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Applying Big Data Analytics to Optimize the Layout of Rural Public Facilities and Enhance Governance Effectiveness

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Abstract Rural public facilities are the basic guarantee to promote rural revitalization, but at present, the layout of rural public facilities has problems such as irrational site selection and uneven coverage. Big data analysis technology provides technical support for the optimization of rural public facilities layout, and through the precise layout of rural public facilities, it can improve the service level, promote the equalization of public resources, and create good conditions for the enhancement of rural governance effectiveness. This study establishes an optimization function with the dual objectives of maximizing walking accessibility and minimizing construction cost, considers constraints such as travel routes, coverage and location, and obtains the Pareto-optimal solution set by solving the simulated annealing algorithm. The empirical analysis shows that when the number of facility points is 62, the weighted service distance is 572.78 kilometers, and the average service distance from the villagers' points to their corresponding rural public facilities is 1.952 kilometers; when the number of facility points is increased to 66, the weighted service distance is decreased to 556.142 kilometers, and the average service distance is reduced to 1.812 kilometers, and the fairness and efficiency of the layout are significantly improved. Based on impedance accessibility analysis, the accessibility score of the optimized Wanji Village Cultural and Fitness Plaza is 7.6, which is better than other comparative areas. The results of the study show that the optimization of the layout of rural public facilities based on big data can effectively improve the level of rural public services, provide technical support for the construction of a digital rural governance system, and promote the enhancement of the effectiveness of rural governance.

Index Terms Rural public facilities, Layout optimization, Simulated annealing algorithm, Accessibility analysis, Pareto optimal solution, Rural governance effectiveness

I. Introduction

In the process of regional economic and social development, the non-equal layout of rural public service facilities is an extremely common phenomenon [1]. Whether in developed or developing countries, due to natural, historical, institutional, economic, cultural and other factors, there will always be a non-equalization of the layout of public service facilities, but there are differences in different degrees or different geographical areas [2]-[4]. In terms of differences in the degree of equalization, usually, developed countries with a higher level of economic and social development, the rural public service facilities layout of the degree of equalization is higher [5]. While developing countries with a lower level of economic and social development have a lower degree of equalization in the layout of rural public service facilities [6]. In terms of geographical differences in equalization, the non-equalization of the layout of public service facilities between urban and rural areas is the most prominent, and the problem of the layout of rural public service facilities is more serious and has a greater social impact, which has attracted the attention of governments, organizations and scholars, who are committed to explore the issue of the equalization of basic public services from different perspectives, and put forward feasible policies and measures to make the layout of rural public service facilities develop in the direction of equalization [7]-[9].

Since the 1960s, developed countries, especially welfare states in Europe, have continued to promote the equalization of the layout of rural public service facilities through a series of initiatives such as strengthening the government's public service function, optimizing the government's organizational structure, and advancing the diversification of the mode of supplying public services, effectively promoting the urban-rural integration and coordination and the overall improvement of the quality of the development of rural areas [10]-[12]. In recent years, in response to the widening gap between urban and rural development in China after the reform and opening up, the government has highlighted a series of basic development policies such as "five overall plans" and "harmonious society", and governments at all levels have gradually improved the capacity and level of rural public services and promoted the equalization of basic rural public services by abolishing agricultural taxes, rural compulsory education, and establishing a new rural cooperative medical system, so as to promote the coordinated development of urban and rural areas [13]-[15]. It can be seen that the equalization of the layout of rural public service facilities is a universal problem, which is not only closely related to the level of economic development of a country or region and the process and quality of urbanization, but also has become a basic function of the public service government [16]. Therefore, in recent years, the optimization of the layout of rural public facilities has also become a hot issue in academic research at home and abroad.

Rural public facilities are an important guarantee for the implementation of the rural revitalization strategy and the production and life of farmers, and are of great significance in promoting rural economic development, improving the living conditions of farmers, and promoting rural social progress. Currently, there are many problems in the layout of rural public facilities: the spatial distribution of facilities is not balanced, the total number of public facilities in rural areas is insufficient, and there are obvious differences in quality; the layout of facilities lacks scientific planning, which leads to inefficient use; the coverage of the service radius is incomplete, which fails to satisfy the basic needs of the vast number of farmers; and there is a large gap between the investment in the construction of facilities and the growing demand for public services from the peasants. These problems not only hinder the development of the countryside, but also constrain the improvement of the effectiveness of rural governance. The scientific layout of rural public facilities is the basic condition for rural revitalization, and a reasonable spatial layout is conducive to optimizing the spatial structure of the countryside and improving the efficiency of public resource allocation. The development of big data technology provides new ideas and methods for solving the problem of rural public facilities layout. By analyzing the data of rural population distribution, traffic flow, resource distribution, etc., the layout planning of rural public facilities can be carried out more scientifically to improve the efficiency of resource utilization and service quality. The use of big data analysis technology to build rural public facilities layout optimization model can solve the problems of strong subjectivity, single consideration factor, poor dynamic adjustment ability and other problems existing in the traditional layout method, and provide more scientific decision-making support for the layout of rural public facilities. In addition, the application of big data analysis technology in the enhancement of rural governance effectiveness can help realize the digital transformation of rural governance and promote the modernization process of rural governance. Through in-depth research on the application of big data in the optimization of rural public facilities layout and the improvement of governance effectiveness, it can provide strong support for the realization of rural public service equalization and the improvement of rural governance system.

This study will start from the theory and method of rural public facility layout optimization, construct a rural public facility layout optimization model based on big data analysis, and solve the optimal layout scheme through simulated annealing algorithm. Firstly, the rural public facilities layout optimization model is established, and the objective function and constraints of the model are clarified; secondly, the solution method is designed based on the simulated annealing algorithm, and the Pareto optimal solution set of rural public facilities layout is obtained; then, empirical analysis is carried out in Dangtu County as an example to validate the model's validity; finally, the path of the application of the big data analysis technology in the enhancement of the effectiveness of rural governance is analyzed, and the related policies and recommendations are put forward. Suggestions. Through this series of researches, we aim to explore the effective methods of using big data analysis technology to optimize the layout of rural public facilities, and to provide theoretical and practical support for improving the effectiveness of rural governance and promoting rural revitalization.

II. Model for optimizing the layout of rural public facilities

Scientific and effective configuration of rural public facilities, optimize the layout of rural public facilities, improve the service level of village and town public facilities, is an important task to promote the realization of the goal of equalization of basic public services in villages. In this paper, we will establish the optimization model of the layout of rural public transportation facilities to provide technical support for optimizing the layout of rural public facilities.

II. A. Overview of the model

II. A. 1) Basic assumptions

1) Facility optimization scheme

The location and number of rural public facilities remain unchanged in this model, and the number of joint entrances and exits, sunken entrances and bus stops in the HSR hub will not be adjusted in consideration of land use, cost and integrated construction. Therefore, only the freestanding entrances and bus stops of the hub need to be adjusted.

2) Facility Location Assumptions

The location of the intersection is simplified as the intersection of the centerline of each inlet and outlet at the intersection, and the roadway is simplified as the connecting line between the intersections. At the same time, due to the independent entrances and bus stops on both sides of the road, in order to facilitate the calculation of its coordinates, assuming its location on the road, its coordinates must meet the linear relationship between the road, and in the two ends of the intersection within the coordinates.

3) Independent entrance and exit assumptions

The new free-standing entrances and exits need to be equipped with other entrances and exits connected to the underpass, taking into account the construction safety and cost, it is assumed that the direction of the new underpass and the direction of the road is parallel or orthogonal, and it is assumed that the new free-standing entrances and exits only need to be connected to the nearest constructed entrances and exits (excluding joint construction entrances and exits).

II. A. 2) Objective function

The optimization objective of this model can be set to maximize the pedestrian accessibility value and minimize the construction cost of public transportation facilities within the station area. The objective function can be initially expressed as:

$$\min f_1 = -\sum_{i=1}^{N_r} A_i^o = -\sum_{i=1}^{N_r}\left[\frac{(N_r-1)C_i\beta_i}{\sum_{j=1,j\neq 1}^{N_r} t_{ij}}\right] \tag{1}$$

$$\min f_2 = b_1 N_1^{new} + b_2 N_2^{new} + e_2 N_2^{del} + b_3 \sum_{u=1}^{N_1^{new}} l_u \tag{2}$$

where f_1 is a negative number of walkability; A_i^o is the walkability of the facility; N_r is the total number of optimized nodes. b_i is the cost of building a new free-standing entrance and exit (10,000 yuan); N_l^{new} is the number of new freestanding entrances and exits. b_2 is the cost of building a new traffic intermediate station (10,000 yuan); N_2^{new} is the number of new transit stations. e_2 is the cost of demolishing a traffic intermediate station (10,000 yuan); N_2^{del} is the number of dismantled traffic stops; b_3 is the construction cost per meter of the underpass (10,000 yuan); l_u is the length of the new underpass.

The objective function was adapted to a minimization format for ease of solution. The decision variables of the model are the horizontal and vertical coordinates of the new facilities and the number of facilities.

II. B.Binding condition basis

II. B. 1) Travel route constraints

In this model, the constraint is embodied as a limit on the value of the corresponding connection in the adjacency matrix M_N between facilities. The constraint is expressed as follows:

$$M_N(i,j) = c \leq 300 \tag{3}$$

where, $M_N(i,j)$ is the adjacency matrix composed of freestanding entrances and transit stops, and there is a direct road connection between freestanding entrances and transit stops; c is the length of the route between freestanding entrances and transit stops (m).

The transit stops on the same route should be kept at reasonable station spacing. This constraint can be expressed as follows:

$$500 \leq l_{ij} \leq 800 \tag{4}$$

where, l_{ij} is the length of the road (m) between transit stops $n(i)$ and $n(j)$ on the same road.

II. B. 2) Rural utility coverage constraints

Based on the site coverage PTI requirements, the constraints are as follows:

$$\begin{cases}\text{The 500-meter coverage PTT}_{500} \geq 90\% \text{ of bus stops}\\ \text{The 300-meter coverage PTT}_{500} \geq 50\% \text{ of bus stops}\end{cases} \tag{5}$$

II. B. 3) Rural utility location constraints

The facility $n(i)$ is on the roadway $l(k)$ and the intersections at both ends are $i(s), i(t)$, and the facility and intersection coordinates need to satisfy the following constraints:

$$\frac{x_i - x_{i(s)}}{y_i - y_{i(s)}} = \frac{x_i - x_{i(t)}}{y_i - y_{i(t)}} \\ x_{i(s)} < x_i < x_{i(t)} \\ y_{i(s)} < y_i < y_{i(t)} \tag{6}$$

where, x_i, y_i are the horizontal and vertical coordinates of node i, respectively; $x_{i(s)}, y_{i(s)}$ are the horizontal and vertical coordinates of the intersection $i(s)$ in the coordinate system, respectively. $x_{i(t)}, y_{i(t)}$ are the horizontal and vertical coordinates of the intersection $i(t)$ in the coordinate system, respectively.

Suppose that the village public facility $n(i)$ is on the exit road in the direction of intersection $i(s)$ and road $l(k)$. Then the distance between the rural public facilities and the intersection requires the constraints on the location of the traffic intermediate station as follows:

$$l_{n-i}(n(i), i(s)) \geq \begin{cases} l_s^{ZK}(k) + 20 & l_s^{ZK}(k) \neq 0 \\ 50 & l_s^{ZK}(k) = 0 \text{ And } R(k) = 1 \\ 30 & l_s^{ZK}(k) = 0 = 0 \text{ And } R(k) = 2 \end{cases} \tag{7}$$

where, $l_s^{ZK}(k)$ for the road k near the intersection $i(s)$ inlet road right spread length (m); $R(k)$ for the road k grade, the main road takes the value of 1, the branch road takes the value of 2:

On the same road, the distance between the traffic intermediate station and the station in the same direction on the location of the traffic intermediate station requirements, the constraints are:

$$l_{n-n}(n(i), n(j)) \leq 50 \tag{8}$$

where, $n(i)$ and $n(j)$ are traffic midway stations on the same road, in the same direction.

The distance between the traffic midway station and the opposite direction station on the same road requires the location of the traffic midway station with the constraints:

$$l_{n-n'}(n(i), n'(j)) \leq 30 \tag{9}$$

where, $n(i)$ and $n'(j)$ are transit stops on the same road, in different directions.

II. C. Optimized model solution based on simulated annealing algorithm

II. C. 1) Principles of the simulated annealing algorithm

Simulated annealing algorithm (SA) is an objective optimization algorithm based on stochastic optimization, with strong local search ability, it is actually a greedy algorithm in the nature of its operation, can effectively use the existing solution information for "climbing" optimization operation, but it is not exactly the same as the mountain climbing algorithm [17]. Hill-climbing algorithm is a complete greedy algorithm, does not have the ability of global search, each search process from the current solution of the proximity of the solution space to randomly select a new solution better than the current solution as the starting point of the next search [18]. While the simulated annealing algorithm adopts a randomized approach to search the solution space and accepts the new solution inferior to the original solution obtained during the search process with a certain probability, so that it can have a certain probability of jumping out of the local extremum trap when it enters and search for the global optimum with a certain probability. It can be seen that the simulated annealing algorithm has a certain global optimization ability, theoretically speaking, in the case of infinite iterations of the calculation it is bound to converge to the global optimum.

The simulated annealing algorithm is a simulation of the heat change process of solid objects in nature, when the heat of solid objects is high, the internal particle motion is more intense and the kinetic energy is larger, and when the heat is low, the internal particle motion tends to be flat and the kinetic energy is smaller, so the process of heat change of solid objects can be regarded as the overall embodiment of the change of internal particles between two different energy states. According to the Metropolis criterion, the probability of the transition of the particles inside the solid object from the existing energy state to the stable energy state at room temperature when the heat is T is $e^{(-\Delta E/kT)}$, where E is the kinetic energy of the particles inside the solid object when the heat is T, ΔE is the kinetic energy change of the internal particles, and k is the Boltzmann constant [19]. According to the Metropolis criterion, the simulated annealing algorithm determines whether the new solution inferior to the original solution is not rejected as the starting point of the next operation, and the acceptance probability of the new solution is shown in equation (10):

$$p = \begin{cases} 1 & f(x_{new}) < f(x_{old}) \\ \exp(-\dfrac{f(x_{new}) - f(x_{old})}{kT}) & f(x_{new}) \geq f(x_{old}) \end{cases} \tag{10}$$

where p is the acceptance probability of inferior solution, k is the regulation parameter, the current heat state corresponding to the evolution generation is T, f is the objective function, $f(x_{old})$ is the value of the objective function of the original solution, $f(x_{new})$ is the value of the objective function of the new solution, and the optimization mode of the objective function is minimization.

From equation (10), it can be seen that the acceptance probability of inferior solution in the simulated annealing algorithm is not only related to the degree of deterioration of the new solution, but also related to the current heat state T, the higher the current heat, the higher the acceptance probability of the inferior solution, and the lower the current heat, the smaller the acceptance probability of the inferior solution. It can be seen that the control of the current heat, i.e., the temperature corresponding to the current state, has an important impact on the algorithm's performance of optimization, in which the commonly used ways of temperature reduction are: classical cooling, rapid cooling, and proportional cooling, as shown in Eqs. (11)~(13), in which α is the proportionality coefficient of temperature reduction, and $0<\alpha<1$:

$$T(t)=\frac{T_0}{\log(1+t)} \tag{11}$$

$$T(t)=\frac{T_0}{1+t} \tag{12}$$

$$T(t)=T_0\alpha^t \tag{13}$$

From Eqs. (11)~(13), it can be seen that the heat cooling in the simulated annealing algorithm adopts a gradual decline, with a higher heat value in the early stage of the run so that it accepts new solutions inferior to the current one with a higher probability, which increases the global search performance and avoids it from falling into the local extremes: in the late stage of the run, the heat value is gradually changed from high to low, which enables it to accept new solutions inferior to the current one with a smaller probability, and avoids current de-emphasis of the better solution, so that it performs local search with higher hill-climbing performance. It can be seen that this approach is in line with the real cooling process of solid objects in nature, and at the same time, it is also in line with the adaptive simulation of changes in the external environment during the operation of the algorithm, which makes it have a certain degree of adaptability in the search process.

II. C. 2) Control of temperature parameters

The temperature parameter is one of the key parameters of the alignment algorithm in simulated annealing, which mainly includes the selection of the starting temperature and the temperature descent method.

1) Selection of the starting temperature t_0

In this paper, the initial temperature t_0 is determined as: $t_0=(F_{min}-F_{max})/\ln P_0$, where P_0 is the initial acceptance probability, $F_{\min}$ and $F_{\max}$ are the initial feasible solutions obtained from randomly minimum and maximum objective function values obtained from the L initial feasible solutions generated.

2) Temperature descent method

In this paper, we adopt the fixed-ratio temperature descent method of the time-aligned algorithm: $t_k+1=\alpha t_k$ where $0<\alpha<1$. At the same temperature, then a fixed number of steps are performed, i.e., iterating the same number of steps S.

II. C. 3) Algorithm termination principles

The feasible solution of the problem discussed in this paper is a 0-1 string of length m, so take the neighborhood of the feasible solution X_0 as the set consisting of the solutions generated by the 0-1 transitions occurring at X_o 's m bits, respectively, and the number of neighbors of an arbitrary feasible solution X is $|N(X)|=m$ In the iterative process, a new feasible solution is generated randomly from within the neighborhood of the current solution , and the generation probability obeys a uniform distribution.

In this paper, we will use two conditions as the exit of the algorithm, only one of which needs to be satisfied to terminate.

1) Zero method

Given a relatively small positive number ε, when the temperature $t_k\le\varepsilon$, it means that the minimum temperature is reached and the algorithm terminates.

2) Control method based on unimproved rule

During the cooling period, the current local optimal solution is not improved for a given number of iterations Q, then the operation is stopped.

II. C. 4) Calculation steps

The following gives the basic steps of the simulated annealing algorithm for searching a single individual, where the minimization problem is taken as an example.

Step1: Set the initial parameters of the run, including the current temperature T in the starting state of the annealing search, the adjustment coefficient k, the current number of iterations n, the upper limit of the number of running iterations N, the current number of searches in the inner loop v, and the upper limit of the number of searches in the inner loop W, where $n=0, w=0$;

Step2. Obtain a new solution S' by employing a random search within a certain neighborhood in the feasible solution space of the current solution S;

Step3: Calculate the energy increment $\Delta E = f' - f$ for the change from solution S to solution S', where f is the value of the energy corresponding to solution S, i.e., the value of the objective function to which it corresponds; f' is the energy value corresponding to the solution s', i.e., the value of the objective function to which it corresponds;

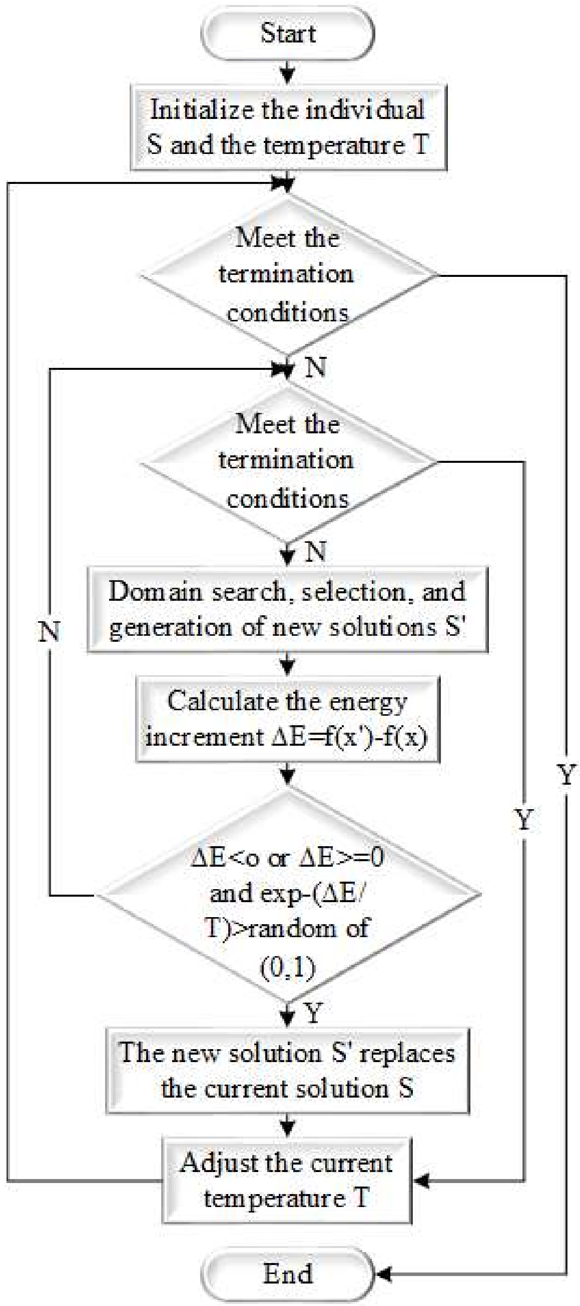


Figure 1: Flowchart of the simulated annealing search for a single individual

Step4. Determine whether to accept the searched new solution according to the acceptance criterion, i.e., if $\Delta E < 0$, accept the new solution S' and replace the current solution with it, and skip to Step7; if $\Delta E \geq 0$, randomly generate the probability value r and skip to Step5, where $0 < r < 1$;

Step5. If $r < e^{(-\Delta E/kT)}$ then accept the new solution S' and replace the current solution with it, $w = 0$, skip to Step7;

Step6. $w = w+1$, if $w < W$, jump to Step2; otherwise $w = 0$, jump to Step7;

Step7. Update the current temperature T according to the temperature control method;

Step8. The current iteration number n is increased by 1 since, i.e. $n = n+1$, determine whether the current iteration number n reaches the set upper limit value N, terminate the program if it reaches, otherwise jump to Step2.

The flowchart of a single individual simulated annealing search is given below, as shown in Fig. 1.

III. Optimization analysis of the layout of rural public facilities in Dangtu County

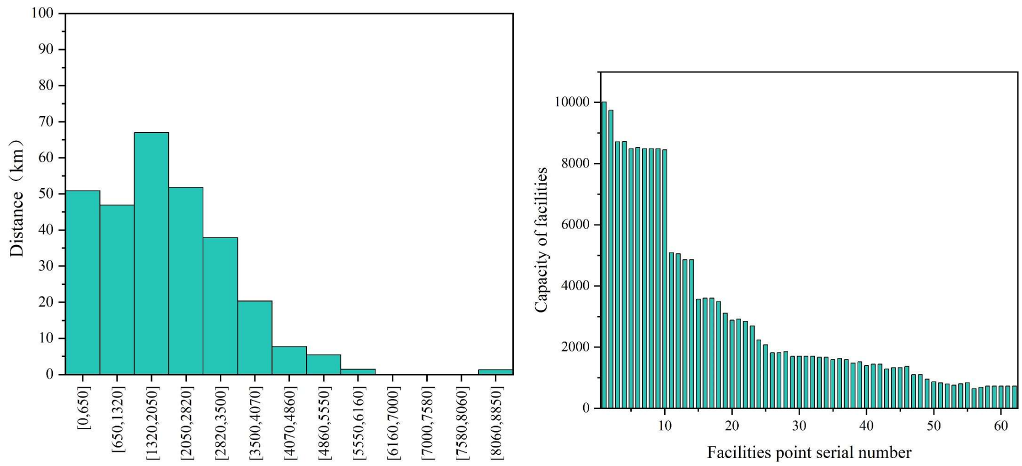
Dangtu County is located in the eastern part of Anhui Province, China, on the east bank of the lower reaches of the Yangtze River, and belongs to Maanshan City. With the increase of rural population year by year, the demand for rural public facilities is also growing gradually, and it is obvious that the original rural public facilities can no longer meet the needs of the rapid development of rural areas, and the layout of rural public facilities is in urgent need of optimization and updating. This chapter will use the rural public facilities layout optimization model proposed in this paper to optimize the rural public facilities layout in Dangtu County.

III. A. Analysis of the results of optimizing the layout of rural public facilities

The established rural spatial dataset is inputted into the program, and according to the set parameters, the rural public facility siting solution is carried out. In the program, the population number is set to 60 according to the empirical value, and the number of iterations is set to 12,000, and the two-dimensional Pareto optimal solution is output. The solutions in the solution set are quickly sorted by non-dominated ordering, and the Pareto-optimal solution set is filtered out again. Due to the limited space, this paper selects the solutions with the number of rural public facility points of 62 and 66 in the Pareto optimal solution set for display and analysis.

1) When the number of rural public facilities is 62

In the Pareto optimal solution set, when the number of facilities is 62, the weighted service distance is 572.78km, and the corresponding penalty function is 15, i.e., among 290 villagers' points, 15 villagers' points are not within the optimal service radius of the corresponding medical facilities, and the corresponding population is 27,720. The overall site layout is shown in Fig. 2, Figs. (a) and (b) show the distances from the settlements to the corresponding village public facilities and the capacity of the selected facilities, respectively. The maximum number of villagers corresponding to the 62 selected rural public facility sites is 9,982, and the minimum number of villagers is 727. The average service distance from each village point to its corresponding rural public facility is 1.952km, and the maximum service distance is 8.505km, with the maximum service distance occurring in a more remote area, where incomplete construction of roads in the vicinity of the village point may be the main reason for the large service distance.



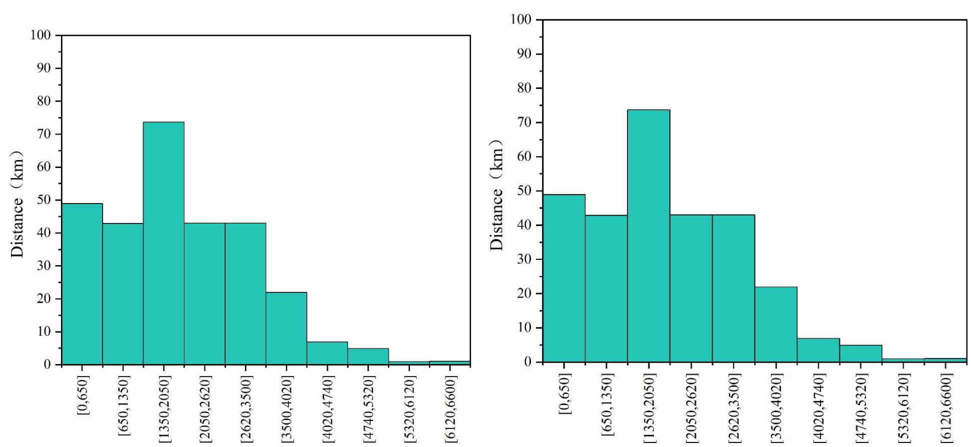
a)Distance from the residential area to the corresponding rural public facilities

(b)Capacity of selected facilities

Figure 2: When the number of facilities in the Pareto solution set is 62

2) When the number of village public facility points is 66

In the set of Pareto optimal solutions, when the number of facility points is 66, the weighted service distance is 556.142km, and the corresponding penalty function is 15, i.e., there are 290 villagers' points in which 15 villagers' points are not within the optimal service radius of their corresponding village public facilities, and the corresponding number of villagers who are not within the optimal service radius is 19,652 people. The overall site layout is shown in Figure 3, with Figures (a) and (b) showing the distance from the settlement to the corresponding village public facility and the capacity of the selected facility, respectively. The maximum number of villagers corresponding to the 66 selected village public facility sites is 14,715, and the minimum number of villagers is 735. The average service distance from each village point to its corresponding village public facility is 1.812 km, and the maximum service distance is 8.312 km. Compared with the solution with 62 facility points, although the number of selected facility points has increased, the average service distance and the number of villagers who are not within the optimal service radius as well as the number of villagers corresponding to these points have decreased. Therefore, the fairness and efficiency of the facility layout are improved with a certain increase in construction and operation costs.



(a)Distance from the residential area to the corresponding rural public facilities

(b)Capacity of selected facilities

Figure 3: When the number of facilities in the Pareto solution set is 66

Overall, the use of this paper's rural public facilities layout optimization model layout optimization results greatly improve the current layout of rural public facilities in Dangtu County, compared to the original layout of the facilities, more on the existing facilities to supplement and adjust the fairness of the villagers in the use of rural public facilities have a greater enhancement.

III. B. Optimized accessibility analysis of rural public facilities layout

In this section, we will take the cultural and fitness plaza of Wanji Village in Dangtu County as an example, and establish the hypothesis and construct the mathematical model of the single-source shortest path starting from Wanji Village for the shortest path of the optimal layout of rural public facility resources. The shortest path drawn is shown in Figure 4. The number 1 in the figure represents the cultural and fitness plaza of Wanji Village, the number 8 represents Delegation Village, and the rest of the numbers represent other villages. From the figure, we can clearly see that the optimal path from number 1 to number 8 is 1-2-3-5-6-8.Obviously,the shortest distance from number 1 to each location can be found by using simulated annealing algorithm. Similarly, the public facilities layout optimization model constructed in this paper in the ancient city of Xi'an can be used to select the best rural public construction sites by the shortest path system of the rural public facilities sites to reach each site, drawing the shortest path result diagram, comparing the average shortest distance to reach other village sites.

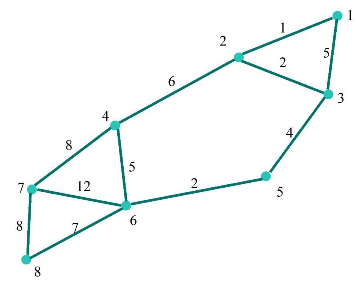


Figure 4: The shortest path diagram

Considering that the factors affecting the shortest path are not only affected by geography or spatial distance, but also by economy, behavior, and concepts, further comparative analysis of the reasonableness of the location setting of Wanji Village Cultural and Fitness Plaza is carried out to conduct an in-depth study by using this paper's optimization model of rural public facilities layout. The basic regional situation of Wanji Village Cultural Fitness Plaza and its neighboring villages in Dangtu County is simplified and analyzed, R denotes Wanji Village Cultural Fitness Plaza, and A-G represents Jidong Village, Puji Village, Guanghua Village, Xiegong Village, Yongxin Village, and Tuanyue Village, respectively. Since the villagers' reachable time changes with the travel mode when they choose the travel mode, in this study, the four transportation modes of walking, riding, driving and taking public transportation are chosen first. Through the field research, the corresponding time of each mode of transportation in the region is 28 min for walking, 11 min for cycling, 17 min for taking public transportation, and 7 min for driving, and the final result is to choose the driving time as the shortest reachable time, and then proceed to the next step of calculation. By analogy, the shortest transportation time from other origins to destinations are calculated by this method, as shown in Table 1.

Table 1: Distance-timetable

Travel location	A	B	C	D	E	F	G
The best way to travel	Driving	Driving	Cycling	Cycling	Driving	Driving	Driving
The shortest reachable time	3min	8min	6min	4min	9min	14min	12min
The shortest reachable distance	1.2km	3.1km	1.4km	0.88km	2.51km	3.6km	4.3km

The accessibility analysis method based on minimum impedance proposed by Allen is adopted, which uses the average minimum impedance from the center point to all the destinations of sports facilities as the accessibility evaluation index of the center point. The accessibility analysis method based on minimum impedance belongs to the network analysis method, and the formula is as follows:

$$M_i = \frac{1}{n-1} \sum_{j=1}^{n} e_{ij} \tag{14}$$

$$M_i = \frac{1}{n} \sum_{i=1}^{n} M_i \tag{15}$$

As the above formula, M_i denotes the accessibility of each node i on the facility layout network; M is the accessibility of the whole network; e_{ij} denotes the minimum impedance between nodes i, j, which can be expressed as the distance, time or cost, etc. The processed data is imported into the formula sequentially, and the calculated destination point is 7.6.

The processed data are sequentially imported into the formula, and the accessibility of place R is calculated to be 7.6. Using the same calculation process, the destination points are repeatedly selected and simplified to serial numbers, S is Shiqiao Central Primary School, Q is Shiqiao Comprehensive Farmers' Market, and in the case of the same fixed departure place, the accessibility based on the impedance of the minimum travel time for the destinations of S and Q are calculated by the above method, and the results are obtained as 7.86 and 8.86, respectively. The results are 7.86 and 8.4 respectively, from which it can be seen that the accessibility value of R is lower than that of S and Q, and it can be known that Wanji Village Cultural and Fitness Plaza has a higher degree of optimization of the layout, and the accessibility effect is better.

IV. Optimizing the path to enhancing the effectiveness of rural governance

With the increasingly deep integration of big data analysis technology into the process of rural governance, its important role in enhancing the effectiveness of rural governance has been emphasized. Combined with the above research and analysis on the optimization of rural public facilities layout, this chapter will take big data analysis technology as the driving force to put forward an effective optimization path to improve the effectiveness of rural governance.

1) Improve the construction of data standards and norms and data sharing and exchange mechanisms, and build a rural digital governance system based on county units.

In view of the problems of scattered sources and different formats of rural governance data, which make it difficult to realize information sharing and business synergy, it is recommended to speed up the formulation and revision of a series of standard specifications for data collection, processing, evaluation, etc., to build a unified rural social governance data standard system, break the barriers of agriculture-related information, and lay a solid foundation to enhance the scientific, refined, and intelligent level of rural governance. Improve the data resource sharing and exchange mechanism of information systems of various departments, and enhance the accuracy and authority of basic data. Promote the construction of digital integration platforms on a county-by-county basis.

2) Fully collect, respond to and satisfy the needs of farmers, and continuously improve the operation mechanism of digital governance in the countryside.

In empowering rural governance with digital technology, follow the basic logic of “villager-centered”, and realize the docking of digital technology with villagers' needs and rural reality on the basis of fully understanding, collecting and mastering villagers' actual needs, experiences and feedback.

3) Enhance the digital literacy of agricultural managers and farmers, and vigorously promote the construction of agricultural and rural digitization talents.

In the process of promoting the digital transformation of rural governance, great importance should be attached to accelerating the training of a cadre of agriculture-related personnel who are proficient in digital management. Through targeted digital skills training, help agriculture-related managers to comprehensively improve digital literacy, establish digital thinking, learn to rely on data to carry out research and analysis, scientific decision-making, fine management and innovative services, and constantly improve the accuracy and intelligence of rural governance. At the same time, extensive digital skills training will be carried out for the masses of farmers, focusing on enhancing the awareness and ability of farmers to participate in rural public affairs by digital means.

4) Broaden the sources of funding for digital village construction through multiple channels, and improve the quality and coverage of information networks in rural areas.

In view of the fact that funding in some areas is unable to meet the needs of digital village construction, it is recommended that the sources of funding for rural information infrastructure construction be broadened through multiple channels, that private capital be supported to enter the field of digital village infrastructure construction, and that the introduction of strong Internet enterprises to provide technical support services be explored through the purchase of services by the Government or through cooperation with State-owned enterprises. In the context of the comprehensive promotion of the rural revitalization strategy, investment in information infrastructure in rural areas, especially in remote rural areas, has been increased.

V. Conclusion

Big data analysis technology plays an important role in rural public facilities layout optimization and governance effectiveness improvement. A series of empirical results were obtained by constructing a rural public facility layout optimization model and introducing a simulated annealing algorithm to solve it.

The optimized layout of rural public facilities in Dangtu County is significantly improved, and when the number of facility points is 62, the average service distance from villagers' points to rural public facilities is shortened to 1.952 kilometers; when the number of facility points increases to 66, the weighted service distance decreases from 572.78 kilometers to 556.142 kilometers, and the efficiency of the layout is improved significantly. The accessibility analysis based on minimum impedance shows that the accessibility value of the cultural and fitness plaza in Wanji Village with optimized layout is 7.6, which is lower than that of the comparison object, which is 7.86 and 8.4, confirming the rationality of the optimization scheme. The application of big data analytics technology in rural governance should follow four optimization paths: improve the data standard specification and the sharing and exchange mechanism, and construct a county digital governance system; meet the needs of farmers, and improve the operation mechanism of digital governance; improve digital literacy, and strengthen the construction of rural digital talent team; and broaden the source of funding, and improve the quality of rural information network. The Pareto-optimal solution set obtained by the model provides a variety of options for rural public facilities layout decision-making, which helps decision-makers make reasonable choices according to actual demand and resource constraints, and promotes the realization of the goal of equalization of basic public services in rural areas.

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