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Consolidation strategies for the delivery of perishable products

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ABSTRACT

A set of agricultural suppliers with low demands can save on long-haul transportation costs by consolidating their product. We consider a system with stochastic demand and a single consolidation point near the suppliers. We propose a look-ahead heuristic that takes advantage of economies of scale by aiming to ship larger quantities. We experimentally compare the heuristic's performance against other simple policies, a rolling horizon algorithm, and a stochastic dynamic programming model. Our numerical results demonstrate that the heuristic provides solutions that are near the lower bound provided by the dynamic programming model, and that the benefits of consolidating depend on the size of the suppliers' demand. We also propose a proportional cost allocation rule that encourages the suppliers to cooperate with each other instead of operating independently.

1. Introduction

Collaborative strategies in the supply chain can greatly improve a company's performance. With the increase in competition, globalization and demanding customers, many firms believe they cannot continue to compete alone (Kumar and Banerjee, 2012). Collaboration between firms offers opportunities to share risks, increase system efficiency, reduce costs, minimize unsatisfied customer demand, and increase their competitive advantage (Cao and Zhang, 2010). However, collaboration will only work if *criticality* is present, where criticality is defined as "the notion of high recognized interdependence in which one supply chain member will not act in his own best interest to the detriment of the supply chain" (Spekman et al., 1998).

In recent years, there is also an increasing interest in the potential savings of cooperation between multiple decision makers within or across supply chain levels. Specifically, joint strategies across multiple suppliers can decrease system-wide transportation costs through the consolidation of common products. Cooperating suppliers aim to minimize total joint costs but also need to determine an allocation that sustains continuous participation by each supplier. We focus primarily on terminal consolidation (defined by Hall, 1987), where items from different origins are sorted at a single terminal to be shipped to different destinations on the same vehicle.

The idea of consolidating to decrease costs is not a recent development. Early contributions to freight consolidation describing the opportunity for lower transportation costs and large shipment loads date back to at least the 1980s (Jackson, 1985; Blumenfeld et al., 1985; Closs and Cook, 1987; Hall, 1987). The terms *shipment consolidation* and *freight consolidation* are more popular in the current research literature than *terminal consolidation*.

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In a shipment consolidation problem, we must determine how much to consolidate before shipping or how many time periods to consolidate before shipping the aggregate volume. Quantity-based polices determine a threshold weight or volume that must be accumulated before a shipment is released (Gupta and Bagchi, 1987). Time-based policies dispatch after the first order in a consolidated load has waited for a predefined time (Mutlu and Çetinkaya, 2010; Marklund, 2011). Hybrid time-and-quantity polices release a shipment when either the quantity threshold is reached or the maximum waiting time has passed (Mutlu et al., 2010). Çetinkaya and Bookbinder (2003) use renewal theory to investigate the quantity and time policy for private carriage and when transport is performed by a public, for-hire company. Ülkü (2009) also shows that quantity-based policies are the most cost-effective with unit-sized demands and Poisson arrivals in a shipment consolidation problem using private carriage. Higginson and Bookbinder (1995) use a discrete-time Markov decision process to study a sequential model where the shipper is required to reconsider the dispatch decision at the arrival of an order. Ülkü (2012) proposes a discrete-time based shipment consolidation policy that allows shipment release only at discrete times of the day while maintaining a certain customer service level.

Consolidating shipments allows shippers to take advantage of economies of scale and achieve decreased transportation costs. For example, Bausch et al. (1995) showed that consolidation of Mobil Oil Corporation's heavy petroleum products could yield annual transportation savings of $1 million. Brown et al. (2001) estimated approximately $35 million savings per year in inventory and distribution costs for Kellogg Company with the implementation of a new consolidation policy. Local and global third-party logistics companies also benefit from consolidation shipment-release policies (Lee et al., 2003; Tyan et al., 2003; Song et al., 2008).

In this paper, we study a freight consolidation problem for perishable products where there is a hard time constraint for the product's stay in inventory at the consolidation center. This problem is motivated by the California cut flower industry, where growers currently do not consolidate their shipments (Nguyen et al., 2013). That is, each grower sends shipments individually to its customers, primarily using a combination of less-than-truckload (LTL) rates and courier services instead of the more advantageous full truckload rates (FTL); high transportation costs are one of the major factors behind California's drop in U.S. cut flower market share from 64% to 20%. Growers from South America, who use a consolidation center in Miami, have concurrently seen their market share rise to 70%. Consolidation strategies are important to take advantage of economies of scale with perishable products and decrease system-wide transportation costs. For California flower growers, Nguyen et al. (2013) showed that consolidation by 20 suppliers for all destinations in the United States could yield annual savings of at least $6 million. If 50 additional growers of the California Cut Flower Commission participated together, the savings could reach $17 million.

This paper is a generalization of the problem studied in Nguyen et al. (2013). Instead of deterministic demand, we focus on stochastic demand. We also consider an environment in which the demand distribution changes between periods; in particular, we differentiate between peak and nonpeak periods, since some agricultural demand follows peak and nonpeak behavior and suppliers must plan accordingly in the weeks before harvesting and shipping. Nguyen et al. (2013) considered the case where California cut flower growers would use a consolidation center in their transportation network. In order for the growers to maintain the claim that California cut flowers are fresher than imported cut flowers, the flowers could stay at the consolidation center at most one day. In this paper, we consider cases where the product can remain longer than a single day in inventory, but there is still a hard time constraint due to perishability. A time constraint greater than one day is realistic for other perishable products. For example, potatoes remain dormant 6 to 12 weeks after they are harvested and can be stored up to 2–3 months before they begin to sprout, depending on the variety and storage temperatures (Yanta and Tong, 2013).

We solve the optimization problem using a stochastic dynamic programming approach, compare the performance of various heuristics, and study how changing demand distributions to the system affect the benefit of consolidation. Furthermore, we propose a cost allocation policy and empirically show that the suppliers benefit from cooperating. We finally note that although this problem was motivated by the cut flower industry, the focus of this model is in developing strategies to lower long-haul transportation costs from a consolidation location to a break-bulk destination. We do not consider inventory costs and the transportation cost from the supplier to the consolidation center in this paper since it is assumed that these costs are significantly dominated by the long-haul transportation cost. These assumptions are reasonable when (1) products are harvested just before they are sent to the consolidation center, (2) perishability limits the amount of time the products can stay in the consolidation center, (3) the unit cost of the items is small, at least compared to the shipping cost, making the opportunity cost of capital insignificant, and (4) the suppliers are located close to the consolidation center. For agricultural products such as cut flowers where there is perishability and the growing cost is small relative to the shipping cost, the above assumptions tend to hold.

The remainder of the paper is organized in the following way. The next section gives a brief literature review. In Section 3, we present the dynamic programming formulation of the problem. We discuss heuristic approaches to the problem in Section 4. The numerical results are in Section 5, and we conclude the paper with possible extensions of the model and future considerations in Section 6.

2. Literature review

The problem we consider has not been addressed to our knowledge in the research literature. However, some aspects are related to inventory control models such as the lot-sizing problem and joint replenishment problem. The following section is a brief review of the most recent developments.