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Stopover and hub-and-spoke shipment strategies in less-than-truckload carriers

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ABSTRACT

This paper presents a methodology to identify when freight consolidation strategies are cost-efficient in the less-than-truckload carriers operations. Shipments are assigned based on proximity and cost criteria to build an initial long-haul shipment solution. This initial solution is later improved by the implementation of Tabu Search algorithm. The proximity criterion takes into account the spatial distribution of shipments loads among centers. The results show that the proposed methodology may reduce the transportation cost by 20% compared to the solution of those heuristics only considering cost criterion.

1. Introduction

In recent years, the evolution of logistics has promoted the outsourcing of transportation operations to the “for hire” carriers. These carriers provide transportation services for several suppliers so that they have to adjust their regular schedules to satisfy the maximum number of customers. When the size of the shipments is small, these companies must consolidate multi-shipment freight in vehicles to increase their load factor. These kinds of companies are known as less-than-truckload (*LTL*) carriers. Their shipments usually involve different origins and destinations constituting a many-to-many network.

The network of *LTL* carriers is divided into two hierarchical levels. Firstly, the transportation of small shipments from suppliers’ origins to carrier’s distribution centers constitutes the local network level. In its general definition, the vehicles depart from the distribution center and visit supplier points picking up the goods to be shipped. When a vehicle has visited its associated region of service it returns to the distribution center at full capacity. Basically, the order to visit the customer points, the vehicle capacity, technology and time restrictions determine the distribution cost (see Robustė et al., 1990).

Subsequently, the freight associated to the inbound routes of a local network is consolidated in a distribution center. Then, goods are loaded in vehicles of higher capacity for being transported to other distribution centers. The routes among distribution centers constitute the long-haul network level. This network is composed by many origins and destinations (O–D) scattered in the region of service. Finally, the delivery process where goods are transported from outbound distribution centers to the final customers is also made in the local network level. In that case, the routes start from the distribution center at full capacity to deliver goods sequentially to the customers of the parcel.

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Although the management of a long-haul network would be basically carried out using direct shipments between O–D distribution centers, their loads difficultly fit the potential capacity of the vehicles. This fact is a key inefficiency for the carrier that needs to be addressed in order to be competitive. Hence, carriers usually use several strategic nodes that group and consolidate the load associated to different origins and destinations acting as distribution centers. The operation in these nodes known as *hubs* causes new handling costs and increases the distance traveled between O–D distribution centers. However, it can reduce the number of shipments (vehicles) in the whole region of service as well as the time of the total transportation chain for O–D pairs due to terminal consolidation. In fact, the advantages of *hub and spoke* networks have transformed the strategic and operational planning of transportation companies from the early 80s, causing major profits as it is reported in Hall (1987a) and Chestler (1985). A lot of research has been done about the optimal location of hubs and long-haul network design. A wide approach of strategic, tactical and operational planning of *LTL* carriers is addressed in Daganzo (2005), whereas in Crainic (2003) a compilation of available methodologies about the long-haul network design problem is provided. More specifically, Hall (1987b) and Blumenfeld et al. (1985) compare analytically the relative efficiency between *direct* and *hub and spoke* shipments. The basic formulation for the uncapacitated multiple allocation hub location problem is shown in Gelareh and Nickel (2011) suitable for a wide range of transportation modes. Moreover, in Alumur et al. (2012), the hierarchical multimodal hub location problem is presented where two types of hubs and hub links for ground and air transportation are considered.

However, there is an additional way to increase vehicle load factor based on the introduction of intermediate stops over distribution centers in an existing O–D route. The load contribution of those intermediate distribution centers may keep the vehicle load factor above a minimal profitable threshold in a relevant part of the shipment length.

This strategy called *stopover* is the basis to fill the whole capacity of the vehicles in one-to-many networks. Burns et al. (1985) proposed the *Economic Order Quantity* (*EOQ*) analytic model to evaluate the optimal shipment size and the number of stops considering both transportation and inventory costs for general carriers. This model is focused on the service of one-to-many networks in which deliveries have to be made in parcels far from the centers (long-haul). This strategy is also analyzed in Daganzo (1988) for one terminal to other centers of less hierarchy level in order to reduce the freight inventory cost. Nevertheless, the development of a specific methodology focused on *LTL* express carrier network design problems has been only proposed in Lin (2001), Lin and Chen (2004) and Lin and Chen (2008) where both *hub and spoke* and *stopover* strategies are considered. In these contributions, the space–time network configuration is formulated as an integer and time constrained multicommodity min-cost flow problem. Apart from that, Mesa-Arango and Ukkusuri (2013) analyze the benefits of consolidation strategies when a shipper invites a set of carriers to submit bids for freight lane. These bids allow carriers increasing truck payload utilization in intermediate links of their routes, fostering the in-vehicle consolidation.

The little number of contributions about a *stopover* strategy in the long-haul network level (many-to-many networks) is due to two major reasons. Firstly, there is a potential inability to constitute one route linking many intermediate distribution centers without violating the time constraints of the long-haul network. Secondly, the strategic planning of the long-haul network has received much attention with regard to the optimal location of hubs and other facilities. These contributions consider the goods assignment as a multi-commodity flow problem. The nature of these analyses does not allow the trip-based approach needed to identify the sequence of stops visited in a particular vehicle route. Nevertheless, the study of *stopover* strategy in ground-exclusive long-haul networks serving small regions can produce relevant cost savings to *LTL* carriers complementary to the *hub and spoke* configurations. In fact, one of the major Spanish *LTL* carriers shows that 66% of its daily long-haul routes visit more than two distribution centers (origin and destination), i.e. they are operated with a *stopover* strategy.

In this research, the effectiveness of *stopover* and *hub-and-spoke* strategies in the long-haul routing design problem is studied for *LTL* carriers. The aim of this paper is to propose a methodology that evaluates under which conditions the implementation of consolidation strategies may reduce the total transportation cost.

In Section 2, the long-haul route design problem is defined as well as the available strategies of shipments. A cost analysis of freight consolidation implementations are carried out in Section 3. In Section 4, we explain how the *stopover* and *hub-and-spoke* strategies have been incorporated into a heuristic algorithm to solve the long-haul network design problem. In addition to that, the efficiency of this algorithm has been assessed in a set of test instances in Section 5. Finally, Section 6 provides conclusions and future research directions.

2. Long-haul routing design problem

The long-haul routing design problem (*LRDP*) consists of finding the least cost vehicle routes that serve shipments among distribution centers within an established amount of time in a region R_s. The transportation network is represented as a complete graph $G = (N, A)$, where $N = \{1 \ldots\ldots n\}$ is the set of distribution centers and $A = N \times N$ is the set of arcs linking distribution centers. For each node pair (i, j), a demand flow w_{ij} is given which represents the daily freight volume or weight between these distribution centers. For the sake of simplicity, we assume that freight demands between distribution centers are expressed in terms of volume units. We define the set S composed by all shipment volumes w_{ij} $(\mathrm{m}^3) > 0$, $\forall i, j \in N$ and the integer functions $or(q)$ and $des(q)$. These functions return respectively the origin $i \in N$ and destination node $j \in N$ of the q-th shipment element $s_q = w_{ij}$, $s_q \in S$.