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A location-routing problem for cross-docking networks: A biogeography-based optimization algorithm

Asefeh Hasani Goodarzi, Seyed Hessameddin Zegordi *

Faculty of Industrial & Systems Engineering, Tarbiat Modares University, P.O. Box 14115-143, Tehran, Iran

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ABSTRACT

This paper considers a location-routing problem in a distribution network with a set of part suppliers, cross-docking centers and assembly plants known as customers. We develop a mixed integer non-linear programming formulation for the problem in which the location for establishing the cross-docks is determined while simultaneously a fleet of vehicles are applied to transport goods from suppliers to the assembly plants via two transportation strategies: direct shipment and shipment through cross-dock (indirect shipment). In the second strategy, it is possible to have routes between suppliers. Not considering two problems of location and distribution planning simultaneously would result in increasing the costs of supplying parts since the transportation strategy has a huge effect on location of cross-docks. In the other words, if some loads can be directly shipped, then this kind of loads should not be taken into account in determining cross-docks location. Thus, a location- routing problem is presented for cross-docking system in this paper. The goal is to determine the location of cross-docks, allocating suppliers to them and routing decisions, so that the location cost and total shipping cost in the network are minimized, considering variable cost of servicing parts passed through cross-docks. The proposed model is NP-hard based on literature. Thus, a metaheuristic algorithm named Biogeography-based optimization (BBO) is utilized to solve the problem. In order to evaluate its efficiency, BBO results are compared with those of PSO, which is a well-known algorithm in the literature. Solving numerical examples for small size problem instances illustrates that the solving approach performs with a negligible gap relative to GAMS, while it performs much better than PSO in most cases in terms of total cost of the network and computational time.

1. Introduction

Nowadays distribution strategy is a fundamental element in each supply chain. As acclaimed by Apte and Viswanathan (2000) about 30% of goods prices are incurred in the distribution process. Thus, enhancing distribution strategies along with satisfying customer's demands is a vital issue. There are several different strategies in distribution networks which generally consist of direct shipping, milk runs, cross-docking and tailored networks (Chopra & Meindl, 2001). If a shipment is about to a full truckload (FTL) meaning the load will fill up the entire truck, it is economical to ship directly from supplier to customer. Although when the products being shipped are less than a truckload (LTL), the other three strategies can be applied based on condition of the network (Dua, Wang, & Lu, 2007).

Cross-docking approach is recognized as one of the basic distribution strategies which refers to a process, in which the products from different suppliers are collected (pickup process) and received at a cross-docking terminal, consolidated with other products shipped to the same destination without permanent storage and finally delivered to the final destinations (delivery process). The incoming shipments are unloaded at the inbound doors of cross-dock, sorted, consolidated and reloaded into outgoing vehicles within less than 36 h. Other handling operations such as weighing, sizing, packaging, pricing and labeling products can also be done on shipments.

In some researches especially in vehicle routing problem with cross-docking (VRPCD) more complex cross-docking systems are referred, although the basic concept of cross-docking goes thorough one of cases demonstrated in Fig. 1.

As demonstrated in Fig. 1a, the network consists of one overseas suppliers and multiple retailers. With a cross-dock located in a region close to retailers, products from supplier are loaded to inbound vehicles, conveyed to the cross-dock, then sorted and

* Corresponding author.
E-mail addresses: Asefeh.hasani@modares.ac.ir (A. Hasani Goodarzi), Zegordi@modares.ac.ir (S.H. Zegordi).

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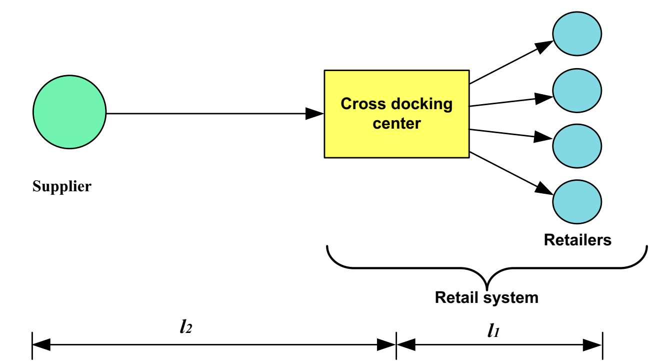

Fig. 1a. Cross-docking network containing one suppler and many retailers ($l_2 \gg l_1$).

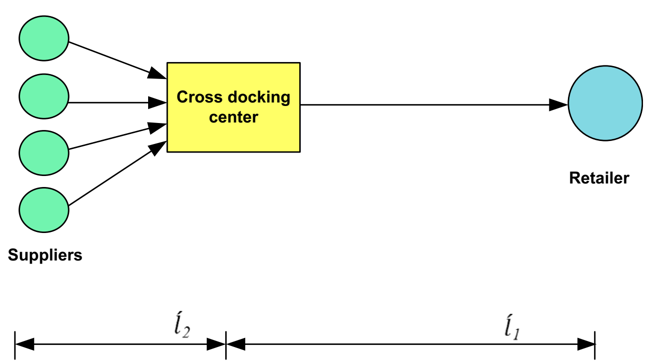

Fig. 1b. Cross-docking network containing many suppliers and a retailer ($l'_1 \gg l'_2$).

loaded to outbound vehicles and finally delivered to retailers. The distribution system in Fig. 1b includes multiple suppliers and one retailer (customer) that orders to suppliers located in a long distance. It is more economical to consolidate products from various suppliers at a cross-dock located in their nearby, instead of direct transportation from each supplier to customer (Shaolong, 2007).

There are various extensions on two basic concepts mentioned above which one of them is shown in Fig. 2.

This approach originates many benefits including the reduction of inventory holding and activities associated with storage of products; reduction of transportation cost by using full truckload and finally faster product flow in the network which leads to decreasing lead-times and improving customer service. Despite its advantages, employing this approach should be carefully evaluated since sometimes it is better to directly move shipments from suppliers to customers (Cóccola, Méndez, & Dondo, 2015).

Decision problems in cross-docking strategy can be divided in some categories regarding the decision making level, i.e., strategic, tactical or operational (Buijs, Vis, & Carlo, 2014). The strategic level of decision making includes cross-docking location and their layout. In tactical level the problem of cross-docking network design is considered. The major decisions at the operational level are the vehicle routing and scheduling, the dock door assignment and the truck scheduling at the cross-dock (Dondo & Cerdá, 2015). Therefore, planning a cross-docking strategy involves different issues including location of cross-docks, vehicle routing, etc. that can be integrated in a problem. In addition, determining the transshipment strategy between suppliers and assembly plants will deeply affect the design of distribution system. In order to explain more, it is possible to directly shipped products from suppliers to plants and these flows should not have any effect on the location of cross-docks. A real application for this problem can be found in automotive industries in which different parts from various suppliers with a vast geographical distribution should be delivered to one or more assembly/production plants. Some suppliers located near plants or their load is near to full truckload, therefore in such situations direct shipment is more economical. For other suppliers may need to establish a (some) cross docking center(s).

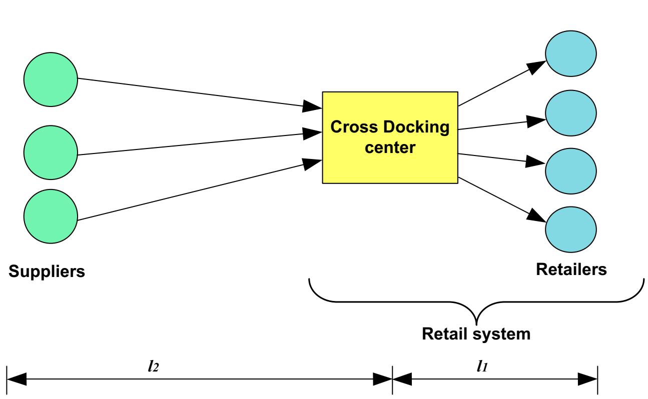

Fig. 2. Cross-docking network containing multiple suppliers and multiple retailers (Shaolong, 2007).

Cross docking is a practical tool for implementing Just-in-time (JIT) delivery in supply chain operations. In the other hand, the main objective of JIT is to minimize transportation and inventory costs while delivering parts frequently and in small quantities. Frequent deliveries would be made in less than truckload (LTL) shipments that result in a considerable transportation cost. Accordingly, the consolidation of these small shipments into full truckloads (FTL) is more economical and involves routing problem to visit multiple suppliers in a route. The consolidation is mostly done in a cross-docking facility (Chuah, 2004).

In recent years, Just-in-time has become a viable, practical method especially in automotive industry, so the goal is to keep inventory levels down by shipping loads more frequently in less order volumes (Hosseini, Akbarpour Shirazi, & Karimi, 2014).

In order to achieve this goal, a model is presented that simultaneously considers location and vehicle routing problem and decides how the loads from each supplier to each assembly plant should be shipped. In fact, it allows less than truck loads (LTL) to be consolidated through cross-docking and allows high-volume loads to be shipped directly from suppliers to assembly plants.

The remainder of the paper is organized as follows. A review on the literature is presented in the next section. Section 3 gives the problem definition and presents a mathematical formulation. The solving methodology is presented in Section 4 in details and Section 5 devoted to the computational results. Finally, Section 6 concludes the paper and offers some suggestions for future research.

2. Literature

So far, some research has been done in various categories of cross-docking, which most of them considered scheduling of vehicles in the cross-dock, dock door assignment and vehicle routing problem, although there are only a few studies that have regarded VRP and location of cross-docking, simultaneously.

The following papers focused on location problem in cross-docking: Bhaskaran (1992), Sung and Song (2003), Gumus and Bookbinder (2004), Sung and Yang (2008), Jayaraman and Ross (2003), Ross and Jayaraman (2008), Bachlaus, Pandey, Mahajan, Shankar, and Tiwari (2008), and Musa, Arnaout, and Jung (2010).

Musa et al. (2010) proposed a model in which vehicles are allowed to be routed either directly from suppliers to customers or indirectly through one of the cross-docks in the distribution network. Based on their model, Hosseini et al. (2014) addressed the transportation problem in a consolidation system and developed a new mathematical formulation for it. They assumed three