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Research on Intelligent Development Path of Countryside under New Infrastructure Construction Based on Multi-Objective Optimization

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ABSTRACT

Aiming at the current problems of low level of intelligent development and backward infrastructure in the countryside, this paper proposes a multi-objective optimization model for rural construction. According to the overall principle of optimization and the current situation of rural infrastructure construction, model assumptions, objective functions and constraints are determined. Facing the problem of calculating the optimal values of the four objective functions, NSGA-II method is chosen to solve and analyze the problem. NSGA-II algorithm is calculated in 100 iterations, and the optimal solutions of the four objective functions are 0.813, 0.943, 0.852, and 0.886, which are better than NSGA and GA algorithms in terms of performance. In order to improve the intelligent development of the countryside, two targeted development proposals are put forward.

Keywords: NSGA-II algorithm; multi-objective optimization; objective function; village intelligent development

1. Introduction

With the rapid development of digital technology, the world is stepping into the digital era. Nowadays, new forms of digital technology such as big data, AI artificial intelligence, cloud computing, 5G, etc. are emerging, and all industries are actively responding to and deeply integrating with them, which provides a favorable opportunity for the intelligent development and innovation of the countryside [1-3]. In particular, the successful use of technologies such as digitalization of rural e-commerce and digitalization of rural governance in China in recent years has provided convenience and foundation for the development of rural revitalization in China [4-7]. Therefore, intelligent development is an important initiative to promote rural revitalization and a necessary way to achieve the revitalization and development of agriculture and rural areas.

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The fundamental to strengthen the intelligent construction and development of the countryside is to accelerate the pace of realizing the national digital infrastructure construction [8-9]. Due to the fact that China's rural e-commerce has been given unprecedented play since the state has carried out e-commerce poverty alleviation policies in recent years, the rural economy has been fully enhanced under the digitalization of e-commerce [10-11]. However, although China's rural villages have realized rural networking and communication, the broadband rate and mobile Internet facilities are still not perfect, and some areas only have 4G, but no high-speed broadband such as 5G [12-14]. Therefore, accelerating the construction of new-generation information infrastructure is a top priority in the process of digital transformation of agriculture and rural areas [15-16]. Through the implementation of the new generation of agricultural and rural information infrastructure construction project, the construction of full-coverage high-speed fiber-optic broadband network, vigorously promote the Beidou satellite navigation system and agricultural remote sensing technology, in order to promote the development of the smart countryside, and strengthen rural revitalization to provide strong talent support and technical support [17-20].

This paper stands in the perspective of the overall principle of optimization, puts forward the hypothesis of multi-objective optimization model, takes the individual fairness index, the overall fairness index, the economic benefit, the economic efficiency as the objective function of the model, and sets the constraints from the four aspects of the construction investment, the technical grade, the traffic volume conservation, and the flow rate, and has arrived at the work of constructing the multi-objective optimization model. Taking the Pareto optimal solution as the starting point, NSGA-Ⅱ is used to solve the multi-objective optimization model for rural construction, and in order to supplement the scientific nature of the research results, GA and NSGA are set as control algorithms, and the comparative analysis of the solving performance further proves the performance priority of NSGA-Ⅱ. Aiming at the current phenomenon of low level of rural intelligent development, 2 development paths are proposed.

2. Multi-objective optimization model for rural construction

2.1. Construction of multi-objective optimization model

2.1.1. Optimization of general principles. In general, rural infrastructure construction should take into account equity and efficiency, be guided by demand, prioritize support for economically underdeveloped areas, serve the public's travel, plan the layout scientifically, adhere to the coordination of production and roads, avoid damage as much as possible, and make full use of the existing infrastructure.

1) Highlighting the key points. Guided by the smoothness of the road network, mass travel and rural transportation needs, improve the capacity of townships, formed villages that benefit a wide range of people, and routes that benefit the general public. Continue to strengthen support for infrastructure construction in underdeveloped and economically weak areas, and prioritize the construction of "demonstration areas". The focus has been on promoting the construction of new infrastructure in all administrative villages, as well as the construction of infrastructure in specialty fields, in order to build an inclusive and equitable rural basic road network. Accordingly, administrative centers such as formed villages and townships have been selected as nodes of the road network.

2) Convenient and efficient. In order to serve the intelligent development of rural infrastructure, centering on local characteristics, creating regional brands, combining with the development planning of cultural tourism and recreation industry, organically combining the development of infrastructure with rural industrial bases, cultural tourism and recreation, characteristic towns, rural tourism and other industrial projects, reasonably arranging and constructing a number of rural service stations, parking zones and convenient service points, enhancing the service level of rural infrastructure, and constructing a convenient and efficient rural backbone Road network. Therefore, industrial parks,

logistics parks, agricultural processing zones and other industrial bases are selected as nodes for intelligent development of rural infrastructure.

3) Integrated development. The project of intelligent development of rural infrastructure is a vast and arduous project, and it is necessary to comprehensively and coordinately lay out and build rural infrastructure, combine the rural infrastructure layout planning with related development planning and so on, and realize the exchange and cooperation between counties and cities and between counties.

2.1.2. Model assumptions. Before constructing a multi-objective optimization model for rural infrastructure buildings, the application scenario of the model should be clarified and model assumptions should be proposed. First, denote the rural infrastructure network by $G(V,E)$, which is formed by the intersection between high-level facility nodes and low-level infrastructure. Let the set of nodes in the model be $V(V_1,V_2,\ldots\ldots,V_m,V_{m+1})$, $V_1 \sim V_m$ be the set of nodes of each type mentioned above, and the set of road sections in the model be E.

The length of the road sections between the nodes is represented by matrix L. i.e:

$$L=\begin{pmatrix} l_{11} & \cdots & \cdots & l_{1n} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ l_{\mathrm{m}1} & \cdots & \cdots & l_{mn} \end{pmatrix} \tag{1}$$

Where: $l_{n\mathrm{m}}$ is the length of the road section between node n and node m.

The interconnectivity level relationship between the nodes is represented by matrix E.

$$E=\begin{pmatrix} \alpha_{11} & \cdots & \cdots & \alpha_{1n} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \alpha_{n1} & \cdots & \cdots & \alpha_{nn} \end{pmatrix} \tag{2}$$

The velocity relationship corresponding to the interconnection level between the nodes is represented by matrix V.

$$V=\begin{pmatrix} v_{11} & \cdots & \cdots & v_{1n} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ v_{m1} & \cdots & \cdots & v_{mn} \end{pmatrix} \tag{3}$$

Second, the following assumptions are made about this multi-objective optimization model:

1) The rural infrastructure network consists of a set of infrastructures that can be upgraded to a higher level.

2) Both existing infrastructures (which can be upgraded to a higher level) and technically feasible infrastructures (if new ones are available) can be considered as candidates for optimization and upgrading.

3) The main modes of infrastructure in rural areas are assumed in this study: transportation and logistics.

2.1.3. Objective function. When performing rural infrastructure optimization, it is important to consider the impacts of new types of infrastructure and different levels of facility upgrading to determine whether there is a need for optimization among nodes. In this study, rural infrastructure optimization and upgrading is regarded as a hybrid network design problem (MNDP) to reflect the actual scenario, and hybrid decision variable modeling is applied and discretized variables are adopted. Finally, the objective of the problem is to achieve the smart rural development and the optimal efficiency of infrastructure development. Therefore, the multi-objective rural road network upgrading problem can be formulated as.

1) Minimizing individual fairness index of rural infrastructure construction. The optimization objective (Z_1) of individual fairness of rural infrastructure construction is to reduce the gap of access convenience between neighboring spatial units. Namely:

$$MinZ_1 = \sum_c NAG^c\left(x_{ij}, y_{ij}\right) \tag{4}$$

Where: c is an incorporated village. NAG^c is the established village c neighborhood accessibility gap. x_{ij} is a 0-1 decision variable, x_{ij} is equal to 1 if the road section (i, j) is newly built or renovated, and 0 otherwise. In addition, y_{ij}^u is a 0-1 decision variable, and y_{ij}^u is equal to 1 if the type of infrastructure (i, j) is u, and 0 otherwise.

2) The overall equity index of rural infrastructure development is maximized. At the same time, rural infrastructure development fairness optimization objective (Z_2) minimizes the gap between the most obvious and the weakest individuals with the most obvious and the weakest transportation advantages in the whole region. Namely:

$$MinZ_2 = P_{ratio}\left(x_{ij}, y_{ij}\right) \tag{5}$$

Where P_{ratio} is the Paloma index, which characterizes the overall equity in rural infrastructure development.

The decision variable related correlation is:

$$x_{ij} = \begin{cases} 0, \sum_u y_{ji}^u = 1 \\ 1, \sum_u y_{ji}^u = 1 \end{cases} \tag{6}$$

3) The economic benefits of rural infrastructure construction are the greatest. Rural infrastructure construction optimizes and improves accessibility and connectivity, and the accessibility and connectivity of industrial parks directly affects the circulation of enterprise development factors, effectively serves industrial development, and indirectly creates national economic benefits. Therefore, the pursuit of economic objective (Z_3) is to maximize the national economic benefits created by the transportation of agricultural products and maximize the investment efficiency of rural infrastructure construction projects:

$$MaxZ_3 = \sum \varepsilon_{ij} \tag{7}$$

Where, ε_{ij} is the economic efficiency of rural infrastructure development (i, j).

4) Maximum economic efficiency of rural infrastructure construction. In the actual optimization process, the rural infrastructure construction that can create national economic benefits is selected, and it should be more inclined to select the rural infrastructure construction with higher investment efficiency and coordinate the investment efficiency of the whole road network. Therefore, the pursuit of economic objective (Z_4) is to maximize the investment efficiency of rural infrastructure construction projects. The derivation of the formula is obtained:

$$MaxZ_4 = \delta_{eff}\left(x_{ij}, y_{ij}\right) \tag{8}$$

Of these, δ_{eff} is the economic efficiency of rural infrastructure development.

2.1.4. Constraints:

1) Construction investment constraints. Rural infrastructure construction funds are important constraints, in a certain period of time the total amount of investment is relatively fixed, so the

construction cost of rural infrastructure upgrading can not exceed the total amount of investment, and set a certain percentage of investment in rural infrastructure construction. Namely:

$$\sum_{u=1}^{5}\sum_{(i,j)\in E_2} g_{ij}^u L_{ij}^u y_{ij}^u x_{ij} \le B_{\text{General}} - B_{\text{Self}} \tag{9}$$

$$\sum_{u=0,4,S}\sum_{(i,j)\in E_3} g_{ij}^u L_{ij}^u y_{ij}^u x_{ij} \ge B_{\text{Self}} \tag{10}$$

Where B_{General} is the investment budget available during the planning period, where the investment budget for rural infrastructure construction projects is denoted by B_{Self}. Usually, the cost of improvement depends on the difficulty of the project and the level of upgrading, g_{ij}^u is the cost of improving the technical level of rural infrastructure 4 construction (i,j) upgraded to type u, and L_{ij}^u is the level of construction when the rural infrastructure is (i,j) graded u.

2) Level constraints. There is a need to ensure that there is only one technology level for each rural infrastructure construction per iteration. Namely:

$$\sum_{u=0}^{5} y_{ij}^u = 1 \forall (i,j) \in E, i<j \tag{11}$$

3) Truck OD traffic volume conservation constraints. Rural freight OD traffic volume conservation, the flow distribution process needs to satisfy traffic volume conservation, i.e., the sum of flows on each OD inter-pair path should be equal to the highway network's freight starting O traffic occurrence, and the sum of flows on each OD inter-pair path should be equal to the freight ending D traffic occurrence. I.e:

$$\sum_{od} F^{od} = \sum Q_o = \sum Q_d \tag{12}$$

For any OD pair, the sum of the flows on all its paths k from point o to point d is equal to the full flow with non-negative flow size, where K is the set of all paths from point o to point d. I.e:

$$\begin{aligned} &\sum_k f_k^{od} = q_{od} \\ &f_k^{od} > 0, \forall k \in K \end{aligned} \tag{13}$$

For any intermediate node i, the entire flow into node i is equal to the entire flow out of node i, $\{k\}$ is the entire inflow from node i, and $\{k'\}$ is the entire outflow from node i.

$$\sum_k q_{i,k}^+ = \sum_k q_{i,k'}^+ \tag{14}$$

4) Flow constraints on rural infrastructure development. The flow on rural infrastructure development is less than the development capacity. That is:

$$Q_{ij} \le \sum_{u=1} W_{ij}^u y_{ij}^u \forall (i,j) \in E, i<j \tag{15}$$

Where W_{ij}^u is the development capacity of rural infrastructure development (i,j) technology level is u.

5) Decision variable constraints for upgrading rural infrastructure development. x_{ij} is equal to 1 if the rural infrastructure (i,j) is newly built or renovated, and 0 otherwise, i.e:

$$x_{ij} \in \{0,1\} \tag{16}$$

If the type of rural infrastructure development (i,j) is u, then y_{ij}^{u} is equal to 1, otherwise it is 0. i.e.:

$$y_{ij}^{u} \in \{0,1\} \tag{17}$$

2.2. Multi-objective optimization problem solving

Multi-objective optimization problems can be transformed to simple single-objective level by the main objective and hierarchical sequence method on the one hand, and then calculated by the single-objective solution method on the other hand, but this kind of method is inefficient, and the objectivity of the weight value of each objective is low or the error of judging the priority of the objectives will have a greater impact on the results. On the other hand, the intelligent evolutionary algorithm combined with the Pareto optimal solution method is used to solve the problem, and the results of this method can better show the relationship between multiple objectives, which is convenient for decision makers to coordinate. Based on the comparison of various algorithms above, this paper selects the NSGA-II algorithm, which has better speed and robustness in multi-objective optimization problems and the widest application range, to solve the optimization model of rural infrastructure construction in this paper.

2.2.1. Pareto Optimal Solution. Figure 1 shows the schematic diagram of Pareto optimal solution, Pareto optimal solution describes the implementation of the allocation of resources in the hypothetical form, such as in the people and resources under certain conditions, if the change of the allocation method is that no one feels that their interests have been damaged, then there is at least one person who believes that they get greater benefits, which is the ideal state of allocation [21-23].

"Dominance, dominance" is the relationship between the solutions of a multi-objective optimization problem, set two objectives f_1, f_2, if solution A corresponding to f_1, f_2 are better than solution B, then solution A is said to be superior to solution B, also known as solution A strong Pareto dominance of the solution B (solution E corresponding to f_1, f_2 are smaller than solution C, D, so solution E is superior to solution C, D). If solution A corresponds to f_1 which is superior to solution B and f_2 which is inferior to solution B, then solution A is said to be indistinguishable from solution B, and solution A is said to be able to Pareto dominate solution B (the same applies to solutions C and D). Solution A is said to be Pareto-optimal if solutions f_1 and f_2 corresponding to solution A are better than all the solutions, and the optimal solution is just an acceptable solution to the problem. The black solid points in the figure indicate the optimal solutions, and all the optimal solutions form the set of Pareto-optimal solutions, which are mapped by f_1 and f_2 to form the Pareto-optimal frontier or Pareto-front surface of the problem.

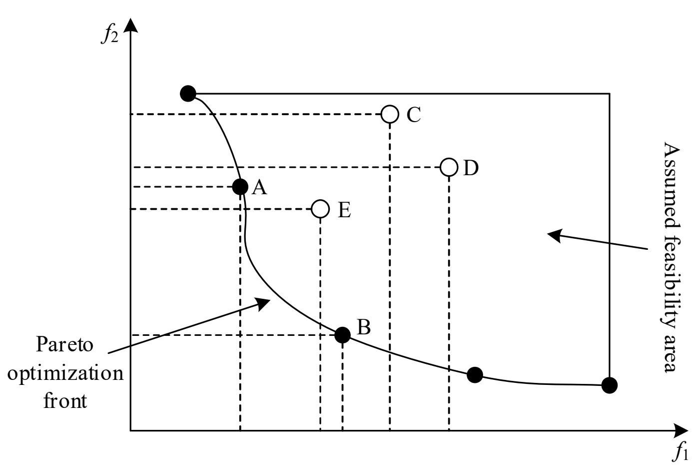

Fig. 1. Pareto optimal solution diagram

2.2.2. NSGA and NSGA-II. NSGA is widely used, but still has the following problems:

1) It has high computational complexity. It is computationally inefficient when facing a large population size.

2) Need to specify the sharing radius. The sharing radius is an important parameter that affects the accuracy of the results.

3) Lack of elite strategy. Elite strategy can improve the running speed and properly avoid the loss of satisfactory solutions.

NSGA-II is obtained by Deb et al. by making the following improvements for the shortcomings of NSGA:

1) A fast non-dominated sorting algorithm is proposed, which is reduced from $O\left(mN^3\right)$ to $O\left(mN^2\right)$ (m is the dimension of the objective function and N is the population size), so that the computational complexity is effectively reduced.

2) Replacing the fitness sharing strategy that requires specifying the sharing radius with the crowding degree and crowding degree comparison operator, and using it as the winning criterion for peer comparison after fast sorting, so that individuals in the quasi-Pareto domain can be extended to be evenly distributed throughout the Pareto domain in order to maintain the diversity of the population.

3) Elite strategy is introduced to vast sampling space to merge the parent population with its offspring population and compete together to generate the next generation population, which is conducive to keeping the excellent individuals in the parent generation to the next generation, and the hierarchical storage of all the individuals in the population avoids the omission of the satisfactory solution, and improves the computational efficiency and robustness of the algorithm.

2.2.3. NSGA-II Basic Processes. The basic process of NSGA-II is shown in Fig. 2. The main principle of NSGA-II: firstly, initialize a population of size N , and after non-dominated sorting of each individual in the population, select, crossover and mutate, thus generating the first generation of offspring population. Secondly, starting from the second generation, the parent and offspring populations were merged to obtain a new population, and the crowding degree was calculated after non-dominated sorting of each individual in the new population, and the new parent population was obtained by selecting the best individuals in the order of non-dominated relationship and crowding degree of the individuals. Finally, the new offspring population is obtained by basic genetic operations. And so on until the condition of iteration termination is reached.

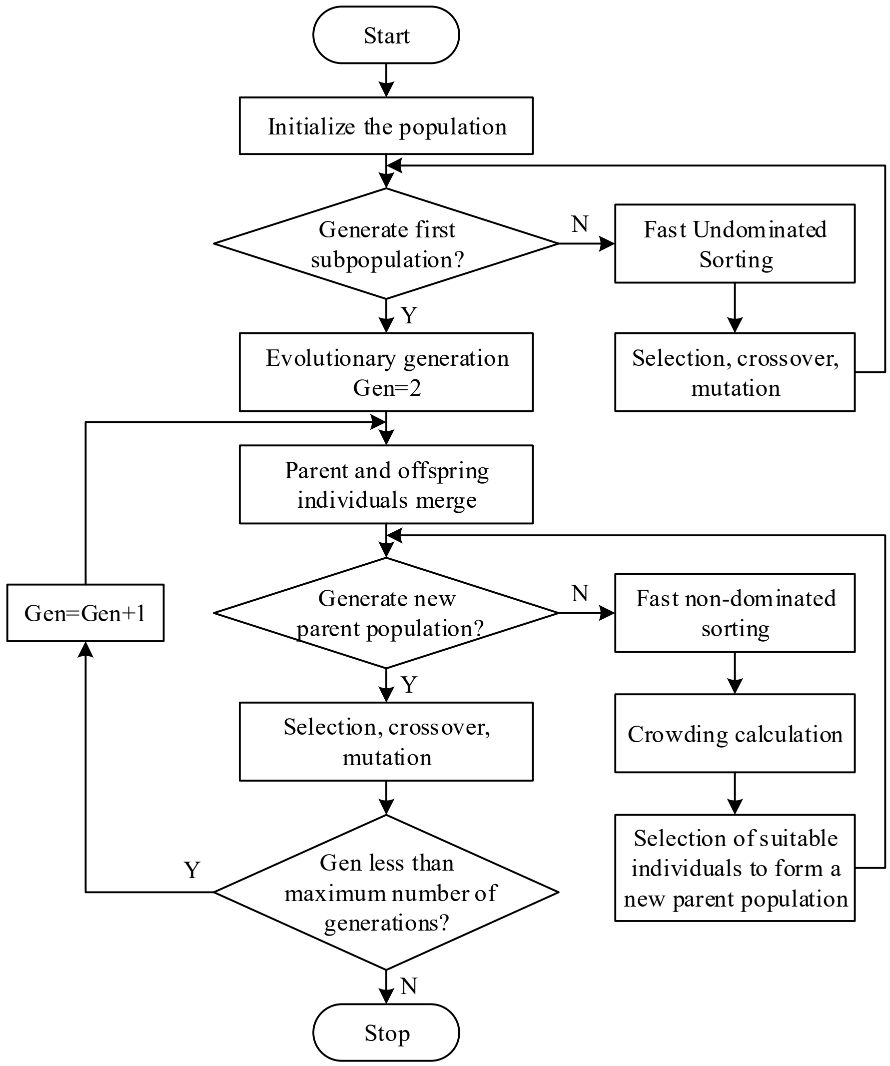

Fig. 2. Basic flow of NSGA-II algorithm

For each non-dominance sort and crowding degree sort of NSGA-, each individual in the population is given two parameters: the non-dominance tier classified by the non-dominance sort and the crowding degree parameter calculated in the crowding degree sort.

1) Non-dominance hierarchy. The non-dominance rank (Rank) of an individual within a population reflects its status, the smaller the non-dominance rank, the better the corresponding individual's objective function value, and each individual compares with each other on the basis of the objective fitness function value, thus determining the dominance relationship.

2) Crowding degree. Crowding is the density of individuals around a specified point in a population, which is used as a basis for ranking individuals within the same non-dominated hierarchy. Figure 3 shows a schematic diagram of crowding degree, where the crowding degree of solution n represents the perimeter of the largest rectangle that can be radiated around by n without being able to intersect with other points in the target space. The larger the perimeter of this rectangle, the less similar solution n is to the surrounding solutions and the more different it is. Individuals with larger crowding distances play an important role in maintaining population diversity and should be preferred.

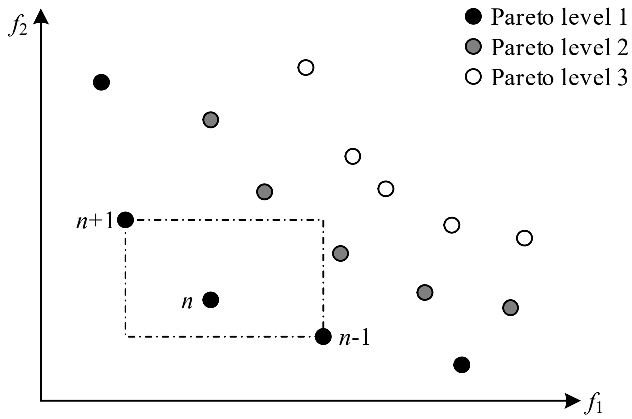

Fig. 3. Congestion diagram

2.2.4. NSGA-II algorithm design:

1) Chromosome coding. Chromosome coding is a feasible solution to the actual problem of some of the "spatial and temporal transformation", transformed to the genetic algorithm can understand the space, is the use of genetic algorithms to solve the problem of an indispensable step in the process of the coding method affects the algorithm's efficiency of the chromosome coding is shown in Figure 4, the elimination of the countryside infrastructure construction station station between the individual genes can not be duplicated, i.e., chromosome 1, 2, 3 represents three feasible solutions. 3 represents three feasible solutions, however, the gene combination between chromosome 2, 3 is identical only the gene arrangement is different, then the two feasible solutions that represents the same site selection program.

Chromosome 1	1	9	8	3	4	5	17	13
Chromosome 2	3	8	1	16	19	6	2	7
Chromosome 3	6	2	16	3	8	7	1	19

Fig. 4. Chromosome arrangement coding schematic

2) Multiple population initialization. Too small or too large a population size affects the accuracy of the solution results and the running time of the algorithm, respectively, but selecting a larger population size increases the possibility of the algorithm converging to the optimal solution and enhances the global search capability of the genetic algorithm. Combined with the research data, this paper adopts the method of random production for the initialization of population size.

3) Calculation of fitness. The reasonable selection of the fitness function determines the performance of the genetic algorithm and the search speed of the optimal solution, and in this paper, the four objective functions in the optimization model of rural infrastructure construction constructed above are the fitness functions.

4) Non-dominated Sorting. In this paper, the ENS algorithm based on sequential search strategy (ENS-SS) is used for non-dominated sorting. Most of the commonly used non-dominated sorting algorithms sequentially determine all individuals in each frontier, on the contrary, the ENS algorithm is to directly determine the frontier where each individual is dispatched in the population. ENS-SS only needs to compare the individuals to be sorted with the individuals that have been sorted, and ignores a large

number of irrelevant non-dominated comparisons in the process of non-dominated sorting to improve the algorithmic computational efficiency.

5) Genetic operation:

(1) Selection: Genetic algorithm selection refers to taking the fitness value as the evaluation standard, eliminating bad individuals and preserving excellent individuals. In this paper, we choose the selection strategy of the tournament: each time a specified number of individuals are drawn from the population, and the best individuals are sent to the offspring population, and repeat until the termination condition is reached.

(2) Crossover: Genetic algorithm crossover refers to the recombination or substitution of local gene segments of the parent chromosome, and mutation and crossover play a very important role in the enhancement of the search ability of the genetic algorithm. In this paper, partial matching crossover is used to avoid duplicate genes in each chromosome.

(3) Variation: genetic algorithm variation refers to gene changes on chromosomes, which can effectively guarantee the existence of populations with diversity and avoid early convergence phenomenon in the solution process. In this paper, we choose the variation method of reversal variation operator, the principle is: randomly determine the two positions on the chromosome, exchange the genes in these two positions for processing, and keep the genes in other positions unchanged.

3. Facility Construction Optimization Analysis and Intelligent Development Paths

3.1. *Optimization Model Arithmetic Analysis*

3.1.1. Parameter setting analysis. Before performing the optimization procedure it is necessary to define the optimization parameters which are population size, maximum number of iterations, crossover and mutation probabilities. The values of these parameters depend on the nonlinearity class of the optimization problem, the type of input variables and the dimensionality of the problem. According to the number of design parameters, based on the analysis of the existing literature, the parameters of NSGA-II in this study are set as shown in Table 1 and the Pareto optimality bound is shown in Figure 5. Since the optimization results using the NSGA-II algorithm depend heavily on the initial population created from a random uniform distribution, the optimal solution resulting from each optimization is different. Therefore, in order to obtain the optimal solution or a near-optimal solution, the optimization was run more than a dozen times with the same singular setting of the NSGA-II algorithm to finally arrive at the optimal Pareto front. In order to perform a comprehensive search of the entire solution domain, more than 1.844 × 1013 design parameter combinations need to be investigated, which is infeasible considering that the average computation time of Energy Plus for the design solutions is about 1.13 min/run, and the computation time required using a 2.05 GHz processor is about several 38.5 million years. In contrast, with the NSGA-II algorithm, MATLAB's evolutionary search for 100 generations of an initial population consisting of 200 individuals can be completed in only 1 minute, a 99.9% reduction in time, making the optimization process feasible in engineering practice. Among the non-dominated solutions generated for the 3D Pareto frontiers, optimal solutions for different stakeholders were identified.

Table 1. NSGA-II Parameter Settings

Parameter name	Value
Population size	200
Maximum iterations	100

Crossover probability	1.2
Mutation probability	0.01

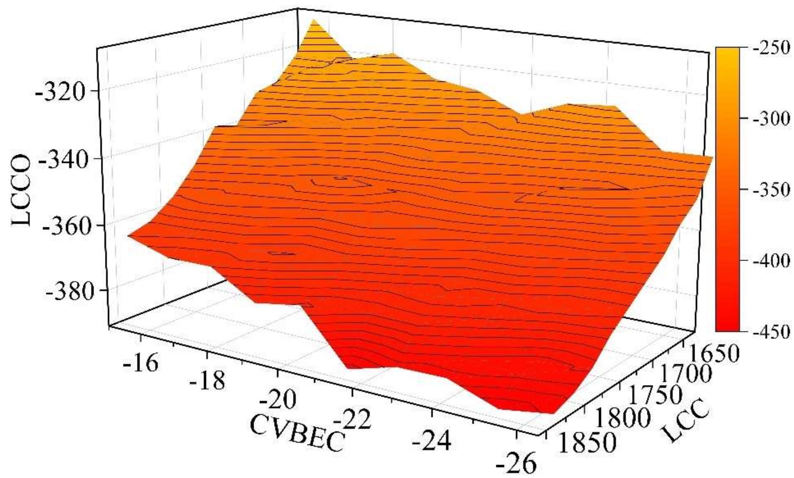

Fig. 5. Pareto optimal boundary

3.1.2. Analysis of optimization results. Based on the multi-objective optimization model proposed in this paper to optimize the infrastructure development of undeveloped plots around villages. Each objective is assigned the same weight in this study, and the summed fitness function is substituted into the NSGA-II method for solving. Therefore, the rural planner's preference for the six objectives is not taken into account when setting the weights of the objective function, but the optimization of rural infrastructure required by the planner is selected from the set of nondominated solutions in the optimization process with NSGA-II, and the convergence results of the algorithm's solved fitness function are shown in Table 2. After several tests it can be seen that the algorithm has fully converged before the number of iterations reaches 100.

Table 2. Fitness function convergence results

iteration	Fitness	iteration	Fitness	iteration	Fitness	iteration	Fitness	iteration	Fitness
1	1.3527	21	1.38844	41	1.38865	61	1.3896	81	1.38966
2	1.36083	22	1.38847	42	1.38865	62	1.3896	82	1.38966
3	1.36161	23	1.38851	43	1.38865	63	1.38961	83	1.38966
4	1.37174	24	1.38854	44	1.38865	64	1.38961	84	1.38966
5	1.372	25	1.38857	45	1.38872	65	1.38961	85	1.38967
6	1.37226	26	1.38861	46	1.38891	66	1.38961	86	1.38967
7	1.37532	27	1.38864	47	1.3891	67	1.38962	87	1.38967
8	1.37598	28	1.38865	48	1.38929	68	1.38962	88	1.38967
9	1.37633	29	1.38865	49	1.38948	69	1.38962	89	1.38968
10	1.37913	30	1.38865	50	1.38957	70	1.38963	90	1.38968
11	1.37959	31	1.38865	51	1.38957	71	1.38963	91	1.38968
12	1.38813	32	1.38865	52	1.38958	72	1.38963	92	1.38969
13	1.38816	33	1.38865	53	1.38958	73	1.38963	93	1.38969
14	1.3882	34	1.38865	54	1.38958	74	1.38964	94	1.38969
15	1.38823	35	1.38865	55	1.38958	75	1.38964	95	1.38969
16	1.38827	36	1.38865	56	1.38959	76	1.38964	96	1.3897
17	1.3883	37	1.38865	57	1.38959	77	1.38964	97	1.39001
18	1.38833	38	1.38865	58	1.38959	78	1.38965	98	1.39056
19	1.38837	39	1.38865	59	1.3896	79	1.38965	99	1.39511
20	1.3884	40	1.38865	60	1.3896	80	1.38965	100	1.39574

After analyzing the results of the multi-objective optimization model for rural infrastructure construction, the results of each objective function value under different types of infrastructure construction scenarios will be analyzed next, and the Pareto solutions obtained by the NSGA-II method are shown in Table 3. Scenarios A to D in Table 3 correspond to the optimal solution of each objective function (individual fairness index, overall fairness index, economic efficiency, economic efficiency) in the set of nondominated solutions, and the bolded values are the near-optimal values of each objective function obtained by the algorithm, for example, the individual fairness index of the rural infrastructure construction scenario A reaches 0.813. After 100 iterations, the individual fairness index, overall fairness index, economic effectiveness, and economic efficiency have objective optimal values of 0.813, 0.943, 0.852, and 0.886, respectively.Although this study does not consider the rural infrastructure builders' preferences for the four objectives in the proposed model in the objective function and sets different constraints, in the optimization of rural infrastructure construction by NSGA-II, using the nondominated rule to select the nondominated solution corresponding to each objective. As a result, the rural infrastructure development solution that is optimal for each objective as well as capable of balancing multiple objectives can still be obtained in the end.

Table 3. Pareto solution obtained by NSGA-Ⅱ method

Construction scheme	Goal			
	Individual equity index	Global equity index	Economic benefit(Hundred million yuan)	Economic efficiency
A	0.813	0.645	0.546	0.562
B	0.709	0.943	0.614	0.587
C	0.713	0.763	0.852	0.614
D	0.694	0.674	0.818	0.886

3.1.3. Evaluation metrics and algorithm performance analysis. In order to further analyze the performance of the algorithm, the NSGA-II algorithm proposed in this paper is tested in comparison with the original NSGA and GA algorithms, and the hypervolume is selected as a measure of the quality of the solution set, which does not need to know the information of the Pareto frontier but compares the volume of the region surrounded by the reference point and the nondominated solution set in the decision space, and the bigger the value of the hypervolume is, the more the optimal solution in the solution set has a better distributive and convergent nature. The larger the value of hypervolume, the better the distribution and convergence of optimal solutions in the solution set. Table 4 gives the hypervolume comparison results of the three algorithms, in which G, H, and I denote the hypervolume values of GA, NSGA, and NSGA-II, respectively. From the table, it can be seen that the hypervolume of the method used in this paper is significantly higher than that of the original NSGA and GA, which is due to the fact that in the process of algorithmic evolution, the resulting conflicting individuals need to be corrected in each generation in order to improve the quality of the solution set. While GA does not verify and correct the conflicting individuals during each iteration, which will lose the diversity of the population to a certain extent, NSGA uses the greedy strategy for the decoding process, but it does not take the overall distribution into account and cannot guarantee the quality of the solution. It can be seen that the conflicting individual adjustment strategy and the addition of priority comparison ranking to the process of generating subgenerational populations proposed in this paper can effectively improve the comprehensive performance of the algorithm as well as the quality of the Pareto solution set.

Table 4. The supervolume comparison of the three algorithms

N	G	H	I	N	G	H	I	N	G	H	I	N	G	H	I
1	0.431	0.509	0.766	26	0.465	0.516	0.731	51	0.43	0.557	0.699	76	0.447	0.517	0.786
2	0.453	0.57	0.714	27	0.46	0.578	0.671	52	0.418	0.51	0.773	77	0.451	0.549	0.628
3	0.457	0.556	0.796	28	0.476	0.503	0.661	53	0.422	0.537	0.732	78	0.455	0.568	0.676
4	0.426	0.599	0.614	29	0.406	0.513	0.785	54	0.444	0.581	0.742	79	0.467	0.508	0.744
5	0.417	0.58	0.705	30	0.453	0.56	0.66	55	0.457	0.522	0.637	80	0.47	0.597	0.709
6	0.467	0.544	0.799	31	0.489	0.592	0.719	56	0.43	0.564	0.77	81	0.414	0.596	0.667
7	0.441	0.571	0.62	32	0.497	0.533	0.698	57	0.479	0.564	0.708	82	0.467	0.515	0.702
8	0.434	0.505	0.679	33	0.411	0.533	0.738	58	0.488	0.521	0.672	83	0.445	0.507	0.76
9	0.498	0.583	0.633	34	0.473	0.512	0.753	59	0.413	0.543	0.688	84	0.435	0.529	0.717
10	0.418	0.599	0.728	35	0.432	0.57	0.781	60	0.497	0.589	0.728	85	0.493	0.532	0.671
11	0.452	0.589	0.622	36	0.412	0.543	0.629	61	0.457	0.547	0.649	86	0.478	0.568	0.614
12	0.481	0.507	0.604	37	0.457	0.534	0.747	62	0.454	0.576	0.767	87	0.416	0.555	0.633
13	0.473	0.551	0.641	38	0.417	0.593	0.76	63	0.465	0.516	0.623	88	0.449	0.557	0.613
14	0.459	0.582	0.723	39	0.48	0.579	0.793	64	0.479	0.56	0.707	89	0.495	0.571	0.667
15	0.4	0.507	0.787	40	0.457	0.575	0.771	65	0.411	0.598	0.672	90	0.424	0.545	0.678
16	0.413	0.577	0.605	41	0.492	0.576	0.601	66	0.428	0.57	0.7	91	0.468	0.516	0.754
17	0.445	0.592	0.611	42	0.446	0.517	0.711	67	0.406	0.574	0.764	92	0.497	0.503	0.604
18	0.425	0.512	0.699	43	0.433	0.558	0.724	68	0.494	0.575	0.686	93	0.452	0.521	0.695
19	0.474	0.581	0.78	44	0.422	0.533	0.776	69	0.437	0.533	0.787	94	0.406	0.59	0.681
20	0.439	0.551	0.622	45	0.494	0.577	0.774	70	0.462	0.507	0.672	95	0.459	0.552	0.688
21	0.494	0.542	0.773	46	0.446	0.505	0.793	71	0.442	0.516	0.796	96	0.441	0.597	0.673
22	0.451	0.573	0.681	47	0.465	0.588	0.692	72	0.49	0.531	0.706	97	0.458	0.573	0.636
23	0.463	0.569	0.721	48	0.455	0.502	0.617	73	0.486	0.505	0.752	98	0.412	0.549	0.705
24	0.403	0.522	0.759	49	0.456	0.504	0.619	74	0.498	0.505	0.71	99	0.485	0.565	0.702
25	0.477	0.587	0.744	50	0.447	0.521	0.642	75	0.462	0.581	0.683	100	0.458	0.565	0.683

In order to further clarify the optimization performance of the proposed methods under different numbers of villages, the number of villages requiring infrastructure construction is set to be 60, and the optimization performance of infrastructure construction under different numbers of villages is verified, and the average running times of the three methods under different numbers of villages are given in Table 5. It can be seen that with the increasing number of villages, the overall average running time of the proposed method is larger than that of the original GA and NSGA, but the difference with NSGA is not large. This is because as the number of villages increases, the target space gradually expands, and the limited available construction funds exacerbate the conflicts in the construction of rural infrastructures, resulting in a large number of conflicting individuals, and as a result of the need to correct these conflicting individuals, the algorithm's evolutionary cost increases, but in order to improve the quality of the solution set, the necessary time overhead is worthwhile.

Table 5. The average running time of the three methods in different number of villages

N	GA(s)	NSGA(s)	NSGA-II(s)	N	GA(s)	NSGA(s)	NSGA-II(s)
1	20.3	20.35	20.41	31	39.8	50.89	73.94
2	20.61	22.97	21.1	32	41.54	53.93	75.58
3	21.27	26.32	21.88	33	42.44	54.25	75.64
4	21.3	26.45	26.43	34	42.76	54.48	75.83
5	22.35	26.73	27.36	35	43.61	55.12	77.82
6	22.77	27.55	27.43	36	43.67	55.21	78.37
7	24.91	27.73	29.49	37	44.19	55.66	78.4
8	25.02	29.35	29.64	38	45.84	57.58	78.54
9	25.7	30.44	29.95	39	45.87	59.5	79.12
10	26.12	31.68	31.4	40	45.92	60.96	79.52
11	26.76	33.06	34.05	41	47.56	62.19	81.02
12	27.14	33.42	34.81	42	47.61	70.99	84.08
13	27.5	33.81	38.94	43	47.66	74.27	84.97
14	28.37	34.43	44.38	44	47.81	74.71	85.34
15	28.57	37.99	45.13	45	48.76	74.79	86.48
16	28.92	39.68	46.79	46	48.97	75.53	88.17
17	31.04	39.83	47.79	47	49.65	75.54	88.22
18	32.2	40.23	51.2	48	50.11	77.25	88.71
19	32.59	42.56	57.09	49	50.6	77.81	91.23
20	32.94	42.95	58.04	50	51.79	78.37	92.27
21	34.3	43.31	59.21	51	52.03	79.08	94.33
22	34.72	46.58	59.43	52	53.06	79.18	96.15
23	35.47	46.91	60.73	53	53.15	80.17	97.79
24	36.91	47.94	62.74	54	53.51	81.33	101.79
25	37.63	48.2	63.39	55	53.82	85.3	104.13
26	37.69	49.2	64.2	56	54.64	85.49	105.08
27	38.28	49.39	72.75	57	55.33	87.02	105.81
28	38.84	49.7	72.89	58	55.4	87.38	106.58
29	39.43	49.89	73.18	59	56.17	88.06	108.74
30	20.3	50.81	73.62	60	57.23	88.64	109.17

Table 6 gives the results of the comparison of the objective function values obtained by solving with the three algorithms respectively, from which it can be seen that for a single objective, the method used in this paper produces overall better results than the NSGA algorithm and the GA, and a high quality solution can be found more quickly.

Table 6. The results of the three methods are compared

Method	Individual equity index		Global equity index		Economic benefit (Hundred million yuan)		Economic efficiency	
	Optimal value	Number of iterations	Optimal value	Number of iterations	Optimal value	Number of iterations	Optimal value	Number of iterations
NSGA-II	0.813	100	0.943	100	0.852	100	0.886	100
NSGA	0.762	100	0.887	100	0.809	100	0.818	100
GA	0.694	100	0.819	100	0.785	100	0.792	100

3.2. *Rural Intelligent Development Path*

3.2.1. Strengthening top-level design for building intelligence. The good performance of technology-enabled rural infrastructure construction is an important reason for the main body of governance to promote the intelligence of rural infrastructure construction, but at the same time, the main body of rural infrastructure construction is not clear about the positioning of intelligent functions, blurred rights and responsibilities, and the construction of supporting policies and systems lagging behind the development of technology, and other issues have also hindered the deep development of the intelligence of rural infrastructure construction. Therefore, it is urgent to draw a blueprint for the intelligent construction of rural infrastructure in the new era in an all-round way. This blueprint includes three aspects: first, innovate the working idea and strengthen the top-level design of intelligent rural infrastructure construction. Realizing the intelligence of rural infrastructure construction is a complex systematic project involving multiple fields, systems and subjects, so it is urgent to adhere to the top-down principle, carry out top-level design and planning for the intelligence of rural infrastructure construction from a global perspective, and realize the unity of the institutional mechanism of rural infrastructure construction and the modernization of the national governance system. Second, break through the existing paradigm of infrastructure construction and innovate the institutional mechanism. The wave of information technology has pushed the construction of rural infrastructure from traditional social management to intelligent governance paradigm, and it is urgent to take the new generation of information technology as the strategic support for the development of intelligent governance in practice, innovate the institutional mechanism of intelligent governance, and shape the paradigm of intelligent rural infrastructure construction. Thirdly, build an intelligent system of rural infrastructure, and put the application of technology on the track of rural infrastructure intelligence. Building rural infrastructure intelligence is a mandatory requirement to guarantee the intelligence of rural infrastructure construction.

3.2.2. Beware of technological overstepping and malpractice. The wide application of intelligent technology in rural infrastructure construction gives technical power to the construction subject, and the construction subject may apply this power to seek political and economic interests, which is characterized as technical overstepping and evil. The behavior of the construction subject using technical power to seek profit is essentially the failure of the subject's technical power constraints, therefore, to prevent the construction of rural infrastructure subject to implement the effective means of technical overstepping and evil profit-seeking is to restrict its technical power. On the one hand, limit the construction subject technical power expansion. Reconstruct the relationship between the main body of construction and technical power, the establishment of the right to have responsibility for the empowerment mechanism, in accordance with the responsibilities of the main body of construction to give its corresponding technical power. The establishment of equal rights and responsibilities of the use of power mechanism, standardize the construction of the main body of the technical power to use behavior. Establish the mechanism of supervisory power that must be held accountable for the failure of responsibility, check and balance the technical power of the main body of the construction, and put the technical power of the main body of the construction into the cage of the system to prevent the expansion of the power of the main body of the construction. On the other hand, promote the prevention of technical overstepping and evil rule of law. Construction of intelligent technical barriers to increase the difficulty of legislation, it is very easy to construction subject both legislation and law enforcement phenomenon, the inherent profit-seeking instincts of the main body of construction may be driven by the technical overstepping and evil cloak of legality. Therefore, there is an urgent need to explore innovative legislative procedures for the intelligent construction of rural infrastructure, to change the sectoral legislation for which the main body of construction is responsible into "open legislation" with the participation of many parties, and to explore the system of avoidance of the legislation of the main body of construction, so as to resolve the risk of the main body of construction using the rule of law as a means to carry out profit-seeking behaviors.

4. Conclusion

In this paper, under the guidance of the general principle of optimization, the model assumptions are put forward, and its objective function and constraints are further determined to complete the task of constructing a multi-objective optimization model for rural construction. Starting from the Pareto optimal solution, NSGA-II algorithm is used to solve the multi-objective optimization problem. After 100 iterations, the objective optimal values of individual fairness index, overall fairness index, economic benefit, and economic efficiency are 0.813, 0.943, 0.852, and 0.886, respectively, and the optimal solutions of their four objective functions are better than those of the NSGA algorithm and GA algorithm, and at the same time, the speed of solving is better. In order to better realize the intelligent development of the countryside, targeted development paths and strategies are proposed from the aspects of strengthening the top-level design of building intelligence and guarding against technological transgression and evil.

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