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Overview of Facility Location Issues

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Abstract

Location problem is an important problem in the field of combinatorial optimization. It is to make location decisions for some limited and important resources such as network servers, nuclear power plants or logistics centers. It is widely used in production management and scheduling, network communication, theoretical computer science, etc. This paper introduces several types of classic facility location problems, and summarizes the characteristics of several types of classic facility location problems through comparative analysis. The research significance of this paper is that after analyzing the characteristics of different models, it can help subsequent researchers to propose different heuristic algorithms for problem models with different characteristics.

Keywords

location problem; algorithm.

1. Introduction

People's research on site selection has a long history. From ancient times, people's site selection for living nests to modern site selection for various manufacturing factories, warehouses and service facilities. Site selection issues are closely related to people's lives. The event that marked the beginning of the study of modern location problems was Alfred Weber's 1-median problem in Euclidean space in 1909. In 1964, Hakimi proposed to select the location of service facilities on the Internet. The issue of network location has been extremely widely used in the location of supermarkets, banks, warehouses, factories and other public facilities. For the site selection of different facilities, the considerations and concerns are also different, resulting in different objective functions and constraints. According to the types of facilities and the different issues considered by decision makers, scholars have put forward many models to solve specific facility location problems in practical problems.

2. Classification of Location Issues

Among the numerous site selection problems, researchers call the P-median problem, P-center problem, and coverage problem the basic site selection problem or the classic site selection problem. Other site selection problems are basically in these three types. The site selection model proposed on the basis of collectively referred to as the extended site selection problem. The following is a comprehensive description of three types of basic site selection issues.

2.1. P-median Problem

Hakimi posed the classic P-median problem in 1964. P-median problem research It is known that the number of facilities that can be established is P. The objective function is to minimize the sum of the weighted distances from the user to the established facility. Although the P-median problem is a classic and relatively simple location problem, the researchers still proved that the P-median problem is an NP-Hard problem (Garey and Johnson, 1979), and proved that

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the p-media Hakimi characteristics of bit problems (Hakimi, 1964). Subsequently, scholars used the classic P-median problem to study the location problem in specific environments, such as the location of facilities in a competitive environment (Hakimi, 1986), and the dynamic P-median problem (Drezner, 1995). Chen and Handler (1993) put forward the PQ-median problem, that is, the conditional median problem. According to this problem study, there are already Q facilities in the service network, and now we consider building P facilities of the same type in the service network. The objective function is the minimum sum of the weighted distances from the demand point to the facilities. Since the P-median problem is an NP-Hard problem, some scholars have also studied the solving algorithm of the P-median problem and proposed heuristic algorithms such as Lagrangian relaxation algorithm and tabu search. Brimberga and Drezner (2013) proposed a local search algorithm. A large number of numerical examples prove that the algorithm is very effective for solving P-median problems on a plane.

2.2. P-center Problem

The P-median problem considers that the sum of the weighted distances from the user to the established facility is the smallest, that is, considering it as a whole, it may cause a user to be farther away from the facility. In order to solve this problem, researchers have proposed P-center problem. The P-center problem is to study that only P facilities can be established in the network, and then users are assigned to the nearest service facility established. The objective function is to minimize the maximum distance between all users and the facility. The P-center problem is the objective function is a Minmax problem. The P-center problem was raised by Hakimi in 1964. Hakimi (1964) first studied the P-center problem on the Internet. The P-center problem, like the P-median problem, is also an NP-Hard problem (Kariv and Hakimi, 1997). Some P-center problems are NP-Complete problems, such as P-center problems based on straight-line distance and Euclidean distance (Masuyayma et al., 1981; Megiddo and Supowit, 1984). Since the P-center problem is an NP-Hard problem, the subsequent research focuses on how to solve the P-center problem quickly and effectively. Many scholars have proposed effective heuristic algorithms, such as the Drezner-Wesolowsky method and the local search method (Hassin et al, 2003), proxy heuristic algorithm (Levinand Ben-Israel, 2004), etc.

2.3. Coverage Issues

The P-median problem and the P-center problem assume that no matter how far the facility is from the user, the user will go to the facility to seek service. The fact is that if the facility is too far away from the user, the user may not go to the facility to seek service. That is, considering that the facility has a service radius r, if the distance between the user and the facility is less than r, the user will go to the facility to seek service, otherwise, it will not. Based on this idea, the researchers put forward the coverage problem. According to the different objective functions and constraints, scholars divide the coverage problem into two types: set coverage and maximum coverage. The constraint condition of the set coverage problem is that all users are covered by at least one facility, and the objective function is to establish the least number of facilities or the lowest cost of site selection. The set coverage problem was first proposed by people to solve the location problem of emergency service facilities such as fire centers (Roth, 1969; Toregas et al., 1971). In this type of emergency facility, users should not be too far away from the facility. For example, it is required that the fire center is no more than 10 minutes away from the user by car, and all users can be served by the fire center. Researchers have also designed many effective algorithms to solve the set covering problem. Common algorithms for solving the set covering problem include Lagrangian relaxation algorithm and genetic algorithm.

Another common type of coverage problem is the maximum coverage problem. Its research has known that only P facility location problems can be established. The objective function is the maximum number of users that can be covered by the facility. This type of problem is also called

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P-coverage problem. The problem of maximum coverage is raised in the study of the location of public service facilities (Church and ReVelle, 1974). In the location of public service facilities, with limited resources, the goal of decision-makers is usually that these public facilities can serve more users. The maximum coverage problem is also an NP-Hard problem (Daskin, 1995).

The coverage model has been widely used in the location of emergency service facilities and public service facilities. Li et al. (2011) comprehensively explained the application of coverage model in the actual location of facilities. The coverage problem assumes that the user is served within the service radius of the facility; otherwise, it will not. In actual problems, the service radius of the facility is not so clear. The impact of the facility on users decreases as the distance between them increases. That is, the service radius of the facility is a decreasing function of the distance. This type of problem is called a gradual coverage problem. In the coverage problem, it is sufficient to consider that the user is covered by one facility. The actual situation is that facilities within a certain range of the user have an impact on the user, that is, considering that the user is covered by multiple facilities, this type of problem is called a combined coverage problem. Recent studies have mostly focused on the expansion of coverage models like these two types.

With more and more applications of mathematical methods and operational research models in the field of management science, scholars are also increasingly studying site selection. In recent years, with the development of computer technology, the solving speed of the location model is getting faster and faster. Researchers combine real-world problems and put forward models that are more in line with practical problems, such as river closure site selection model, random site selection model, robust site selection model, and site selection model in a competitive environment. Depending on the nature of the specific facility and the environment in which the decision makers are located, the constraints and objective functions of the location model are also different. Scholars have put forward many extended location issues on the three classic basic location issues, and in practice the problem has been widely used.

3. Method of Facility Location

3.1. Heuristics Method

Heuristic methods only look for feasible solutions, not optimal solutions. The center of gravity method in the load distance method is a heuristic method. As early as the 1960s, someone proposed to use heuristic methods to solve the problem of large-scale facility location. Today, heuristic methods have been widely used in many occasions.

3.2. Simulation Method

Simulation is an attempt to reproduce the behavior or activity of a system through a model, without having to build and operate a system on the spot, which would cause huge waste, or it is impossible to carry out operation experiments on the spot. There are many applications of simulation methods. In the site selection problem, simulation can allow analysts to repeatedly change and combine various parameters to evaluate different site selection schemes through multiple trials. Simulation methods can describe various influencing factors. The transportation table method has greater practical significance. This method can also be used for dynamic simulation. For example, assuming that the demand in each region changes randomly, the average demand in each region can be estimated through a certain length of simulation operation, so as to determine the distribution center and production center on this basis. It can also simulate the change level of inventory through changes in demand, which can be used to help determine the scale of production, production, transportation, and storage costs. This method is often used to solve larger problems that cannot be solved by hand. For example, a company has 137 demand centers, 5 regional distribution centers, and 4 production plants.

When a conclusion is drawn through dynamic simulation calculation and analysis, if the existing 5 distribution centers are merged into 3, it can be The total cost is the smallest, the plan has been implemented, and annual savings of 130,000 US dollars after implementation. This is a real case in the 1970s.

3.3. Optimization Method

The transportation table method is actually an optimization method, although it is only the optimum of a certain orientation problem. This method is not a feasible solution or a satisfactory solution, but an optimal solution, that is, among all possible solutions, there will be no better solution. However, since this method has to be proved theoretically optimal, it has two major limitations in its use: 1) The model must be relatively abstract and simple, otherwise the solution cannot be obtained. But because of this, the description of the model is far from reality; 2) Many qualitative factors have been ignored, so it is impossible to draw many conclusions that may be drawn under qualitative conditions. In short, there are many methods that can be applied in facility site selection. In particular, the development of computer technology has made facility site selection methods more diverse, but these methods are only used to support decision-making, making decision-making more convenient and saving time and cost. It is impossible to completely rely on it.

3.4. Simple Midline Mode Method

The simple centerline model method is a method of site selection. This method has its limitations. This method only assumes that the optimal point on the coordinates is a feasible site for plant construction, and does not consider whether there are roads there, or the natural topography and population density. And many other important things that should be considered when arranging points.

4. Summary

Facility location selection is a complex issue. Many existing studies have proposed many different research methods from different perspectives. However, no method is universally applicable, and must be combined with specific conditions and specifics. The problem comes to a specific analysis.

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