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OPTIMIZATION ALGORITHM OF PUBLIC SERVICE FACILITIES LAYOUT IN EARTHQUAKE-STRICKEN AREAS BASED ON SA ALGORITHM

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SUMMARY

The environment in earthquake-stricken areas is complex and changeable. The optimization of public service facility layout usually involves multiple objectives, such as maximizing coverage, minimizing service distance, optimizing resource allocation, etc. The coupling conflict between these objectives weakens the functions of public service facilities in earthquake-stricken areas. To improve the emergency response speed of the earthquake-stricken regions and reduce disaster losses, a simulated annealing (SA) based optimization algorithm for the layout of public service facilities in earthquake-stricken areas is proposed. Considering the public service demand in different stages of the earthquake-stricken area, set the minimum maximum weighted distance, the minimum number of facility points, and the minimum total weighted distance of the service demand point area within the service area of the public service facility point as the objective function, and set constraints such as each demand point is covered by at least one facility point, and the minimum number of public service facility points, build a multi-objective optimization model of public service facilities layout to avoid coupling conflicts between multiple objectives. The SA algorithm is used to solve the multi-objective optimization model of public service facility layout. SA algorithm adopts temperature update function and sets heuristic cooling criteria. Combining the success-failure method and the variable scale method, a new solution is generated using the effective offset. The improved Metropolis algorithm is used to set the acceptance criteria for the solution to obtain the optimal layout result for public service facilities in earthquake-stricken areas. The experimental results show that the algorithm can effectively optimize the layout of public service facilities in earthquake-stricken areas, and improve facility coverage and resource utilization.

Key words: *SA algorithm, earthquake-stricken area, public service facilities, layout optimization algorithm, cooling criterion, temperature update function.*

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INTRODUCTION

In the process of post-disaster recovery and reconstruction, the reasonable layout of public service facilities is particularly important [1]. Public service facilities, such as emergency shelters, medical aid stations, and material supply points [2], are the key to ensuring the basic living needs of residents in disaster areas, improving rescue efficiency, and reducing disaster losses. However, how to realize the rapid and scientific layout of public service facilities under the limited time and resources [3] has become an urgent problem. SA algorithm, as a heuristic search algorithm, can effectively avoid falling into the local optimal solution [21], and find the optimal solution in the global scope, which has attracted much attention. SA algorithm, by simulating the physical annealing process, constantly iteratively searches in the solution space to accept the nonoptimal solution in a probabilistic way [5], thus increasing the possibility of jumping out of the local optimal solution [22]. This feature gives SA algorithm significant advantages in solving the problem of public service facility layout optimization [6].

Ugwu et al. gave priority to the functions of medical facilities [7], and formulated a disaster recovery plan for the interdependent infrastructure system. Improve the response speed and efficiency of emergency medical rescue and reduce the shortage of medical resources caused by disasters through the layout of medical facilities in the post-disaster recovery plan. In the process of formulating the recovery plan, the risk assessment shall be carried out for medical facilities and the infrastructure they depend on to identify and improve potential weak links and provide a reference for future disaster prevention [24]. The post-disaster recovery work usually needs to be completed in a very short time to minimize the impact of disasters, so the formulation and implementation of the recovery plan are extremely demanding. Jain et al. studied the combination optimization model of post-disaster emergency resource allocation based on metaheuristics [8]. In the post-disaster emergency resource allocation, the meta-heuristic algorithm can more comprehensively consider various factors, such as resource demand, transportation cost, time constraints, etc., and develop a more reasonable allocation scheme. The meta-heuristic algorithm can be flexibly adjusted according to the specific needs of the problem, such as changing the parameters of the algorithm, introducing new search strategies, etc., and can adapt to the post-disaster emergency resource allocation problem of different scales and complexity. However, the design of meta-heuristic algorithm has an important impact on the quality of the solution. Different algorithm designs may lead to different solution effects, so it is necessary to fully consider the design details and performance evaluation of the algorithm. Mothadernejad et al. used the two-stage optimization method to determine the post-disaster recovery plan of the road network [23]. This method divides the post-disaster recovery process into different stages, each of which has specific goals and optimization priorities. Through the phased method, key issues such as early emergency recovery and late comprehensive recovery in the post-disaster recovery of road networks can be more targeted. Due to different objectives and optimization priorities in different stages, the two-stage optimization method can flexibly adjust the recovery strategy according to the actual situation. Through phased optimization, the recovery cost is reasonably controlled on the premise of ensuring the recovery effect. However, this method needs to face many uncertainties. Uncertain factors such as weather changes and secondary disasters in the post-disaster recovery process have an impact on the implementation of the recovery plan, resulting in a deviation between the actual recovery effect and the expected. Sanderson et al. modeled the regional elasticity of infrastructure after the interruption of natural disasters [10], so as to early warn and prevent global problems caused by local failures and improve disaster resistance. This method can reveal the vulnerable links of infrastructure networks in disasters and provide a scientific basis for formulating targeted recovery strategies. The modeling process takes into account multiple disaster scenarios and recovery paths, which helps to improve the resilience of the infrastructure network, that is, its adaptability and resilience in the face of disasters. However, the infrastructure network itself is highly complex and interrelated, and the modeling process is extremely complex. The unpredictability and abruptness of natural disasters make it challenging to comprehensively account for all potential disaster scenarios and recovery trajectories during the modeling phase [9]. Addressing the limitations of existing approaches in the optimization of public service facility placement, a novel optimization algorithm for the arrangement of public service facilities in earthquake-affected regions is introduced, leveraging the Simulated Annealing (SA) algorithm. Analyze the current situation and problems of the layout of public service facilities in earthquake-stricken areas, clarify the optimization objectives, and build a mathematical model suitable for the optimization of the layout of public service facilities in earthquake-stricken areas. The SA algorithm is used to solve the model, obtain a series of candidate layout schemes, and determine the optimal layout scheme from them to provide decision support for the layout of public service facilities in earthquake-stricken areas. This study will help to improve the scientificity and rationality of the layout of public service facilities in earthquake-stricken areas, reduce disaster losses, and improve rescue efficiency [4].

ALGORITHM FOR OPTIMIZING THE LAYOUT OF PUBLIC SERVICE FACILITIES IN EARTHQUAKE-STRICKEN AREAS

Analysis of the Problem of Optimizing the Layout of Public Service Facilities in Earthquake-Stricken Areas

After natural disasters such as earthquakes, the demand for public service facilities increases rapidly. In a specific period, the public service facilities in earthquake-stricken areas are often limited, and there is a time requirement for relief, how to effectively select the location of the public service facilities in the earthquake-stricken areas, and rationally arrange the limited medical rescue facilities is extremely important [11]. With the development of earthquake disaster and rescue, the demand for public service facilities changes constantly, which further enhances the complexity of optimizing the layout of public service facilities.

According to the time of the evolution of the earthquake disaster and the amount of rescue demand at each stage, as well as the state of distribution, the layout of public service facilities in earthquake-stricken areas is categorized into T_1 T_2 T_3, three phases, and for each phase the public service requirements and the location of the public service facility to be selected are known. Site selection for m ($m = 3$) public service facilities, the distance of public service facilities, and the amount of rescue demand satisfaction as a measure of the layout of public services in earthquake-affected areas [12]; and the need to consider for each stage, the balance of workloads for m individual public service facilities. Considering the changes in public service demand in earthquake-stricken areas in $T = \{T_1, T_2, T_3\}$ stage, the overall one-time public service facilities layout was optimized [13]. After the address of m public service facility is determined, no further changes will be made, so that the disaster relief workload of each public service facility at each stage can be balanced as much as possible, and all public service facilities can give full play to their roles at each stage [14]. The analysis process of the optimization problem of the layout of public service facilities in earthquake-stricken areas is shown in Figure 1.

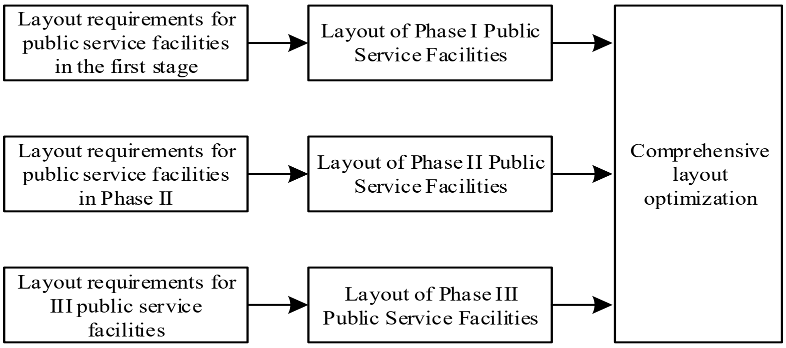

Figure 1. Schematic diagram of optimized layout of public service facilities

As can be seen from Figure. 1, this study has fully considered the optimization needs of the layout of public service facilities in earthquake-stricken areas at different stages, and optimized the layout of public service facilities in earthquake-stricken areas at different stages in a comprehensive way, so that the optimized results of the layout of public service facilities in earthquake-stricken areas can better satisfy the actual restoration needs of the earthquake-stricken areas.

Multi-objective Optimization Model Construction for the Layout of Public Service Facilities in Earthquake-stricken Areas

Based on the optimization problem of the layout of public service facilities in earthquake-stricken areas, a multi-objective optimization model of the layout of public service facilities in earthquake-stricken areas is constructed. The multi-objective planning model is a mathematical model introduced by operations research to optimize the layout of facilities, which can solve the optimal layout of public service facilities in earthquake-stricken areas under multi-objective and multi-constraint conditions [15]. The model is comprehensive and can take into account the shortest distance, maximum coverage, and other factors. By constructing a multi-objective optimization model for the layout of public service facilities in earthquake-stricken areas, the layout of public service facilities in earthquake-stricken areas can be reasonably optimized [16], so that the urban residents can choose the best place suitable for their own disaster avoidance and evacuation after an earthquake disaster occurs, and they can arrive at the place in the shortest possible time by using the shortest path. In addition, from the point of view of fairness, under the conditions of cost-effectiveness and the limitation of the number of facilities, if it is not possible to cover all of them [17], the evacuation sites should cover the areas with high-risk coefficients and high demand weights as much as possible.

A multi-objective optimization algorithm is constructed for the layout of public service facilities in earthquake-stricken areas. Setting known quantities as demand point $I = \{1, 2, \cdots, n\}$, public service facility point $J = \{1, 2, \cdots, m\}$, the shortest path d_{ij} between demand point and the point of the facility, and the weighting w_i of demand point. Define the variable to be the least number of public service facility points selected, symbolized by N. Define the binary variable as follows: If the demand point i is covered, then $y_i = 1$; otherwise $y_i = 0$; if the public service facility points j are selected, then $x_j = 1$; otherwise $x_j = 0$; if the point of demand i has just been overridden by the selected public service facility point j, then $a_{ij} = 1$; otherwise $a_{ij} = 0$. There are $x_j = \{0,1\}, \forall j \in J$ $y_j = \{0,1\}, \forall i \in I$ $a_{ij} \in \{0,1\}, \forall i \in I, j \in J$, Based on the fairness principle, the objective function of the minimum maximum weighted distance D in the service area of public service facilities in earthquake-stricken areas is set up as follows in equation (1):

$$\min O_1 = D \qquad (1)$$

The objective function for setting the weighted sum of covered demand points to be maximum, i.e., maximum coverage of public service facility points in the earthquake-affected areas with high demand weights, is as follows in equation (2):

$$\max O_2 = \sum_{i \in I} w_i y_i \qquad (2)$$

To reflect the principle of efficiency, the weighted total distance of the demand point area served by the public service facility points in the earthquake disaster area is set to be minimized [18], and the objective function is constructed as follows in equation (3):

$$\max O_3 = \sum_{i \in I} \sum_{j \in J} w_i d_{ij} a_{ij} \qquad (3)$$

With the goal of cost minimization, the minimum number of public service facilities selected in the earthquake disaster area is N, and the objective function is constructed as follows in equation (4):

$$\min O_4 = N \qquad (4)$$

For the above objective function of optimizing the layout of public service facilities in the earthquake disaster area, the constraints are set as follows:

- The constraints that the demand point i can be covered only when the public service facility point j is selected as a refuge are as follows in equation (5):

$$a_{ij} \le x_j \qquad (5)$$

- The constraints that ensure that every demand point is covered by at least one facility point are as follows in equation (6):

$$\sum_{j \in J} a_{ij} \ge 1 \qquad (6)$$

- The constraints that ensure the selected public service facility point must be the minimum number of N as follows in equation (7):

$$\sum_{j \in J} x_j = N \qquad (7)$$

- Only when the demand point i is covered by the public service facility point *j* and *j* is selected as a refuge, the demand point is covered by the facility point *j* is as follows in equation (8):

$$y_i \le \sum_{j \in J} a_{ij} x_j \quad (8)$$

- The constraints that the weighted distance d_{ij} for the selected public service facility point *j* and its coverage of points of need i must be less than or equal to the maximum weighted distance are as follows in equation (9):

$$D \ge \sum_{j \in J} a_{ij} d_{ij} \quad (9)$$

The SA algorithm is employed to address the multi-objective optimization problem concerning the positioning of public service facilities within earthquake-impacted zones, ultimately yielding the most favorable configuration of such facilities in these regions.

Solving the Model Based on the Simulated Annealing Algorithm

Based on the above, it can be seen that the optimization model of the layout of public service facilities in the earthquake-stricken area contains $\min O_1 \sim \min O_4$ multiple optimization goals. There are often conflicts between these goals, that is, the optimization of one goal may sacrifice the performance of other goals. Traditional single-objective optimization methods are difficult to directly apply to multi-objective optimization problems because there is usually no unique optimal solution to multi-objective optimization problems, but a set of optimal solutions (Pareto optimal solution set). The simulated annealing algorithm is a heuristic random search algorithm, which solves optimization problems by simulating the annealing process of solid materials. The algorithm has the advantages of strong global search ability, easy implementation, wide application range, etc. It is especially suitable for solving complex, nonlinear, multi-constrained optimization problems. Therefore, SA algorithm is used to solve the multi-objective optimization model of the public service facility layout built in section 2.2.

The SA algorithm is a stochastic optimization technique that employs a Monte Carlo iterative approach, inspired by the physical process of metal annealing, where principles from thermodynamics are integrated into statistical methods [19]. The algorithm's foundation lies in the analogy between the annealing of solid substances in physics and the nature of combinatorial optimization challenges. Initiating at a high starting temperature, the SA algorithm progressively reduces temperature parameters while leveraging random search in conjunction with probabilistic jump features to explore the solution space for the global optimum of the multi-objective optimization model concerning the placement of public service facilities. This means it can probabilistically escape local optima and converge towards the global optimum [20]. The SA algorithm is recognized as a versatile optimization tool, theoretically capable of achieving probabilistic global optimization. The process for applying the SA algorithm to solve the multi-objective optimization model for public service facility layout involves the following steps:

Initialization of Parameters

According to the actual need to set the public service facilities layout, multi-objective optimization model, the variation range of each parameter. Generate an initial solution x_0 randomly within this range, use x_0 calculate the target values $E(x_0)$ for the layout of public service facilities; randomly generate $\varepsilon \in (0,1)$ as a probability threshold, and set the initial temperature T_0 and germination temperatures T_f, the SA algorithm is set to solve the multi-objective optimization model of public service facilities layout, and the expression of the cooling law is as follows in equation (10):

$$T(t+1) = \xi T(t) \tag{10}$$

Among them, ξ is the annealing coefficient, $0 < \xi < 1$ t which is the number of iterations.

Generate New Solutions

In the neighborhood of the current solution x, it produces a new solution $x' = x + \Delta x$. Utilizing the new solution x' generates the expression for calculating the incremental target value for the layout of public service facilities as follows in equation (11):

$$\Delta E(x) = E(x') - E(x) \tag{11}$$

- If $\Delta E(x) < 0$, then order $x = x'$; If $\Delta E(x) > 0$, set the expression for the probability of generating a judgment value as follows in equation (12):

$$p = \exp\left[-(\Delta E / \phi) T\right] \tag{12}$$

Among them, ϕ is a constant, usually taking the value of 1. T indicates the temperature. If $p > \varepsilon$ so, then order $x = x'$; otherwise the original solution x is retained.

A probabilistic judgment value is generated as a result of the probability calculation by formula (12).

- Keep generating new solutions in the neighborhood and repeat step (3).
- Generate results based on the probability judgment value, and reduce the temperature T according to the set cooling law.
- Repeat steps (2)-(5) until the convergence condition is satisfied.

Cooling Criteria and Acceptance Criteria of SA Algorithm

When SA algorithm is used to solve the multi-objective optimization model of public service facility layout, the temperature update function is used to set the expression of SA algorithm heuristic cooling criteria as follows in equation (13):

$$T_t = \frac{T_0}{t^m} \tag{13}$$

Among them, T_0 is the initial temperature. $m \geq 1$ Is a constant, which is take $m = 3$ n in this paper; t is the number of iterations; T_t is the control temperature after t times cooling.

When generating solutions for the multi-objective optimization model of the layout of public service facilities, a method of generating new solutions using effective offsets is proposed by combining the success-failure method and the variable scale method. The effective offset refers to the offset when the current solution is accepted. If the previous offset is not effective, the solution generation function is improved as follows:

$$Y_i^t = X_i^t + Z_i^t \tag{14}$$

$$Z_i^t = \frac{T_i\left(b_i - a_i\right)}{\sqrt{\sum_{j=1}^{n} V_j^2}} \left| \frac{1}{\left|U_i\right|^m} - 1 \right| \tag{15}$$

The formula, X is the current solution of a multi-objective optimization model for public service facility layout, Z is the iteration offset, Y is a new solution. U and V is the [-1,1] uniformly distributed random quantity, i is vector components, a_i and b_i are the lower and upper bounds of the components of the vectors i.

If the previous offset is a valid offset, the success-failure method is applied: if the value of the accepted penalty function for the current solution decreases, the offset is marked with a success flag; otherwise, the offset is marked with a failure flag, and then the offset for the next iteration is computed according to the following formula:

$$Z_i = \begin{cases} 2.4 \cdot Z_i, Z_i \leq 1.0e^{10} \\ -Z_i / 1.8, Z_i \geq 1.0e^{-8} \end{cases} \tag{16}$$

Formulas (14)-(16) can improve the computational efficiency and reliability of the simulated annealing algorithm, on the one hand, maintains the appropriate temperature drop rate, on the other hand, keeps a certain degree of dispersion of the generated random vectors. When a feasible solution is found and the number of temperature drops is greater than 400 times, a localized fine search is entered. In order to improve the convergent search effect near the minima, a variable scale method determined by random numbers and the current optimal solution is used in the local fine search stage, and the expression of the new search interval is proposed as follows.

$$b_i' = \begin{cases} \beta_i + \left(b_i - a_i\right)/\sigma, b_i' \leq b_i \\ b_i, b_i' > b_i \end{cases} \tag{17}$$

$$a_i' = \begin{cases} \beta_i - \left(b_i - a_i\right)/\sigma, a_i' \geq a_i \\ a_i, a_i' < a_i \end{cases} \tag{18}$$

In the above formula (17) to (18), β_i is the component of the current optimal solution; σ is a pseudo-random number from 1 to 50 to shorten the search interval and improve the search efficiency. In the localized fine search stage, the adaptive factor is reduced by a certain ratio at each cooling.

For the optimization of the layout of public service facilities in earthquake-stricken areas, the randomly generated test points are firstly processed appropriately to ensure that they satisfy the given boundary constraints and then the corresponding objective function values are calculated. The formula is as follows:

$$Y_i^t = \begin{cases} \left(\xi_i^t - b_i\right) MOD\left(b_i - a_i\right), \xi_i^t > b_i \\ \xi_i^t, a_i \le \xi_i^t \le b_i \\ \left(a_i + \xi_i^t\right) MOD\left(b_i - a_i\right), \xi_i^t < a_i \end{cases} \tag{19}$$

In the formula (19), i is the components of the vector, a_i and b_i are the lower and upper limits of the components of the vectors i, ξ_i^t is the result of the calculation of formula (15). Y_i^t is the generated new solution. Through the above process, it is guaranteed that the generated new solution satisfies the given constraints of optimizing the layout of public service facilities in earthquake-stricken areas.

The acceptance criteria for the solution of the multi-objective optimization model of public service facilities layout in earthquake-stricken areas are calculated according to the improved Metropolis algorithm, and its formula (20) is as follows:

$$\{X_t \to Y_t\} = \begin{cases} 1, \beta(Y_t) \le \beta(X_t) \\ \exp\left(\dfrac{\beta(X_t) - \beta(Y_t)}{QT_t}\right), \beta(Y_t) > \beta(X_t) \end{cases} \tag{20}$$

Among them, Q is the adaptive factor.

During the computation, an evaluation and refinement of the currently viable best solution are conducted to guarantee that the solution retained in memory remains the currently feasible optimal one. In the solution acceptance criterion, the problem of singular solution is also dealt with: if there is a positive number in the objective function or constraint function that is larger than a given large enough, the solution is singular. When a singular solution is encountered, a new solution is generated and iterated to ensure the robustness of the algorithm.

Adhering to the cooling and acceptance criteria established for the SA algorithm, the procedure outputs the optimal solution for the multi-objective optimization model concerning the positioning of public service facilities within earthquake-affected regions. The SA algorithm is renowned for its robust global exploration capabilities and its ability to avoid entrapment in local optima. During its search, the algorithm probabilistically accepts suboptimal solutions, thereby circumventing the limitation inherent in traditional optimization methods that they may readily converge on local optima. The layout optimization of public service facilities in earthquake-stricken areas often involves multiple complex constraints. SA algorithm can comprehensively consider the set constraints and obtain an optimization scheme that meets the actual needs. Improve the service efficiency and coverage of facilities by optimizing the layout of public service facilities in earthquake-stricken areas.

EXPERIMENTAL ANALYSIS

In order to verify the optimization algorithm of the layout of public service facilities in earthquake-stricken areas and optimize the effectiveness of the layout of public service facilities in earthquake-stricken areas, an earthquake-stricken area was selected as an experimental analysis object. On May 18, 2019, a magnitude 6.2 earthquake disaster occurred in this area. Optimizing the layout of public service facilities is an important part of reconstruction work in disaster areas. The Matlab simulation software is used to simulate the optimization solution process of the public service facilities layout in earthquake-stricken areas, and verify the optimization performance of the public service facilities layout of the algorithm in this paper. The topographic map of the earthquake-stricken area is shown in Figure 2.

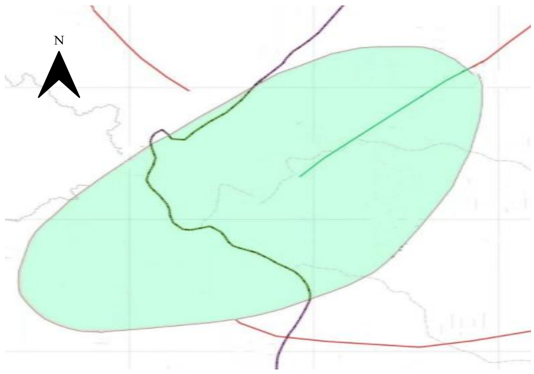

Figure 2. Topographic map of earthquake-stricken areas

The distribution of points of demand for public service facilities in this earthquake-affected area is shown in Figure 3.

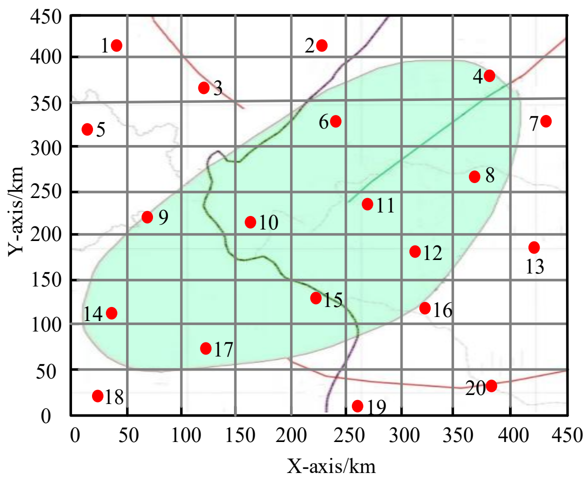

Figure 3. Demand for Public Service Facilities

The demand for public service facilities in the earthquake-stricken area in Figure 3 shows that there is a large demand for public service facilities in this earthquake-stricken area, and the reconstruction project in the earthquake-stricken area is in urgent need of the services provided by public service facilities.

In order to ensure the orderliness of the experiment, the parameters of the proposed method were set as shown in Table 1.

Table 1. Proposed method parameters

Parameter	Numerical value
Initial temperature	1000
Termination temperature	1
Internal cycle times	100

The demand for public services at different stages in some of the demand points in this earthquake-affected area is shown in Figure 4.

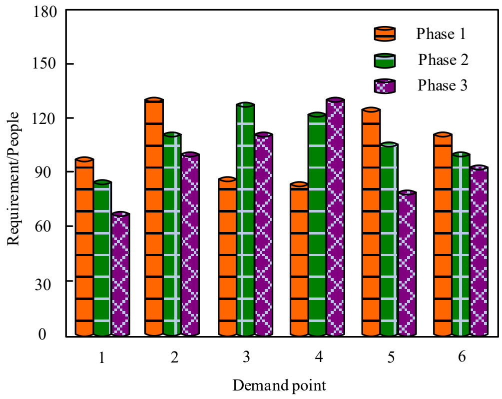

Figure 4. Demand for Public Services

The experimental results in Figure. 4 show that the algorithm of this paper can clarify the public service demand in the earthquake-stricken areas, and provide the basis for the optimization of the layout of the public service facilities according to the public service demand in different areas. There are obvious differences in the demand for public services in different regions of the earthquake-stricken areas. Using this algorithm to optimize the layout of public service facilities in earthquake-stricken areas. The algorithm is capable of considering the varying public service requirements across different zones and phases within earthquake-affected regions, thereby more effectively addressing the needs of reconstruction and recovery efforts as well as the demand for public services in these areas.

The layout of public service facilities was unified to meet the public service needs of the earthquake-stricken areas at different stages. The capacity of each public service facility location was quantified, with the findings depicted in Figure 5.

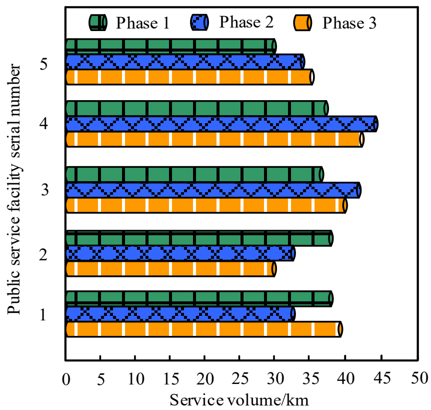

Figure 5. Service volume of public service facilities

The experimental outcomes illustrated in Figure 5 demonstrate that the algorithm presented in this study is capable of accurately determining the service capacity of various public service facilities. After determining the service volume of each public service facility point, the appropriate public service facility points are allocated for different areas.

Using the algorithm in this paper, based on the objective function and constraints of the multi-objective optimization model of public service facilities layout in earthquake-stricken areas, the SA algorithm is used to solve the optimization model. The 10 representative groups of solutions obtained by using the algorithm in this paper are shown in Table 2.

Table 2. Multi objective solution results

Solution number	Fitness value	Number of public service facilities	Construction cost/10000 yuan
1	0.254	20	9541
2	0.315	21	10512
3	0.185	22	9752
4	0.624	21	9685
5	0.584	20	10214
6	0.056	20	9871
7	0.314	20	9458
8	0.185	20	9625
9	0.345	19	9915
10	0.294	20	10052

From the experimental results in Table 2, it can be seen that the algorithm in this paper can use SA algorithm to solve the multi-objective optimization model of public service facilities layout in earthquake-stricken areas. Among the 10 representative solutions obtained, there are obvious differences in fitness values. In the 10 solutions, the number of public service facility points is 19-22; The construction cost is 95.41 million yuan - 10.512 million yuan. The multi-objective optimization model of public service facilities layout in earthquake-stricken areas built by the algorithm in this paper is a multi-objective optimization model, and the objective function value cannot reach the optimal value at the same time. The decision-maker of public service facility layout can determine the appropriate public service facility layout scheme according to the actual situation.

The No.1 solution in Table 2 is selected to set up 20 public service facilities to provide emergency rescue services for the earthquake-stricken area. The optimization result of the layout of public service facilities in this earthquake disaster area is shown in Figure. 6.

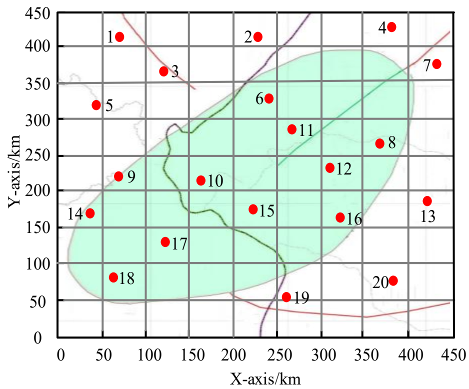

Figure 6. Optimization Results of Public Service Facility Layout

Comparison of Figure 6 and Figure 3 shows that the algorithm of this paper can realize the layout optimization of public service facilities. The optimized layout of public service facilities fully takes into account the demand for public service facilities in Figure 3, and can cover the demand points of public service facilities. The layout optimization result in Figure 6 verifies that this paper's algorithm can effectively achieve the layout optimization of public service facilities.

Using the No. 1 solution in Table 2, the optimization of the layout of public service facilities in the earthquake-stricken area is carried out, and the facility settings of each public service facility point are shown in Table 3.

Table 3. Layout and Setting of Public Service Facilities

Facility Point Number	Name of Public Service Facilities	Service distance /km	Facility Point Number	Name of Public Service Facilities	Service distance/km
1	Medical and health facilities	854.6	11	Social welfare institute	806.2
2	Social welfare institute	794.2	12	Earthquake warning system	795.5
3	Temporary shelter	694.5	13	Medical and health facilities	945.3
4	Temporary shelter	804.5	14	Temporary shelter	811.5
5	Water and power supply facilities	905.4	15	Fire protection facilities	1567.1
6	Temporary shelter	741.9	16	Temporary shelter	751.6
7	Temporary shelter	804.7	17	Temporary shelter	945.7
8	Temporary shelter	715.1	18	Medical and health facilities	1625.1
9	Temporary shelter	645.3	19	Water and power supply facilities	1234.5
10	Social welfare institute	910.4	20	Temporary shelter	846.5

Analysis of table 3 shows that public service facilities in the earthquake-affected areas include medical and health facilities, social welfare homes, water and electricity supply facilities, fire-fighting facilities and emergency shelters. Social welfare centers are used to provide temporary accommodation and care for vulnerable groups such as widows, orphans and the elderly. Emergency shelters have been set up to provide a safe and temporary refuge for residents of earthquake-stricken areas. Utilize fire fighting facilities to improve disaster prevention and mitigation capabilities in the disaster area. Adopt the algorithm of this paper to carry out a reasonable layout of public service facilities to ensure that the rescue teams and materials can arrive at the disaster area quickly and provide timely rescue services for the affected people. The water supply and power supply facilities are used to provide basic livelihood protection for the affected people.

Public service facilities should be organized in such a way as to ensure equitable access to all affected populations and to avoid social discontent and unrest resulting from unequal distribution of facilities. The accessibility of facilities is important, i.e., the affected people can easily reach and use these facilities. The statistics of the number of people covered and the coverage rate of the public service facilities in the earthquake-affected areas set by the algorithm in this paper are shown in Table 4.

Table 4. Coverage Number and Coverage Rate

Facility Point Number	Coverage population/person	Capacity per person	Coverage rate/%
1	1564	18516	8.46
2	3545	9158	3.15
3	2845	6185	2.85
4	1620	7158	1.64
5	1985	6841	1.25
6	2451	8451	1.34
7	2685	7418	1.85

8	2945	10254	2.06
9	2841	8165	1.35
10	1985	9025	1.48
11	2641	10052	1.25
12	2846	11384	1.34
13	2345	9465	1.85
14	3954	8156	2.64
15	4352	7158	2.06
16	2945	3945	2.45
17	2874	5064	4.25
18	2914	7159	5.16
19	3085	9452	2.85
20	3645	3785	1.67

When optimizing the layout of public service facilities in earthquake-affected areas, the higher the number of facilities and the more evenly they are distributed, the higher the coverage rate will be. For areas with frequent population movement, the coverage rate of public service facilities needs to be higher in order to meet the needs of the mobile population. Using the algorithm of this paper to optimize the layout of public service facilities, the coverage rate of public service facilities is higher than 1%, which can meet the needs of public service facilities in the earthquake-stricken areas.

In order to further verify the performance of this paper's algorithm for optimizing the layout of public service facilities in earthquake-stricken areas, the changes in the expected total cost, construction cost and other indexes are compared between the pre-optimization and post-optimization of this paper's algorithm, and the statistical results are shown in Table 5.

Table 5. Comparison of Layout of Public Service Facilities

Indicator Name	Before optimization	After optimization
Expected total cost/10000 yuan	92612	75161
Construction cost/10000 yuan	64654	49524
Procurement cost/10000 yuan	29451	24185
Transportation cost/10000 yuan	3.05	2.56
Number of facility points	22	20
Resource utilization rate/%	2.85	4.16

By analyzing the optimization results of public service facilities layout in earthquake-stricken areas in Table 5, the expected total cost of public service facilities layout optimization has decreased from 926.12 million yuan before optimization to 751.61 million yuan after optimization, with a significant decrease. This shows that the optimized layout of public service facilities has significantly reduced the overall operating costs, which is helpful for disaster areas to use resources more effectively in post-disaster reconstruction and long-term operation. The construction cost of public service facilities layout was reduced from 646.54 million yuan to 495.24 million yuan. The main reason is that the optimized layout reduces unnecessary facility construction and reduces construction costs through more effective design and planning. The procurement cost of public service facilities decreased from 294.51 million yuan to 241.85 million yuan, a decrease of about 18%. This algorithm reduces the procurement cost of public service facilities through centralized procurement, selection of more economical suppliers, etc. The transportation cost was reduced from 30500 yuan to 25600 yuan. Although the absolute value was small, it also reflected the improvement of efficiency. After optimization with the algorithm in this paper, the number of public service facility points is reduced from 22 to 20, reducing by 2. This shows that in the optimization process of this algorithm, the reasonable layout and coverage of facilities are taken into account, avoiding repeated construction and resource waste, and ensuring the efficiency and accessibility of services. The resource utilization rate of the algorithm in this paper increased from 2.85% to 4.16%, an increase of about 46%. This is one of the important achievements of the optimized layout, which shows that the optimized facility layout can better meet the actual needs of the disaster area and improve the efficiency and effect of resource use. The experimental results verify that the algorithm in this paper has achieved remarkable results in the layout optimization of public service facilities in many aspects, not only reducing the total cost, but also improving resource utilization, optimizing procurement and transportation processes, and reducing unnecessary facility construction. It will help the disaster area recover public service functions faster, improve the quality of life of residents, and also provide useful reference for future post-disaster reconstruction and public service facilities planning.

CONCLUSION

Based on simulated annealing algorithm, the layout optimization of public service facilities in earthquake-stricken areas is studied in depth. SA algorithm shows strong search ability and global optimization performance when solving the optimization problem of public service facilities layout in earthquake-stricken areas. Through the mechanism of gradually decreasing temperature during simulated annealing and probability acceptance of non optimal solutions, it can effectively avoid falling into local optimal solutions, so as to find more reasonable layout schemes in the global scope, make the obtained optimization results closer to the actual situation, and improve the feasibility and practicability of layout schemes. Through experimental verification, the optimized layout scheme can more effectively meet the basic living needs of residents in the disaster area.

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