports (Eng-Larsson & Kohn, 2012) all dispatch consolidated shipments at a certain frequency. Because such efforts would lead to larger volumes per shipment, they are often claimed to not just improve environmental performance but also reduce costs (e.g. Ülkü, 2012). For instance, according to the Executive Vice President of DHL Solutions & Innovations, "increasing the load factor of trucks is an attractive way to achieve more sustainability, as it not only improves the carbon

* Corresponding author. Tel.: +1 617 253 1701.
E-mail addresses: peter.berling@iml.lth.se (P. Berling), frengl@mit.edu (F. Eng-Larsson).

http://dx.doi.org/10.1016/j.ejor.2015.09.041
0377-2217/

footprint, but is also very appealing from an economic perspective" (Ehrhart, 2010).

In practice, most consolidation projects are initiated by a third party logistics service provider. One example is Volvo Logistics, a service provider, who set up an intermodal truck–train solution between Sweden and Germany in 2008, called Viking Rail (see e.g. Eng-Larsson, 2012). The solution was set up to accommodate a request from a large customer to become more "climate-smart". One objective of the new solution was therefore to reduce GHG-emission; the other was to avoid road tolls and traffic taxes in Central Europe. To initiate the project, a full train was contracted from DB Schenker. The train was to depart with 36 trailers in both directions. Owing to this, it would take several days for the demand from the customer who initiated the solution to reach the scale necessary for a profitable departure, so other customers were needed. But when choosing which customers to include in the solution, the service provider faces a trade-off: If she decides to offer a high frequency service, it is more likely that time-sensitive customers join. However, the high frequency may make it difficult to gather enough demand per departure to reach the necessary scale. If instead she decides to offer a low frequency service, there is plenty of time between departures to consolidate demand. This may however mean that few customers are willing to join, which also makes it difficult to reach the necessary scale. So what customers should be included in the consolidated solution? At what frequency should the solution dispatch? And what is the optimal price of the new service? In this paper we analyze this problem, and evaluate the environmental implications of the optimal policy.

Shipment consolidation policies have been well researched before. But despite the fact that most transports are outsourced to service providers (Hong, Chin, & Liu, 2004; Jaafar & Rafiq, 2005; Mellin & Sorkina, 2013), previous research largely ignores the fact that service providers interact strategically with their customers in these situations. In this research we make an attempt in capturing this by explicitly considering the contracting dynamics of a shipment consolidation setting. We investigate the problem, by considering a non-asset service provider responsible for N customers' deliveries from one region to another. In our model, the service provider offers two long-term contracts at two different prices to each customer: direct express delivery with immediate dispatch at full cost, or consolidated delivery at a given dispatch frequency at a reduced cost. A customer then chooses the contract that leads to the lowest total expected cost. We consider two different pricing strategies: *individual prices* by which the service provider has the power to price discriminate customers based on their willingness-to-pay; and *standard prices*, by which the service provider offers the same price to all customers.

Although researchers and politicians seem confident in consolidation projects as a means to reduce GHG-emissions, projects are rare in practice and often fail. For instance, there have been 150 consolidation projects in urban settings in Europe over the last 25 years, but only 5 of these have survived after subsidies were withdrawn (SUGAR, 2011). The Viking Rail project initiated by Volvo Logistics was discontinued after 5 years of operation,[1] and service providers in similar situations have reported difficulties in making their consolidation projects profitable, despite low operating costs on scale (see e.g. Lammgård, 2012). In solving the service provider's problem, we see that the optimal policy may be to not offer a consolidated solution, particularly if a standard price is used. This indicates something about the incentives to offer and use consolidated transports; in many instances there are simply no financial incentives to do so. In cases where it is optimal to offer a consolidated solution, we show that the optimal policy depends on customer heterogeneity, and is either one with frequent shipments that includes many customers or one with infrequent shipments that includes only the most time-insensitive customers. This implies that to run a successful consolidated solution, the service provider must accurately match customer heterogeneity with the right policy. We argue that this may shed some light on why consolidation projects are rare in practice and often fail. First, it may be difficult to match heterogeneity with the right policy; second, it may be difficult to adjust the policy to changes in heterogeneity once the policy is in place.

Lastly, we show that even if the consolidated solution is implemented, its environmental implications are not clear-cut. Consolidation may, in fact, lead to more environmental impact than direct deliveries, due to inventory build-up and a higher-than-optimal frequency of the consolidated transport.

The paper is structured in the following way. In the next section, related literature is reviewed, before our model is described in more detail in Section 3. In Section 4 we analyze the simultaneous pricing-timing decision of the service provider, and prove some underlying properties in three cases: (1) when customers are identical; (2) when customers are heterogeneous and can be charged individual prices; and (3) when customers are heterogeneous but are charged the same price. We show that in all cases, the underlying properties ensure that optimization can be done through a simple search procedure. The optimal policy's sensitivity to costs and customer heterogeneity are then investigated in Section 5. Next, in Section 6, we analyze the environmental implications of the optimal policy, and illustrate the difficulties of implementing freight consolidation with an example using realistic figures from a European context. Section 7 concludes the paper. Appendices A–D provide the last proofs.

2. Literature

By investigating the pricing and timing of a consolidated transport service, this paper relates to literature on (1) transport pricing, (2) the timing of consolidated shipments, and (3) cost allocation in joint replenishment.

Since standard transport services are sold in a Bertrand-like fashion, with strong price competition, the price can often be seen as exogenous to the individual service provider. This is reflected in the transport planning literature. For instance, Kim and Van Wee (2011), Euchi, Chabchoub, and Yassine (2011), and Bolduc, Renaud, and Boctor (2007) all consider transport planning problems where the price of the transport services offered by service providers is assumed to be exogenous. We follow this literature and let the price for the direct delivery be exogenous to the service provider.

However, although the service provider has limited pricing power for standard services, there is more room to adjust the price for a customized or differentiated service. This is reflected in research on both cost-based pricing and relationship-specific pricing on the transport market. Cost-based pricing is discussed in Spasovic and Morlok (1993) and Yan, Bernstein, and Sheffi (1995). Spasovic and Morlok (1993) use a framework to determine marginal costs, which are then used to evaluate drayage rates in rail-truck intermodal services. Yan et al. (1995) use network flow models to estimate the alternative costs of intermodal transports to guide the pricing decisions of the service. Relationship-specific pricing, where the price is determined by a powerful customer, is discussed in Henig, Gerchak, Ernst, and Pyke (1997) and Alp, Erkip, and Güllü (2003), who analyze a buying firm's problem of how to simultaneously determine inventory policy and transport contract parameters in a periodic review inventory model. Ülkü and Bookbinder (2012a,b)) consider the pricing problem for a 3PL or manufacturer that differentiates its price to the customer based on the delivery time promised and the customers' sensitivity to time to maximize its profit. They do not consider a long-term contract between the customers and the 3PL/manufacturer; instead the price can, and should, be adjusted each time a demand occurs. Brusset and Temme (2005) and Berling and Eng-Larsson (2014)

[1] http://www.gp.se/ekonomi/1.2339085-volvo-lagger-ner-taget.