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Demand clustering in freight logistics networks

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ABSTRACT

Demand clustering in freight logistics networks is an important strategic decision for carriers. It is used to incorporate new business to their networks, detecting potential economies, optimizing their operation, and developing revenue management strategies. A specific example of demand clustering is truckload combinatorial auctions where carriers bundle lanes of demand and price them taking advantage of economies of scope. This research presents a novel approach to cluster lanes of demand. Community detection is used to cluster the emergent network finding profitable collections of demand. Numerical results show the advantages of this method.

1. Introduction

Logistics clusters are increasing around the world following the example of successful models like Dubai, Panama, Rotterdam, Memphis, Sao Paulo, Singapore, among others (Yu et al., 2005; Boile et al., 2011; Sheffi, 2012, 2013). Complementarities and synergies contribute to the economic prosperity of the constituent firms (commodity production, storage, transportation, and other supporting activities). Logistics clusters are significantly important for companies that provide freight transportation services. Sheffi (2013) summarizes the main competitive advantages achieved by transporters providing services in these places. The high volume of freight between clusters generates larger shipments. Thus, economies of scale are achieved because the shipment unitary cost is lower for vehicles that are filled to capacity. Firms operating large vehicles, e.g., Valemax ships or double stacking trains, considerably benefit from these economies. When vehicles are not filled by single shipments, freight logistics companies can distribute costs by consolidating several shipments in facilities and vehicles, and, hence, achieving economies of density. Intermodal companies related to the maritime and railroad modes usually benefit from this activity. Additionally, for the trucking mode, less-than-truckload (LTL) companies take advantage of these features. The huge amount of freight entering and leaving logistics clusters reduces idling times and fosters economies of frequency. In general, these economies benefit companies in all modes. Last but not least, symmetric flows between clusters propitiate economies of scope by reducing the fraction of shipment unitary cost associated to empty repositioning. This considerably benefits all modes, especially those with fixed facilities within clusters, e.g., docks, terminals, stations, consolidation facilities, etc.

Governments recognize the economic importance of logistics clusters and increasingly provide incentives for firms to (re)locate into these facilities (Sheffi, 2013). However, this is a slow process. Sometimes it is not even an alternative for many shippers and carriers that face enormous relocation costs, off-shoring issues, and potential detriment of relationships with clients. Additionally, logistics clusters might not be a feasible option because they have not emerged naturally, they are not a

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priority for local governments, or they are not suitable for unstable economic landscapes. In these cases, flexible firms with low use of specialized facilities have competitive advantages over other rigid modes. The challenge for these firms is developing operations that mimic the advantages of logistics clusters, increase revenues for transporters, and add value to their clients.

Truckload (TL) companies are the best example of flexible freight transportation carriers. Undeniably, TL is the most popular type of operation for the most popular freight mode: Trucking. This mode accounts for 29% of the for-hire-transportation market share. This value is higher than the joint share for the second and third modes, i.e., air (16%), and rail (8.0%) (USDOT, 2012). Setar (2013a, 2013b) estimates that TL accounts for 61% of the 2013 US general trucking industry revenue ($193.4 Billion). TL firms are considerably impacted by economies of scope (Caplice, 1996; Jara-Diaz, 1981, 1983; Mesa-Arango and Ukkusuri, 2013) and frequency (Sheffi, 2013) induced by empty trips resulting from freight imbalances.

Firms know that empty trips profoundly affect their economy. Companies like Best Buy, Coca-Cola Supply LLC, JB Hunt Transport, Johnson & Johnson, Walmart Stores, Inc, among others, have participated of the Empty Miles program (VICS, 2014) to share unused transportation capacity and reduce empty-trip inefficiencies (Belson, 2010). In 2009, the chain of department stores Macy's cooperated with shippers and carriers to reduce 1500 empty trips in the US. In average, they saved $25,000 transportation costs annually for each shared lane (VICS, 2009). JCPenney, another important department-store chain, shared 41,000 backhauls that saved them $8.1 Million between 2008 and 2009 (Andraski, 2010). Schneider National, the largest private TL carrier in North America, increased dedicated backhaul revenue by 25% on specific accounts thanks to this initiative (VICS, 2009). Unfortunately, empty trips are not rare for trucking operations. 25% of the 2010 truck-kilometers in Europe where traveled empty (De Angelis, 2011). Reduction of empty trips can significantly benefit society because they are related to serious externalities like emissions, traffic congestion, and wear of roads. The monetary savings obtained by Scheider National also saved them 5554 gallons of diesel fuel that eliminated 61.65 tons of carbon dioxide, 147.24 tons of articulate matter, and 1.47 tons of nitrous oxide. Similarly, JCPenny eliminated 9750 tons of CO_2 by utilizing 20% of its empty miles in 2009 (4 million miles) and 6% (1.3 million miles) in 2008.

Although empty trips can be reduced through collaboration, TL carriers can develop strategies to promote this behavior making them more attractive and profitable. The challenge is detecting and clustering synergetic lanes, i.e., lanes that minimize empty trips when operated together. Additionally from a revenue management perspective, the right combination of TL volume and price has to be considered in the development of profitable clusters of demand. However, prices and volumes add a new level of complexity to this problem. The high level of competition in the TL market makes the development of pricing strategies very difficult. Thus, carriers that look at market values when analyzing clusters realize that they vary significantly. Variations in the observed traffic volumes (Caplice and Sheffi, 2006) also occur in a symbiotic fashion. This happens for several reasons: seasonal changes (e.g., end of the year or harvests), forecasting errors, macroeconomic impacts (e.g., economic recessions or booms), network disruptions (e.g., inclement weather), among others. An approach that incorporates these sources of uncertainty can significantly benefit the development of demand clusters.

The concept of clustering has been approached in similar works. Bidding advisory models have been developed to bundle lanes in TL combinatorial auctions (CA) (Song and Regan, 2003, 2005; Wang and Xia, 2005; Lee et al., 2007; Chang, 2009; Huang and Xu, 2013; Xu and Huang, 2013, 2014; Kuyzu et al., 2015; Triki et al., 2014; Ergun et al., 2007). Additionally, geographic clustering has been used to reduce the computational complexity of vehicle routing problems (Bowerman et al., 1994; Bodin and Golden, 1981; Dondo and Cerdá, 2007; Özdamar and Demir, 2012; Schönberger, 2006; Simchi-Levi et al., 2005). Similarly, clustering has been used to understand the distribution of freight demand and simplify logistics operations (Cao and Glover, 2010; Sharman and Roorda, 2011; Singh et al., 2007; Qiong et al., 2011). However, these works present several limitations. In many cases revenues are not considered -or highly simplified- when demand bundles are constructed. Furthermore, uncertainty related to lane price and volume is not captured. On the other hand, clustering approaches used in the past focus on geographic proximity but cannot capture network effects resulting from the complex interdependencies among lanes. The main objective of this paper is proposing a systematic framework for demand clustering in freight logistics networks that overcomes these limitations. The contributions of the framework to literature are fourfold: (1) incorporating economic interdependencies among clustered lanes considering network effects, (2) considering market prices in the clustering process, (3) integrating uncertainty associated to variations on lane prices and volume, (4) developing a computationally efficient method. These contributions are demonstrated with numerical experiments.

The paper is organized as follows. Section 1 introduces and motivates this research. Section 2 reviews related literature. Section 3 clearly defines the problem to be solved. Section 4 presents the methodology to solve it. Section 5 presents numerical results and advantages. Section 6 summarizes the work and provides future research directions.

2. Literature review

This section reviews relevant literature related to carrier economies and network clustering. It is observed that an efficient method for demand clustering in freight logistics networks that accounts for shipment volume and price uncertainty is missing in literature. This motivates the development of the proposed model.

Finding groups of demand with synergetic properties in freight logistics networks is very important for strategic analysis, decision making, and business improvement at TL firms. However, detecting these lanes is not an easy task. Analyzing the exponential number of all the possible combinations of lanes (Song and Regan, 2003), prices and desired volumes is a hard