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Solution method for the location planning problem of logistics park with variable capacity

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ABSTRACT

In this paper we study a logistics park location planning problem in which the capacity of the logistics park is determined by the sectors used to establish it in an open site. Since the size of each sector is not necessarily the same in every potential site, the capacity of the logistics park is thus variable, which makes this problem different from the traditional location problems in which the capacity of each facility is fixed. The task of this problem is to determine the location of the logistics parks, the sectors to be used to establish the logistics park in each open site, and the allocation of customers to the established logistics parks so as to minimize the total costs for establishing the logistics parks and supplying the demands of customers. The size mode is introduced to deal with the nonlinear establishment cost function and consequently this problem is formulated as an integer linear programming (ILP) model. Since CPLEX can only solve the ILP model with small-size problems, a tabu search (TS) hybrid with filter and fan (F&F) is presented to obtain near optimal solutions. In the hybrid algorithm, the TS is used to improve the solution by changing the allocation of customers to open sites while the F&F is used to further improve the solution by adjusting the status of sites (i.e., open or closed). In addition, an elite solution pool is constructed to store good solutions found in the searching history. Whenever the hybrid algorithm is trapped in local minima, a new start solution will be generated from the elite pool so as to improve the search diversity. To evaluate the performance of the proposed hybrid TS method, the column generation (CG) method with an acceleration strategy is developed to provide tight lower bounds. Computational results showed that the proposed hybrid algorithm can obtain optimal solutions for most of the small size problems and satisfactory near-optimal solutions with comparison to lower bounds for large size problems.

1. Introduction

As an important part of supply chain management, the distribution system design is a strategic issue for large scale corporations. The key components of the distribution system design are the facility location and customer allocation. The facilities should be located near the warehouses to decrease the transportation cost and the capacity of each facility should supply the demands of the customers allocated to it. Recently, various logistics centers have been established around large cities for quickly distributing freights. In the meanwhile, many societal problems concerning the freight transportation have consequently emerged, such as traffic congestion, air pollution and high energy consumption. To efficiently cope with these problems, it is preferred that the logistics centers should be integrated by the logistics parks.

The logistics park is called "Freight Village" in Germany and "Distribution Park" in Japan. It is a very complex facility consisting of logistics management systems, advanced information systems and cooperative freight transportation systems. The logistics park is designed to cooperate with logistics centers, decrease inventory cost, and supply customer demands better for both private companies and society. Freights are firstly transported to the logistics park, then reallocated in the park by destination, and finally transported to customers. The logistics park is managed generally by the third-party logistics company that has signed cooperation contracts with other logistics companies to efficiently run the logistics systems. However, some logistics parks have not been fully utilized because of unreasonable location or excess service capacities. Since the establishment of a logistics park needs a great deal of money and land, the location and scale of the logistics park should be determined scientifically and optimally.

The traditional capacitated facility location problem has attracted a lot of attention from many researchers. Weber [1], Bechman [2], and Drezner [3] introduced the planning of location

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and size for facilities. Hansen et al. [4–5] changed the model proposed by Yoo and Tcha [6] and obtained a multi-capacitated plant location problem (MCPLP) where potential locations have the same size set for platforms. To solve the MCPLP, a tabu search (TS) method is developed by the author. Lee [7–8] considered a generalization of the multi-product capacitated facility location problem (MPCFLP) in which there involves a system with a choice of various facility types and several different products required by customers. Each facility type offers a different capacity on a particular product with different fixed costs. Benders decomposition and Lagrangean relaxation are used to solve this problem. Mazzola and Neebe [9] presented both exact and heuristic solution procedures for another kind of MPCFLP in which the demand for a number of different product families must be supplied from a set of facility sites, and each site offers a choice of facility types exhibiting different capacities. Taniguchi et al. [10] presented a mathematical model to determine the optimal size and location of public logistics terminals and adopted the queuing theory and nonlinear programming techniques to obtain the best solution.

Unlike the above literatures in which the capacity of each facility is fixed, this paper investigates the location planning problem of logistics parks with variable capacities. In this problem, there are a number of available sectors in each potential site and the establishment of a logistics park does not necessarily need all the sectors in this site. In addition, the number of available sectors and their sizes are not necessarily the same in each potential site. So the capacity of each established logistics park is variable and determined by the total size of used sectors in the site. The task of this problem is to determine the location of the logistics parks, the sectors to be used to establish the logistics park in each open site, and the allocation of customers to the established logistics parks so as to minimize the total costs for establishing the logistics parks and supplying the demands of customers. The size mode is introduced to deal with the nonlinear establishment cost function, and consequently this problem is formulated as an integer linear programming (ILP) model. Although this model is similar to the one proposed in [6], the problem we considered is a different one. In the model of [6], the capacity of each facility is selected from the same candidate capacity set that has been predetermined. But in our model, the capacity of each logistics park has its own candidate capacity set, and is a function of the decision variable, i.e., the status of a site and the adopted combination of sectors in this site.

This paper is organized as follows. Section 2 is devoted to presenting the ILP model for this problem in which the discrete size mode is introduced. The hybrid heuristics is described in details in Section 3. In Section 4, a column generation algorithm is designed to obtain a tight lower bound for this problem. At last, the computational results and our conclusions are presented in Section 5.

2. Mathematical formulations

2.1. Problem description

In this problem, there are always several potential sites for selection in a region, and in each potential site there are many available sectors with different sizes (Fig. 1) that can be used to establish a logistics park. As shown in Fig. 1, the size of each sector may be different and consequently the corresponding cost of each sector is different (the different colors mean the different unit size costs). The size of used sectors is a variable of the establishment cost function for a logistics park in an open site. Therefore, the establishment cost function is nonlinear. An example is shown in Fig. 2. With the increase of the capacity of the logistics park by utilizing more sectors, the establishment cost increases nonlinearly at the same time.

Fig. 1. Potential sites distribution.

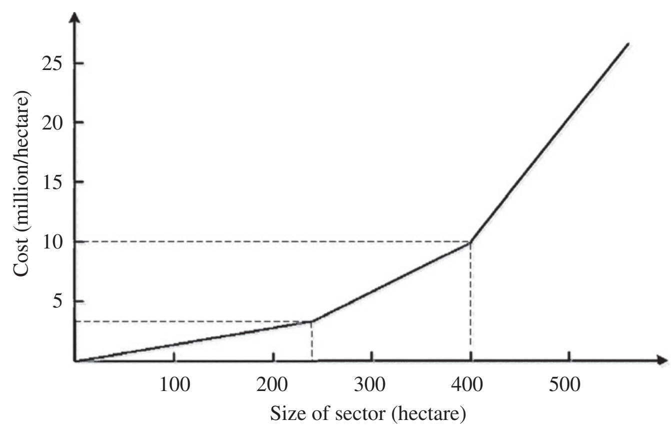

Fig. 2. An example for establishment cost function.

2.2. Size mode

Once a sector is selected to establish a logistics park, it is required that the whole piece of this sector should be used instead of only partial piece. Based on this practical requirement, we introduce the size mode so that the problem can be formulated as an integer linear programming model. The size mode is based on the selection of sectors in a potential site. As mentioned in Section 2.1, in a site there are several adjacent sectors to be selected for the establishment of a logistics park, and the size mode refers to the combination of the available sectors, and consequently the cost and capacity of different size mode are generally different.

For example, in a potential site shown in Fig. 3, there are four available sectors denoted as a_1, a_2, a_3, a_4. The sizes of these four sectors are (1, 2, 2, 3), and the corresponding costs are (1, 2, 3, 3) respectively. Here, though the sectors a_2 and a_3 have the equal size, the size mode of "a_1+a_2" is different from that of "a_1+a_3" because they have different costs. All the size modes for this potential site are given in Table 1.

Since the sectors may not be adjacent in the geographical distribution, some size modes may be infeasible. For example, the sectors a_1 and a_3 are at the diagonal positions in Fig. 3, so the size mode of "a_1+a_3" cannot be chosen as a whole site to establish the logistics park. Therefore, the size modes 6 and 9 are deleted.