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Design and analysis of a satellite network with direct delivery in the pharmaceutical industry

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ABSTRACT

Creating and maintaining an efficient distribution network is essential for companies in the modern pharmaceutical industry. Medicine delivery usually takes place via depots and/or satellites, and the proposed model for assessing the issue determines the facility and routing decisions simultaneously. We develop a technique that iterates between an upper bound and a lower bound, based on a blended Lagrangian relaxation branch-and-cut approach where we exploit separability and linearity. We conducted computational experiments on real-life instances from the Dutch pharmaceutical industry distribution network. We show that the solution method can provide solutions for real-life cases within reasonable time windows.

1. Introduction

The efficient distribution of products to customers is one of the most important tasks of a manufacturing company. Srivastava and Benton (1990) state that the overall cost of transportation and warehousing is over 20% of the gross domestic product. Transportation costs are particularly important for the pharmaceutical industry. In the Netherlands, for example, this has been made much more crucial by the insurance companies when choosing whether to buy a particular brand, resulting in intense price competition among medicine suppliers. This competition has led to a significant decrease in the profit margins of medicine suppliers and distributors. The design of distribution networks has therefore become very useful to suppliers, since it provides an opportunity to both reduce logistics costs and improve customer service quality. Without efficient distribution networks, pharmaceutical companies cannot survive in this current competitive market.

There are two key factors relevant to designing an efficient distribution network: location and routing decisions. Traditionally, these two levels of decision-making have been handled independently of one another; it has been shown, however, that this strategy often leads to suboptimal solutions (Salhi and Rand, 1989; Li et al., 2016). We are therefore tackling the distribution problem of the pharmaceutical industry by considering location and routing problems simultaneously. The distribution network needs to be designed in such a way that customer expectations with regard to short service times and tight supply deadlines are met. Although late-arrivals are unacceptable, it is possible to distribute the medicines earlier within a defined time window. Accordingly, we will develop a solution technique reflecting these challenges.

The distribution network of a pharmaceutical company consists of the design of depots, from which medicines are transported to customers. In practice, the fixed costs associated with opening an additional depot are very high. In light of this, opening satellites (distribution centers) may be a sound strategic choice, since they can extend service range and minimize routing costs. At satellites, vehicles can drop a portion of their holding capacity, and these unloaded medicines can then be transshipped to customers by another truck starting at the satellite. Accordingly, a satellite is considered as a facility that can supply customers if the satellite is open and

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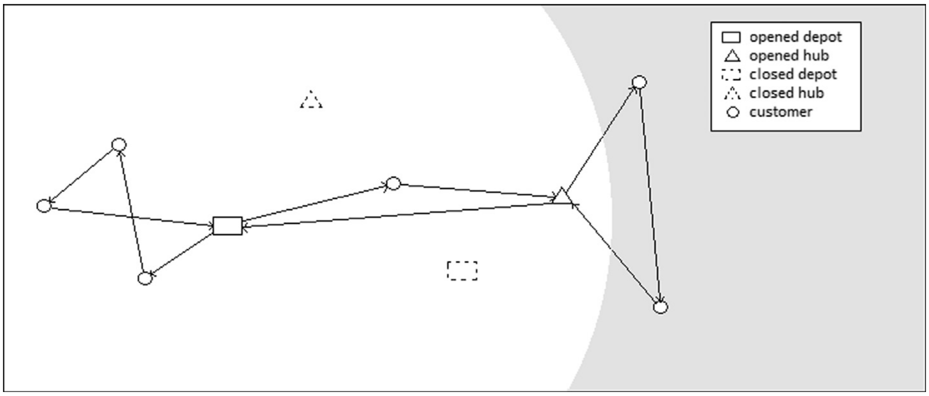

Fig. 1. Sample solution to a medicine-distribution problem.

connected to a depot. The main advantage of a satellite in comparison to a depot is the former's significantly lower opening costs.

In summary, this study analyzes a real-world LRP (location routing problem) faced by pharmaceutical industry distributors. The attributes of the problem are as follows. There exists a set of depots, satellites, and customers. It is assumed that a fleet of vehicles is already available, hence no fixed costs are associated with the vehicles. Furthermore, the medicine packages are considered to be sufficiently small, allowing many customer demands to be satisfied by one vehicle. The travel time consists of the length of the route plus the service time needed at the satellites and customers. A feasible route starts and ends at the same node, and the travel time for the route cannot exceed a predetermined maximum route length. There are fixed costs associated with opening a depot or satellite. A satellite (distribution center) is an intermediary point for a customer and a distributor. The satellites can only supply customers if the satellite is located along a route that originates at a depot. Direct delivery from the depot is also possible within the medicine supplier situation. The facilities are capacitated in such a way that they can only handle a certain number of customer orders. In a feasible solution, every customer is visited within their designated time window. The challenge is to determine which depots and satellites to open and, simultaneously, to develop corresponding vehicle routes that visit the open satellites and customers. The objective is to minimize total costs, which may be divided into facility costs and routing costs.

Fig. 1 illustrates a possible feasible solution to the distribution problem the pharmaceutical industry is facing. The depots, satellites, and customers are depicted as rectangles, triangles, and circles, respectively. The dashed lines imply that the facility is not open in terms of the current solution, while the gray area is outside the service range of the activated depot. Therefore, the rightmost satellite is activated to be able to serve customers.

To solve this problem faced by medicine suppliers, we will design a mathematical model and develop a technique that iterates between lower bounds and upper bounds. For computing upper bounds, we will make use of the decomposed problem structure and develop heuristics based on node-based approaches, greedy techniques, enhanced Clarke and Wright routing techniques, and sub-network formations. For the lower bound, we will exploit the linearity as well as the separability and develop a blended branch-and-cut Lagrangian relaxation approach. We will test our solution technique for real life instances based on the Dutch pharmaceutical industry distribution network.

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Our contribution is twofold. First, we are extending the previous research on location-routing problems by considering a direct-shipment structure where links between depots and customers are allowed when this can lead to a better utilization of the network. Moreover, to the best of our knowledge, this is the first time that a Lagrangian relaxation with branch-and-cut on allocation constraints is applied to LRP within an iterative upper bound and lower bound heuristic.

The remainder of the paper is organized as follows. Section 2 reviews the literature most relevant to the problem under consideration. Section 3 provides the mathematical formulation. While in Section 4, the overall framework of the solution method is presented. Here, we will first elaborate on the upper bound heuristic created for the solution method. The procedure to find the lower bound at each iteration of the solution technique will then be explained. The computational results of the study are presented in Section 5, followed by conclusions.

2. Related literature

Distribution network design determines and manages the supplying of goods to the right location at the right time (Xu et al., 2001). In the classical facility location problem, it is assumed that each good is shipped directly from its origin to its destination by a single driver (Balinski, 1965). In such cases, the empty travel distances are relatively large, since the driver immediately returns to

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