ISSN: 2664-9640

A brief analysis of commercial or emergency facilities location problem

Kecheng Wu, Fenglian Xiang, Qi Gu, Chao Chen

School of Sichuan University of Science & Engineering, Sichuan 644000, China

Abstract

Reasonable location problem research is of great significance in economic, social and scientific aspects. This paper gives a comprehensive overview of the current location problem, and introduces three classic location problem for different siting situations, influencing factors, location models and their solution methods: the P-median problem, the P-center problem, and the coverage problem. At the same time, according to the evolution and development of the current location problem, three more representative derivative location problem are discussed: competition problem, multiple target problem, dynamic location problem, and the classical location problem and the derived location problem are combined. questions to make a comprehensive comparison. Finally, combined with the current solution algorithm for the location problem, the future research direction and noteworthy points of the location problem are given, and the expectation of the location research in the era of big data is given.

Keywords

Classic location; competitive location; multiple target location; dynamic location; location modeling.

1. Introduction

The location problem is planned in the field of operations research, and its research scope is extremely wide. The main research objects here are commercial or emergency facilities such as hospitals, banks, logistics centers, and fire centers. Different types of facilities consider different factors. The existing research results show that the location problem has experienced a very long research cycle, and has gradually formed its complete research system since the beginning of the 20th century. The location selection problem will continue to deepen and refine with the development of society, and its model will also be improved, so the algorithm to solve these problems needs to reach the corresponding height, which has always been the focus of the study of location problem.

2. Overview of location problem

The location decision theory is gradually enlarged and perfected. It is applied to all aspects of practical life problems, and many different types of location problems are derived. Table 1 gives a summary of the current mainstream siting issues.

Table 1: location problem type

Criteria for the classification	classification name	location problem
Are there alternatives Number of location facilities Facility location timeliness others	Discrete or Continuous Multiple target or Single target Static or Dynamic Competitive or Non-competitive	P-median location problem P-center location problem coverage location problem dynamic location problem Competitive location problem

According to the characteristics and applicability of each location classification classification, Daskin[1] divided into four categories: analytical model, discrete model, continuous model, and network model. Analytical models are generally based on large-scale assumptions and ignore special cases, and this model method cannot be well applied to practical decision-making. The application of discrete model in location is based on the selection of discrete points in candidate addresses, and its problems can be expressed by mathematical tools such as integer programming and graph theory. The continuous model is based on the location of facilities on the plane that is influenced by multiple factors. The network model is based on the location of the network structure formed by points and edges, and its application range is small. The current mainstream location problems belong to discrete models and continuous models.

3. Introduction to location problem

3.1. Classic location problem

The classical location problem usually refers to the three basic problems of the P-median problem, the P-center problem and the coverage problem. Its model structure is relatively simple and often only considers a single requirement. The location problem has a huge impact on the development of the subsequent location research.

2.1.1 P-median location problem

The P-median problem has always been a hotspot in the study of location problems, and it is widely used in distribution centers, fire centers and other service facilities. The goal is to have the shortest average distance or time, which can also be called an optimization problem. The model can be described as:

$$\min \sum_{i} \sum_{j} h_i d_{ij} Y_{ij} \qquad (2-1)$$

i is the serial number of the target customer group; j the serial number of the facility; h_i is the demand of the target customer group; d_{ij} is the distance between the target customer group i and the selected facility j ; when the target customer demand point i is satisfied by the facility j , Y_{ij} is 1, 0 otherwise. It belongs to the NP-complete problem. When P is a variable, it becomes a typical NP-Hard problem, which needs to be solved by an optimized and efficient algorithm. In order to minimize the average weighted distance or time between demand points and service centers when considering the p-median problem. Reference[2]proposes a simple new heuristic method for specific problems, and analyzes its superiority sex. Reference[3]used the artificial bee colony algorithm model to solve the P-median problem, which is one of the meta-heuristic algorithms used to solve combinatorial optimization problems, and achieved good results in experimental tests. Reference[4]investigates the commonly used heuristics to solve the P-median problem and studies its progress.

2.1.2 P-center location problem

The P-center problem has also become the smallest and largest problem, which refers to P facilities. For each emergency point, it is served by the facility that is closest to it among the selected facilities. All emergency points are required to correspond to the facilities that serve them Minimizing the maximum service distance between all emergency points and their service facilities, the problem can be described as:

$$\begin{gathered} \min D \\ D \geq \sum_{j} d_{ij} Y_{ij}, \ \forall i \end{gathered} \qquad (2-2)$$

d_{ij} is the distance between the target customer group i and the selected facility j .The target equation finds the minimum and maximum distance between the target customer group and the closest facility distance D .The constraints define the maximum distance from any target customer group i to the closest facility j .when the target customer demand point i is satisfied by the facility j , Y_{ij} is 1, 0 otherwise.

Reference[5]optimizes the traditional model by considering the random fuzzy demand of customers, and combines several algorithms to solve the random fuzzy model; some scholars use the heuristic search method to solve. Reference[6]proposes a new layout scheme for aviation emergency rescue by using the analytic hierarchy process model combined with the P-center model of emergency facility location selection in the context of aviation search and rescue. Reference[7]improved the exact algorithm, so that the solution rate of the original model was significantly improved. Reference[8]studied the mathematical properties of the P-centric model to reduce the scale of its problems, and proposed a backtracking algorithm based on upper and lower bounds to speed up the solution.

2.1.3 Coverage location problem

Covering problems are divided into set covering problems and maximum covering problems. It is a classic NP-hard problem in the field of operations research. The ensemble coverage problem requires that all demand sites build the minimum number of facilities to meet the demand under the condition of coverage, and its objective equation is as follows:

$$\min \sum_{j} c_j X_j$$
$$s.t.\begin{cases} \sum_{j\in N_i} X_j \geq 1, \forall i \\ X_j \in \{0,1\}, \forall j \end{cases} \qquad (2-3)$$

c_{ij} is the cost of facility construction. The objective equation finds the minimum facility construction cost to meet all demands within a given time (distance). If you choose to build a facility at point j ,so X_j is 1, 0 otherwise. It should be noted that this equation does not take into account the size of the demand, which can be satisfied by the facility regardless of its size.

The maximum coverage problem is to maximize the number of demand points that can be radiated by these facilities under the condition of known facility attributes (the number of facilities that can be established and the radius that can be covered). The maximum coverage model can be described as:

$$\max \sum_{i} h_i z_i$$
$$s.t.\begin{cases} Z_i \leq \sum_{j} X_j, \forall i \\ \sum_{j} X_j \leq P \end{cases} \qquad (2-4)$$

h_i is the demand of target customer group serial number i ; if the node is overwritten, z is1, 0 otherwise. The objective equation is to find how to set up P service points to maximize the demand that can be covered. Constraints determine that a facility serves a target group of customers within a specified distance, and constrains the number of facilities to be less than or equal to P .

There are generally two types of methods for solving this maximum coverage problem. The first type is to use an exact algorithm to solve, but this type of method cannot effectively simulate and solve the actual problem due to the single consideration; the second type is the heuristic algorithm, which is also the most commonly used method. The situation considered in the traditional maximum coverage location model is too theoretical and does not take into account the correlation between service points in practice. Moreover, most of these models directly use the Euclidean distance for calculation, without considering the relevant attributes of the actual road network, the actual usability is poor, and there are many limitations, such as

ISSN: 2664-9640

immeasurable losses caused by these errors. Some scholars have improved the traditional model in view of these shortcomings. Reference[9]establishes the maximum coverage model based on the actual road network, which better fits the actual road conditions and has strong applicability, and also provides a significant research direction for later scholars. Reference [10]optimizes the traditional model, adopts the method of combining the location set coverage model and the maximum coverage model, and proposes a GIS-based site selection model application process, and makes practical analysis and improvement of the response model according to practical problems.

3.2. Derived location problem

On the basis of the previous three classic location problems, other factors are added to form the derivative location problem. Since the derived location problems are combined according to different actual needs at the same time, there is a large overlap in each classification. This section only Some representative derivative problems are described.

2.2.1 Competition location problem

Under the pressure of industry competition, many location problems have risen to the situation where competitive factors have to be considered. Such problems can be understood as considering the interaction of new and old facilities of the same type in the stage of location decision. From an economic point of view, Alternatives cannot ignore the impact of competition. Since the selected facilities generally have the nature of long-term service, the current research on the competitive siting problem mainly focuses on the static problem. that is the crux of these issues, for example, the Reference [11]considers the elastic demand of the market, and analyzes a series of impacts of chain enterprises after new facilities enter the market. Reference[12]proposes a strong mathematical decision-making algorithm that can quickly solve large-scale problems with similar competitive properties. The difficulty of competitive location problem is very obvious. In some more complex location methods, the competition of facilities generally only considers the number of similar facilities in the market, and lacks certain rigor. However, if it is necessary to take into account the rigor of competition issues and the game between similar facilities, the complexity of the problem will be greatly increased.

2.2.2 Multiple target location problem

In practical problems, various types of location (such as public sector, state-owned enterprises, private enterprises, etc.), due to resource constraints, often set multiple goals in the in the location process, usually the transportation cost, construction cost, customer service level coordinate planning for goals. Generally, the objective that needs to be satisfied is used as a constraint, and a model that minimizes the input is constructed based on this. When researching the location of medical service facilities, some predecessors proposed that not only to minimize the expected transportation cost, but also to consider other rigid requirements of facility services, such as the time urgency of services. Reference[13]also considers the two goals of minimizing cost and maximizing demand in similar research. Reference[14]proposed a high-dimensional multi-objective evolutionary algorithm based on population association strategy and enhanced solution set criterion, which not only has stronger competitive performance in dealing with high-dimensional multi-objective optimization problems, but also improves the performance of dealing with different types of Pareto fronts ability.

The location of modern facilities usually tends to be multi-demand and multiple target, and a practical location scheme cannot avoid the problem of multiple target. This also complicates the research on location problem, such as the need for actual surveys of target areas, diverse data collection, and surveys involving user experience, which increase the difficulty in data collection and model solution.

2.2.3 Dynamic location problem

ISSN: 2664-9640

For the location of emergency or commercial facilities such as sales centers, logistics centers, fire stations, etc. It takes a long time to serve after the establishment of the construction, but the factors of the location decision are changing, such as the flow of people, transportation costs or traffic Factors, etc. These factors may cause the original facility location to become no longer optimal at some time in the future. If re-planning is considered, the cost of building new facilities is too high, and the problem of dynamic location is born.

Some scholars have chosen different emphases in the original location cases, and have studied the related issues of dynamic location in detail. For example, the reference [15]studies the problem of relocation of demand points when the weight of demand points changes in a known way in time and latitude, and gives the optimal solution method for different location problems. Dynamic programming can also be carried out in the context of multiple facilities. Reference[16]extended the conventional multi-facility location problem dynamically, and studied two analytical methods for the dynamic problem. Dynamic location problem is more strategic to a certain extent. It is a further in-depth study of location to help people consider the sustainability of location schemes. However, this type of location research has not been perfected, and its own scientific and practical nature. There are major defects in applicability. For example, the changing factors of alternative addresses or regions are often unpredictable, which will lead to the development of dynamic location schemes in a more subjective direction, and the scientific validity is obviously insufficient.

3.3. Summary of location problem

The division or decision-making of location problems is mainly analyzed according to the needs of actual problems. Different location models have their own advantages and disadvantages for solving different problems. These limitations may come from model establishment and algorithm selection. These advantages and disadvantages are not absolute or cannot be improved. The correct evaluation criteria need to analyze the actual needs. Generally speaking, table 2 gives a comprehensive description of the above location problems, and makes a summary in combination with the references.

Table 2: Summary of location problem

Question category	Target	Model advantage	Limitation
P-median location problem	Find the minimum weighted average distance from each demand point to the facility	Seek fairness in all demand points as much as possible	Since only the average distance is used as the standard, the practical application object is relatively limited
P-center location problem	Find the minimum maximum distance from any demand point to the nearest service point	Guarantee service coverage and improve service quality on top of this	Uneven distribution of target points may lead to insufficient scientific validity
Maximum coverage location problem	The number of service stations and the service radius are known to maximize the coverage demand	Maximize service efficiency when limiting facility attributes	The model is more traditional and lacks scientific consideration in its practical application
Collection coverage location problem	Guaranteed to cover all demand points and minimize the cost of facility construction	Minimize facility input costs where demand is determined	Involves the allocation of demand points of various facilities, resulting in more complex problems

ISSN: 2664-9640

Competition location problem	How to join the market for similar facilities to optimize location	Can do more specific analysis of product entering the market	Static usability has certain limitations, resulting in more complex problems
Multiple target location problem	Minimize costs with the constraints of achieving goals	It is beneficial to analyze the correlation between multiple targets	The amount of calculation is huge, and the optimization property for processing too many objectives is poor
Dynamic location problem	Consider time-varying planning of facilities based on static location	Saves the cost of re-planning when considering optimality changes	Variable factors are unpredictable, and the scientific nature of the model needs to be considered

4. Conclusion

Although the classic location problems are of milestone significance, and there are many scholars who study them, the problems caused by the overly simple models are difficult to make up. Many scholars are committed to optimizing their algorithms, so that such problems can be calculated more efficiently and accurately, but only a few scholars have improved their scientific and practical application, so the classic location problems can be focused on in future research. In the improvement of the model to improve its practical application ability, the traditional model is rarely used.

Derivative location problems are more widely used and deeper than classical location problems, and they also start later. Most of the derived location problems are slightly modified from the classic location problems, and only a few problems can be divided in detail, such as the categories mentioned above. Such problems combine knowledge in other fields or increase the complexity of the model to meet the needs. The scientific and practical application of location is relatively higher, but it may also be counterproductive due to algorithm limitations. Therefore, in addition to the improvement of the model, the derived problem also needs to optimize the algorithm.

Compared with the mainstream discrete location, the research on continuous location should also be emphasized. The research on continuous location selection is difficult and started late, and related research was formed around the end of the 20th century. All aspects need to be deepened and improved, and a more systematic method of continuous location selection is needed.

Driven by the era of big data, the research on location tends to be more transparent and complicated. Strong data support enables location research to better rely on integrated development, which greatly improves location. The reliability of the scheme is also a major advantage of big data. How to carry out scientific and reasonable data mining and analysis of location based on existing data is something that scholars need to actively explore and study, and it is also a good research direction for location in the future.

5. Future works

This paper focuses on the current mainstream location problem, considers its models, algorithms and other applications, and compares the related algorithm models involved. It can be seen that the current location problem is still how to scientifically and systematically optimize the configuration of existing facilities. Anything must be considered based on this

ISSN: 2664-9640

problem. The and how to select the location of new delivery points researchers also need to find more advanced and scientific and how to select the location of new delivery points methods based on the experience of predecessors and the development and changes of the social era.

Acknowledgments

This paper is funded by the Innovation and Entrepreneurship Training Program for College Students (China), Project Number: S202110622066, and it funded by Enterprise Informatization and Internet of Things Measurement and Control Technology Sichuan Provincial University Key Laboratory Project, Project Number: 2020WYY01,2020WYY02.

References

[1] DASKIN M S. What You Should Know About Location Modeling [J]. Naval Research Logistics, 2008, 55(4): p.283-94.

[2] DZATOR M, DZATOR J. An effective heuristic for the P-median problem with application to ambulance location [J]. OPSEARCH, 2013, 50(1): 60-74.

[3] BASTI M, SEVKLI M. An artificial bee colony algorithm for the p-median facility location problem [J]. International journal of metaheuristics, 2015, 4(1): 91-113.

[4] MLADENOVIĆ N, BRIMBERG J, HANSEN P, et al. The p-median problem: A survey of metaheuristic approaches [J]. European Journal of Operational Research, 2007, 179(3): 927-39.

[5] WEN M, RUI K. Some optimal models for facility location–allocation problem with random fuzzy demands [J]. Applied Soft Computing Journal, 2011, 11(1): 1202-7.

[6] Zhu Yan, Shao Quan, Jia Meng, et al. Research on the Layout Method of General Aviation Emergency Rescue Points [J]. Henan Science, 2015, 33(02): 265-70.

[7] MGS A, JAD B, RM C. An improved exact algorithm for a territory design problem with p-center-based dispersion minimization - ScienceDirect [J]. Expert Systems with Applications, 146.

[8] Shang Chunjian, Ning Aibing, Peng Dajiang, et al. A Reduced-Order Backtracking Algorithm for P-Center Location Problem [J]. Application Research of Computers, 2021, 38(03): 734-7+69.

[9] Wang Haowen, Wu Chuxiong, Chen Chi, et al. Research and Realization of Maximum Coverage Double Layer Site Selection Based on GIS [J]. Chinese High Technology Letters, 2021, 31(04): 387-95.

[10] Chen Zhifen, Li Junwei, Lu Fangxin, et al. Optimization of site selection and layout of urban fire stations and its enlightenment to Xiongan New Area [J]. Journal of Safety Science and Technology, 2018, 14(09): 12-7.

[11] Wanbo, Yang Chao, Chen Qin. Research on location selection of new facilities in chain enterprises based on elasticity of demand [J]. Statistics & Decision, 2017, (13): 4.

[12] He Yongmei , Peng Dajiang, Shang Chunjian, Zhang Huizhen. A Competitive Decision-Making Algorithm for Facility Location Problems with Soft Capacity Constraints [J]. Computer Engineering and Applications, (50-54).

[13] NONE. The plant location problem: new models and research prospects [J]. Location ence, 1997, 5(3): 203.

[14] Qin Hao, Li Junhua. High-Dimensional Multi-objective Evolutionary Algorithm Based on Population Association Strategy and Reinforced Solution Set Criterion [J]. Control and Decision: 1-10.

[15] DREZNER Z, WESOLOWSKY G O. Facility location when demand is time dependent [J]. Naval Research Logs (NRL), 2015, 38.

[16] SCOTT, J A. Dynamic location - allocation systems: some basic planning strategies [J]. Environment & Planning A, 1971, 3(1): 73-82.