Research on the Model and Method of Site Selection for Power Grid Material Distribution Center

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Abstract. This paper conducts an analysis of the site selection methods for power grid material distribution centers. It proposes the fundamental principles for site selection and organizes and compares representative models and commonly used methods in site selection issues. Taking the establishment and solving process of the site selection model for power grid material distribution centers as an example, the specific methods and procedures of Sparrow Search Algorithm applied to site selection problems are explained, and analyzes the shortcomings of this method. Finally, building upon the comparison and summary of simulated annealing algorithm and Sparrow Search Algorithm in the preceding sections, this paper combines their strengths to propose an approach for optimizing the solution method，that is, using the former to update the iterative optimal solution of the latter, in order to reduce the risk of falling into local optimization, enhance the accuracy of problem-solving, and improve distribution efficiency. This contributes as a reference for similar site planning and decision-making processes.

1 Introduction

With the continuous development of the power industry and the ongoing upgrading of power equipment, the role of the power grid material distribution center has become increasingly crucial. Site selection with the continuous development of the power industry and the constant upgrading of power equipment, stands out as the primary concern in the construction of power grid material distribution centers, and the rationality of this selection directly impacts the efficiency and cost of material the role of the power grid material distribution center has become increasingly crucial. Therefore, determining an appropriate site out as the primary concern in the construction of power grid material distribution centers, and the rationality of site selection directly impacts the efficiency and selection cost strategy has of become material one distribution.

This paper delves into the issue of site selection for power grid material distribution centers, conducting in-depth research on fundamental principles, commonly employed methods, and the establishment and resolution process of site selection models. A power grid material distribution centers, conducting a novel site selection approach based on Sparrow Search algorithms is proposed, explaining its capability to swiftly and accurately identify optimal site selection solutions.

2 Principles for the location of the power grid material distribution center

The location of the power grid material distribution center is one of the key decisions for power companies and power supply departments[1]. It involves the effective distribution of power grid equipment, materials, and maintenance supplies to maintain the reliability and continuity of power supply. The general principles of location include:

2.1 Efficiency principle

The site selection should allow for the delivery of materials to users in the shortest possible time to ensure the efficiency of the supply chain, and consider the storage capacity of the selected location to meet demand and respond to temporary demand fluctuations.

2.2 Economic principle

The cost of land use and operation should be considered to ensure the economic rationality of the site selection.

2.3 Accessibility principle

With convenient transportation, materials can be quickly delivered, quickly responding to demand and reducing energy loss.

2.4 Adaptability principle

Ensure that the planning and operation of the site and facilities comply with all applicable regulations and rules.

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3 Basic methods for selecting the location of power grid material distribution center

The location of distribution centers can be divided into qualitative and quantitative methods.

3.1 Qualitative research methods

Qualitative research is based on the analysis of factors that affect the rationality of site selection, and establishes a comprehensive evaluation index system. It often uses analytic hierarchy process and fuzzy comprehensive evaluation to evaluate multiple alternative solutions and obtain the optimal solution. Due to the strong subjectivity of qualitative methods in reflecting the experience, preferences, and willingness of decision makers in the research process, a large number of subjective judgments can easily lead to significant evaluation bias. Therefore, it is appropriate to combine qualitative methods with quantitative methods in site selection practice.

3.2 Quantitative research methods

The quantitative research on facility location problems is based on the principle of maximizing logistics costs and timeliness, establishing mathematical models, and obtaining the optimal location plan through model solving. According to the characteristics of the target area of the location problem, it can be divided into continuous location models and discrete location models. In continuous location models, the representative ones include the cross median model and the precise centroid method. The cross median method typically involves finding the median of each coordinate dimension, which can quickly determine the center of a geographic region, making it relatively easy to calculate and suitable for small-scale geographic regions [1]. The precise centroid method typically considers geographic obstacles and can provide more accurate results, better reflecting the actual geographic characteristics.

In discrete location models, the set coverage model is commonly used. It determines the facility nodes that can meet the needs of several demand points with known demands, including the minimum number of facilities and suitable locations [2]. The set coverage model is suitable for covering as many elements as possible, without caring about the number of times each element is covered. The maximum coverage model is suitable for maximizing coverage or considering random uncertainty factors.

The location of logistics distribution centers is an NP-hard problem. Algorithms for solving such problems include linear programming and heuristic algorithms. Taking branch and bound method and simulated annealing method as examples, branch and bound method can usually find the global optimal solution and is suitable for combinatorial optimization problems [3]. This algorithm searches the solution space by continuously decomposing the problem into subproblems, which is easy to debug and has strong interpretability.

Simulated annealing is suitable for complex continuous optimization problems and combinatorial optimization problems. This method is self-adaptive, and can gradually adjust the search strategy during the search process. It can change the probability of accepting worse solutions based on the nature of the current solution, thus avoiding falling into local optima [4]. Compared to branch and bound methods, simulated annealing is generally more suitable for solving large-scale problems.

3.3 Sparrow Search Algorithm

The sparrow search algorithm is based on the foraging behavior of sparrows in nature, and uses group cooperation and information sharing to find the optimal solution [5]. The basic principle is as follows:

Step 1: initialization. Randomly generate a certain number of solutions as potential solutions to the problem. Calculate the fitness of each individual, indicating the quality of the solution in the problem space.

Step 2: strategic search. Simulate the actions of individuals in the search space. Based on the fitness of the current position, individuals choose to move towards better solutions with a certain probability, while also potentially moving towards worse solutions to maintain population diversity. Individuals share information through foraging behavior or certain rules to accelerate the global search process.

Step 3: update stage. Calculate the fitness of the updated individuals to determine whether the new solutions are better than the old ones. Based on the fitness values, select individuals to enter the next generation population. Strategies such as roulette selection are used. Some individuals may also be replaced to maintain the diversity of the population.

Step 4: iteration. Iterate until the maximum number of iterations or a satisfactory solution is found.

Step 5: convergence. Through continuous search and information sharing, the population gradually converges to a better region of the solution space, eventually finding an approximate optimal solution to the problem.

The search steps include local search, global search and adversarial search. "Local search element" is the local search element behavior of each individual in the natural state, which simulates the foraging behavior of birds in the adjacent area, and can choose strategies such as "random disturbance" and "neighborhood search" to explore the solution space around the individual. "Global search" refers to individual information sharing and cooperation, which is similar to the communication between birds. Individuals spread information about the optimal solution, so as to guide the population to move to a more favorable solution space. By introducing randomness and competitive elements, "antagonistic search element" imitates the competitive behavior among individuals [6].

This method uses a variety of search strategies, which helps maintain diversity in search and potentially escape local optima. Compared to the currently widely used simulated annealing algorithm (SA), the sparrow search algorithm (SSA) has the following advantages: First, simple and efficient: SSA is relatively simple, easy to implement and adjust, and facilitates the rapid resolution of some optimization problems.

Secondly, faster convergence: Due to its search strategy and neighborhood operations, SSA effectively explores the potential solution space, and can converge to a better solution faster than SA.

Thirdly, Good universality: SSA can be used for a variety of optimization problems, including continuous optimization, discrete optimization, and combinatorial optimization.

4 Basic model for the location selection of power grid material distribution center

When modeling the location of distribution centers, the principle of minimizing logistics costs is usually followed to obtain the best location plan. Based on the characteristics of power grid material transportation and regional distribution requirements, this article explains the location modeling method and process by taking the establishment and solution process of the location model for power grid material distribution centers as an example, based on the relevant theories and methods of location modeling.

4.1 Model establishment

Power grid materials, such as transformers, cables, insulation materials, etc., need to be supplied to maintenance and repair sites in a timely manner to ensure the continuity of power supply. Locating a distribution center in a suitable location can shorten the material transportation time and improve the efficiency of the supply chain [7]. The location of the distribution center is directly related to the reliability, efficiency, and disaster response capabilities of the power grid supply.
This article chooses the center of gravity method to construct the basic model of location selection. There are n demand points in the region, and a new logistics distribution center is needed. The amount of goods and distribution costs from the distribution center to each demand point are known, and the distribution center has sufficient inventory [8]. For the undetermined logistics distribution center, the objective is to minimize the total distribution cost to all demand points, and the following functional model is established:

$$U = min \sum_{i=1}^{n} w_i c_i d_i \quad (1)$$

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (2)$$

$$i = 1, \ldots, n$$

U indicates the total transportation cost. w_i indicating the product from the distribution center to the demand point i unit transportation rate. c_i indicating the product from the distribution center to the demand point i the loading capacity. d_i indicates the pending distribution center and demand point i the Euclidean distance between.

⑤ x , y respectively, the horizontal and vertical coordinates of the pending distribution center. x_i ， y_i separately for the demand points i the horizontal and vertical coordinates.

4.2 Solution of the model

In the sparrow search algorithm, a virtual sparrow is created to search for food, and the location of the sparrow X It can be represented by the following matrix :

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & x_{n3} & x_{nm} \end{bmatrix}$$

Among them, m The number of sparrows, $X_j = (x_j, y_j)(j = 1, \cdots, m)$
the first optimal logistics distribution center to be determined j a feasible solution.

The fitness value of all individuals $F_{(x)}$ can be expressed as:

$$F_{(x)} = \begin{bmatrix} f([x_{11} & x_{12} & \cdots & x_{1m}]) \\ f([x_{21} & x_{22} & \cdots & x_{2m}]) \\ \cdots & \cdots & \cdots & \cdots \\ f([x_{n1} & x_{n2} & x_{n3} & x_{nm}]) \end{bmatrix}$$

Among them, the individual fitness value is recorded as $f_j = \sum_{i=1}^{\infty} w_i \cdot c_i \cdot d_i \quad (i = 1, \ldots, m)$

The group with better optimization results is the discoverer, and the location update formula is as follows:

$$X_j^{t+1} = \begin{matrix} X_j^i \cdot e^{(-\frac{j}{a \cdot Iter_{max}})}, R_2 < ST \\ X_i^t + Q \cdot L \\ j = 1, \ldots, m \end{matrix} \quad (3)$$

Among them, t indicates the current iteration number, j is the number of the sparrow, X_j^{t+1} represents the the location of the sparrow j after $t+1$ iteration. $Iter_{max}$ is the maximum iteration number, $\alpha \in (0,1]$ is a random interval, $R_2 \in [0,1]$ which is a warning signal interval, $ST \in [0.5,1]$ is a safety threshold, $Q \sim N(0,1)$. When $R_2 < ST$, no predator is found, the finder will expand the search area, otherwise it means that the predator has been found and all sparrows must fly to a safe area.

The location update formula for participants is as follows:

$$X_j^{t+1} = \begin{matrix} Q \cdot e^{(\frac{X_{worst}^t - X_j^t}{j^2})}, j > \frac{n}{2} \\ X_p^{t+1} + \left|X_m^t - X_p^{t+1}\right| \cdot A^{+} \cdot L \\ j = 1, \ldots, m \end{matrix} \quad (4)$$

X_p^t is the optimal position for the fitness of the t generation sparrow, X_{worst}^t is the position with the worst fitness value for the t generation sparrow, $A = (a_1, a_2)$, a_1, a_2 is randomly distributed with a value of 1 or -1, and $A^{+} = A^T (AA^T)^{-1}$ .If, $j > \frac{n}{2}$,indicating the number j participant did not eat, and the sparrow's fitness value was in a low state.

When a certain percentage of sparrows detect danger, the sparrows receiving the danger signal update their position as follows:

$$X_j^{t+1} = \begin{matrix} X_{best}^t + \beta\left|X_j^t - X_{best}^t\right|, f_j > f_g \\ X_j^t + K\left(\frac{X_j^t - X_{worst}^t}{(f_j - f_w) + \varepsilon}\right), f_j = f_g \\ j = 1, \ldots, m \end{matrix} \quad (5)$$

X_{best}^{t} indicating that the discoverer in the t iteration finds the position with the best fitness value. $\beta \sim N(0,1)$,the step control parameter representing the standard normal distribution.$K \in [-1,1]$indicating the direction and step length of the sparrow's movement,f_j indicates the number j the fitness value of sparrows,f_j with $f_w$which represents the sparrows with the best and worst global fitness values currently,$\varepsilon \to 0_+$ is a very small number. When $f_j > f_g$ indicates that sparrows are on the edge of the population and are easily preyed upon. When $f_j = f_g$ when the sparrow in the middle receives a danger signal, it needs to approach the population to reduce the risk of being preyed upon.

4.3 Improvement scheme of model

If we want to avoid the sparrow search algorithm from falling into local optimum and improve the scientificity of model solution, we can introduce simulated annealing algorithm. The principle of the algorithm is based on the simulated annealing process of solid fuels, and its essence is based on probability, so its addition can help jump out of the local optimum.

The results obtained by sparrow search algorithm in each iteration are perturbed according to SA principle, so that the algorithm has the ability to jump out of the local optimal solution [9]. When the algorithm meets the number of iterations, the final optimization result is output.

In simulated annealing algorithm, $f_{(x)}$ is the optimization objective, and x_{max} is the current optimal solution obtained by sparrow search algorithm [10]. In the iterative process, the algorithm randomly perturbs the current solution x_{old} to generate a new solution x_{new}. If $F_1(x_{old}) \geq F_1(x_{new})$, the new solution will overwrite the old solution. Otherwise, the poor solution x_{new} will be selected and accepted with a certain probability, whose probability p is defined by the Metropolis criterion:

$$p = pexp\left(-\frac{F_1(x_{new})y - F_1(x_{old})}{pkT}\right) \quad (6)$$

In the expression, k represents the number of iterations. T is the current temperature value, which is used to control the convergence rate of the model in this study. T will gradually decrease during optimization. Its temperature difference represents the difference between the old and new solutions.

5 Conclusion

This article focuses on the location method and model of power grid material distribution center. Considering the characteristics of power grid material supply chain, it proposes the basic principles that should be followed in the location of distribution center, and briefly introduces and compares the common models and methods for location. Finally, taking the establishment of the location model of power grid material distribution center and the solution process of the sparrow search algorithm as an example, the specific methods and processes are explained. This method simulates the process of group behavior and information transfer in nature by searching for the optimal solution in the problem space through local search, global search, adversarial search, and information sharing. The information sharing between individuals increases the global search ability of the algorithm, while the random movement of individuals increases the exploratory ability of the algorithm, and it is feasible to update the optimal solution combined with simulated annealing algorithm. Therefore, it has certain practical value in solving the model.

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