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Research Article

Comprehensive Objective Optimization Analysis of Construction Projects under Multiobjective Particle Swarm Optimization

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Due to the future development of the construction industry towards the sustainable development direction of green, ecology, and safety in the future, the ultimate goal requirement of engineering projects will be higher, and the investment traditional objectives, time limit, and quality cannot meet the requirements of comprehensive management objectives. Therefore, safety and environmental management were added in this paper based on traditional management objectives from the perspective of the project owners, the relationship between objectives was analyzed, and an equilibrium optimization model of objectives was constructed. A series of Pareto optimal solutions were obtained by using multiobjective particle swarm optimization (MOPSO). Then, the best scheme was selected from the series solutions by using the efficiency coefficient method according to the specific requirements of project management. Finally, taking the objective comprehensive optimization management of a wind power project in Sichuan province as an example, 1000 paths are run by using a multitarget particle swarm algorithm, and the mean and standard deviation of the 1000 paths are calculated. The rationality of the model and the practicability of the multiobjective particle swarm optimization algorithm in the study of engineering project comprehensive optimization management were verified. It has realized the multiobjective optimization management of engineering projects and contributed to improving the quality of engineering management.

1. Introduction

Along with the idea of sustainable development of China's construction industry being put forward, project management is developing towards green environmental protection, energy conservation, emission reduction, informatization, and construction industrialization. Therefore, the objective management that is still based on traditional investment, time, and quality cannot meet the requirements of modern management comprehensive optimization. As an investment party, the project owners urgently need to carry out the comprehensive optimization management of engineering projects to improve the production efficiency and meet the market demand.

In traditional engineering project management, what project owners mainly consider are the quantifiable objectives, while the safety and environmental objectives are seldom considered, which ignores the correlation with other objectives. In recent years, as people attach more and more importance to the safety and environment of engineering projects, it is more suitable for modern management optimization to consider it during the engineering project comprehensive optimization management.

Cao [1] analyzed the relationship between safety, environment, and cost from the perspective of construction enterprises and established the optimized model of multiobjective in project time limit-cost, time limit-quality, safety-cost, and environment-cost. Kong [2] analyzed the interaction relationship between various objectives in detail, established four relationship models of cost-time limit, quality-time limit, environment-time limit, and safety-time limit, and formed a multiobjective equilibrium optimization model by integrating the single-objective model of which the solving method was then studied. Zhang and Chen [3] proposed that safety management was added to the project target management system, making use of the analytic hierarchy process to establish the project target system in time limit-cost-quality-safety.

To reduce the frequency of safety accidents and the losses of casualties, and to decrease the influence of both the natural environment and social environment, safety and environmental management were added in this paper based on traditional management objectives from the perspective of the project owners. Different scholars have different approaches to the study of project optimization management.

Badu and Suresh [4] first proposed that three related linear programming models can contribute to engineering projects with multiobjective optimization tasks. According to the assumption that there is a linear relationship between the process quality level, time limit, and cost, this method establishes three models in respect of linear programming to study the balanced relationship between the quality, cost, and time limit. Vrat et al. [5] established the objective programming model by a piecewise linear function. Pollack-Johnson [6] et al. determined each work's quality level through the analytic hierarchy process and established an integer linear programming model for multiobjective optimization. Azaron and Tavakkoli-Moghaddam [7] established a multistage and multiobjective comprehensive optimization model for the construction period, cost, and quality under the environment of a random network planning graph. Dai [8] established the time limit-quality-cost relationship model based on the quadratic functions of time limit-cost and time limit-quality. Zhao [9] verified the feasibility of reliability theory as a constraint condition in the multiobjective optimization of engineering projects through an example based on determining the time limit reliability and cost reliability. Wen and He [10] introduced the physical planning method and solved the preference function by using the comprehensive decision-making model of project quality-time limit-cost established by the preference function and the preference setting of decision-makers to provide a basis for the project's comprehensive decision. Li et al. [11] introduced the system reliability and cost present value into the multiobjective optimization model and applied it to engineering examples, which made up for the lack of previous models that did not consider the time value of capital and the overall reliability. The relationship between the schedule, cost, and quality is described objectively, and the improved model and algorithm have certain universality, which is also applicable to other construction projects. Wen and He [12] established a comprehensive decision-making model of the project quality-duration-cost and preference setting of decision-makers by introducing a physical planning method and using a preference function. Heravi and Faeghi [13] pointed out that the optimal utilization of resources should be achieved by considering the time limit, cost, and quality in the design stage. They combined the Monte Carlo simulation method to process the time limit and cost data and estimated the quality by using the fussy data to carry out multiobjective optimization. Ali et al. [14] established an optimized time limit-cost-quality model based on looser linear assumptions in the general form of three functions (time limit, cost, and quality), which minimizes the influence on the variation of limited time, cost, and quality and makes it more close to engineering practice. Sarkar [15] proposed that a resource optimization model for bridge projects using a genetic algorithm be developed. Using the proposed model is to search for an optimum set of resources that will optimize both cost and time, under various constraints related to desired productivity, work conditions, and resource availability limit. Huang et al. [16] proposed a BIM construction engineering cost optimization technology based on a particle swarm optimization algorithm. The paper establishes the engineering project cost-time balance optimization mathematical model. After analyzing the existing research on construction quality quantification and considering the actual phenomenon of "student syndrome" in the project progress, Jiang et al. [17] proposed the quantification index of single work quality level. An objective measure method of project quality level is established according to the reliability theory of the work network system. It overcomes the subjectivity of work weight coefficient determination.

At present, the traditional multiobjective optimization method cannot meet the requirements of the increasing accuracy of solving multiobjective optimization problems. With the rapid progress of intelligent algorithms, the intelligent algorithm has been sought after by many scholars and has been applied to solve various problems of multiobjective optimization.

Premkumar and Manikandan [18] advanced the speed control system on the motor by adopting the bat algorithm optimized adaptive neuro-fuzzy inference system. Parameters such as learning rate (η), forgetting factor (λ), and steepest descent momentum constant (α) of the controller are optimized for various modes of brushless DC motor with the three algorithms: genetic algorithm, particle swarm optimization, and bat algorithm. The controller built on the antlion algorithm optimized fuzzy PID supervised online recurrent fuzzy neural network has been advanced by Chllappan Agees Kumar. This speed control system is designed for a brushless DC motor. There are a few learning parameters such as learning rate (η), dynamic factor (α), and number nodes (Ni) of the neural network controller. Applying the genetic algorithm, particle swarm optimization, ant colony optimization, bat algorithm, and antlion algorithm to the control system optimizes the defined parameters of it. Lah et al. [19] optimized the time limit-quality-cost comprehensive model through the genetic algorithm and demonstrated the superiority of the genetic algorithm in processing the time limit-quality-cost comprehensive model. Combined with the fuzzy multi-attribute utility method, Zhang and Xing [20] adopted a fuzzy multiobjective particle swarm optimization algorithm to obtain the scheme of the fuzzy time limit-cost-quality equilibrium optimization problem. Combining the marginal utility theory and linear basic model, Xi [21] proposed a comprehensive model through the combination of utility theory and linear basic model and focused on studying particle swarm optimization with compression factor and adaptive weighted particle swarm optimization based on an algorithm of standard particle swarm. From the perspective of construction, Zhuo and Lu [22] established a time limit-cost-quality optimization model by taking the time limit of each work in the double-code network diagram as an independent variable based on the unity of opposite relationship among time limit, quality, and cost, then optimized and solved through standard particle swarm optimization. To improve multiobjective tasks in substation projects, Zhang [23] proposed a cost model derived from three traditional management objectives and adopted particle swarm optimization. Liu [24] adopted the improved particle swarm optimization algorithm to carry out the multiobjective dynamic optimization of construction projects and considering the time value of funds in the establishment of the time limit-cost optimization model, and proposed the time limit-cost model that introduced the present value of costs. Yi and Gao [25] established a multiobjective optimization fuzzy expected value model with time-cost-quality balance in 2015 and solved it by combining three intelligent algorithms: fuzzy simulation, neural network, and MOPSO. The effectiveness of the multiobjective particle swarm optimization algorithm is verified by empirical analysis. Liu et al. [26] studied the coordination efficiency coefficients of project quality, cost, time limit, and resources, established the multiobjective collaborative optimization model of quality, cost, time limit, and resources, and introduced the methods and steps of applying the particle swarm optimization algorithm to solve the multiobjective optimization of engineering projects. Wang et al. [27] divided the project into various engineering activities for research and used nonlinear functions to quantitatively describe each other's relation among the duration, quality, and cost objectives. A multiobjective comprehensive optimization model is to be established according to the multiattribute utility function that can generate results through the real code modified genetic algorithm. By introducing a genetic algorithm into resource optimization, Luo et al. [28] solved the two optimization problems of "limited resources–shortest construction period" and "fixed construction period–resource balance" and obtained more satisfactory results than using the network planning technology and mathematical programming method. It overcame the shortcoming that traditional resource optimization methods could not guarantee the optimality of solutions. HSPSO, an enhanced particle swarm optimization algorithm advanced by Wang and Feng [29], adopted the strategy of multi-subgroup stratification to achieve better convergence speed and optimization accuracy. To solve the comprehensive optimization problem of engineering projects, the mathematical optimization model of duration-cost-quality and the multiobjective optimization model were established. By analyzing fuzzy descriptions of the relationship among three objective functions of duration, cost, and quality, Zhang and Zue [30] established a fuzzy equilibrium optimization model that takes the process duration as the decision variable and proposed the genetic immune particle swarm optimization algorithm derived from the particle swarm algorithm.

According to the relevant research, the relationship between the objectives of engineering projects has experienced the change from a linear relationship to a nonlinear relationship, which makes the established equilibrium optimization model more able to reflect the actual situation. The multiobjective research of engineering projects is carried out from the three objectives of initial duration, cost, and quality. With the continuous improvement of the level of project objective management, the traditional objective management has been unable to meet the requirements of reality, and the safety and environment have been more and more concerned by people. The research method also changes from the original traditional algorithm to the intelligent algorithm.

2. Relationship Analysis of the Equilibrium Optimization Model for Engineering Projects

The investment, time limit, and quality objectives in an engineering project are dialectical relations of unity of opposites and affect each other. The relationship between the three traditional goals is when the quality level decreases, the time limit and investment decrease correspondingly; when the time limit is shortened, the quality level of the project decreases and the investment increases correspondingly; and similarly, when reduced investment is required, the quality of the project is weakened and the time limit of the project increases. The investment and construction period objectives of the engineering project will affect the quality objectives, and in turn, the project quality requirements will affect the construction period and investment objectives. Initially, the construction unit manages the target to achieve a balance between investment, construction period, and quality.

Modern project management involves investment, time limit, quality, safety, and environment. It is always an ideal state pursued by modern project managers to realize the comprehensive and optimal management of various objectives of engineering projects. The comprehensive and optimized management of engineering projects has been gradually transformed from the traditional objectives to the comprehensive objectives.

The safety and environmental objectives of engineering projects belong to social benefit objectives. The occurrence of safety accidents during the implementation of engineering projects not only threatens the personal safety of construction workers but also brings huge economic losses to engineering projects. With the promotion of the concept of green environmental protection, energy conservation, and emission reduction in the construction industry, sustainable development strategy has become an important measure to implement the "scientific concept of development" in the construction industry. Therefore, based on the traditional objectives, the project owners added safety and environmental objectives to carry out comprehensive optimization management. The project safety and environment were reasonably arranged to improve the safety and environmental level of engineering projects, which is of great significance to achieving the comprehensive optimization management of engineering projects.

The objectives of project management are interrelated, balanced, and optimized. The project management process is a whole process that runs the integrated through the project construction. The integrated analysis of investment, time limit, quality, safety, and environmental objectives is carried out from a new perspective and level. The objective relationship of project management is shown in Figure 1.

First, there is an antagonistic relationship between the objectives of the project. If the quality of the project is required to be higher, more investment and time would be spent. In this case, the investment and time limit target will be the cost, and the environmental target will be required to be higher. If the planned time limit is advanced, the investment target needs to be improved and the quality target reduced, and the construction safety will be affected to some extent. If a reduction in investment is required, the quality objectives of the project will decline, the project will be difficult to complete within the time limit required by the contract, and the requirements for safety and environmental objectives will decrease accordingly.

Second, there is a unified relationship between the objectives of the project. If the project investment is increased appropriately, the construction speed can be accelerated to make the project put into use in advance and achieve the purpose of accelerating the project investment recovery. The construction target will promote the realization of the investment target to some extent. If the quality target is required to be improved, although it will increase the investment in the construction period and the time limit and improve the environmental target, the operation cost and maintenance cost can be saved and the total investment of the project can be reduced in the operation stage of the project, and the project can obtain better economic benefits. That is, the quality objective would promote the realization of investment objectives to a certain extent. The formulation of optimized schedule targets can make the project progress have continuity and balance, which can not only shorten the time limit but also obtain better quality and lower investment.

Third, the project owners shall manage the safety and environmental objectives on the premise that the project investment, time limit, and quality meet the requirements of the contract. If the safety and environmental objectives of the project are not effectively managed, the investment, time limit, and quality of the project will inevitably be affected. The investment, time limit, and quality control of the project will in turn impact the management effectiveness of safety and the environment.

In conclusion, the investment, time limit, quality, safety, and environmental objectives in project management are a unity, which influence and restrict each other. The change of any objectives will restrict other objectives. Therefore, it is necessary to balance the five objectives in the comprehensive optimization management of the engineering project.

3. Introduction to the Theory of Multiobjective Optimization and the Method of Synergistic Efficiency Coefficient

3.1. Introduction to Multiobjective Optimization Theory. Multiobjective optimization problem refers to the optimization of each objective by analyzing the performance of each goal under certain constraints. Multiobjective is not a combination of simple goals, but a relationship that is interrelated and restricted to each other. The strengthening of one of the goals will inevitably lead to the weakening of other goals. In the Pareto optimal solution set, the best solution approved by the owner is selected according to the needs of the decision-maker and the actual situation of the engineering project.

The multiobjective optimization problem can be expressed in that the algorithm looks for $x^* = [x_1^*, x_2^*, \ldots, x_n^*]$ so that $f(x^*)$ can meet the constraint conditions and achieve the optimal at the same time. In the algorithm, n is an optimization objective function that may produce contradictions, x is a D dimensional decision vector, and $x_{d\,\min}$ and $x_{d\,\max}$ are the lower and upper limit of each dimension vector. The constraint conditions of the algorithm are $\min Z$.

3.2. Multiobjective Particle Swarm Optimization. There are two kinds of multiobjective optimization methods: traditional algorithm and intelligent algorithm. Due to the complexity of multiobjective comprehensive optimization and the increasing requirement of multiobjective optimization, the traditional algorithm gradually shows various deficiencies, and the intelligent algorithm emerged at the right moment. Many powerful intelligent optimization algorithms have been proposed by researchers from various countries, such as tabu search, genetic algorithm, artificial neural network, and particle swarm optimization [31].

MOPSO is an intelligent evolutionary computing technology that initializes a set of random solutions and then searches for optimal solutions through iteration and dominance. Compared with other intelligent algorithms, MOPSO is a rapidly developed artificial intelligence search method in recent years. The algorithm has extraordinary advantages in fast convergence and simple operation; moreover, it reduces the number of adjusted numbers and simplifies the way to obtain optimization results [32]. As a result, it immediately attracted widespread attention of scholars in the field of evolutionary computing and a huge amount of accomplishments has been achieved within a few years once it was proposed. Therefore, this algorithm is scientific and operable [33]. Therefore, this algorithm is scientific and operable [33]. The algorithm has advantages in comprehensive optimization management, so it has potential application prospects in various fields such as engineering management, biological information, mechanical engineering, communication engineering, and computer engineering.

In this paper, an equilibrium optimization model was established for the five objectives involved in project management, and a multiobjective particle swarm optimization algorithm was introduced into the field of project

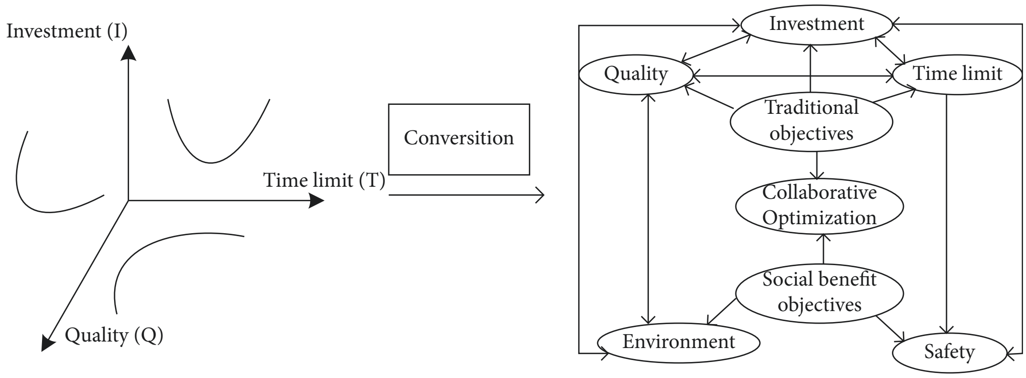

Figure 1: Managed object transformation diagram.

optimization to analyze the applicability of the multiobjective particle swarm optimization algorithm in the comprehensive optimization model of engineering projects. Finally, the reasonable allocation of project investment, time limit, quality, safety, and environmental objectives can be realized.

3.2.1. The Main Operator of Multiobjective Particle Swarm Optimization. Assume that the time parameter is t, the particle is i, and the space parameter is n. The flight speed is $v_i(t)$ and the position is $x_i(t)$. In the iterative process, each particle is dominated by two extrema (individual extremum $p$best and global extremum $g$best), and the particle's velocity and position are updated according to the optimal rules. The MOPSO is influenced by learning factors that are C_1, C_2. The result of repeated experiments reveals that it can show a prominent convergence effect if $C_1 = C_2 = 2.0$.

3.2.2. Establishment of the Fitness Function. The MOPSO algorithm can effectively and accurately handle most global optimization problems, with inherent parallelism and distributed features. To avoid the subjectivity of setting each target weight, a fitness function based on the ideal point method is established. This method has the following advantages: It only needs to find the optimal solution for every single objective function, and it is not necessary to know the weight of each objective function [24]. This thesis establishes the fitness function based on the ideal point method as in

$$F(x) = \sqrt{\left(f_1(x) - f_1^*\right)^2 + \left(f_2(x) - f_2^*\right)^2 + \cdots + \left(f_n(x) - f_n^*\right)^2}. \quad (1)$$

Here, $f_n(x)$ is the nth objective function value and f_n^* is the optimal solution of the nth objective function value.

Then the multiobjective optimization problem will become the problem of solving the smallest $F(x)$. When solving a specific problem, we should first solve the single object and obtain the optimal solution $f_n(x)$ of each objective function f_n^*, then substitute into equation (1) to form the fitness function of the multiobjective particle swarm algorithm. Finally, the multiobjective optimization is carried out.

3.2.3. Problems That Should Be Paid Attention to in Multiobjective Particle Swarm Optimization. The following problems need to be paid attention to when using a multiobjective particle swarm optimization algorithm to carry out the comprehensive optimization management of engineering projects:

(1) *Parameter Setting.* For different optimization problems, appropriate parameters should be selected to achieve the optimal effect [34]. Reasonable parameter setting can make the algorithm obtain the Pareto optimal solution for engineering projects accurately and effectively. Among them, the selection of the particle population size depends on specific problems. The larger the particle number, the larger the algorithm search scope, the easier to find the global optimal solution, and the longer the running time. For the comprehensive optimization of engineering projects, the particle number can be set to 100 or 200.

(2) *Dynamic Adjustment of Speed.* In the absence of dynamic speed regulation, the local optimal is where the algorithm tends to fall resulting in low convergence accuracy and difficulty in convergence. The reasonable setting of the maximum velocity V_{max} is the key to finding the optimal region. If the setting V_{max} is too large, the particles are likely to fly away from the optimal region, while if V_{max} is too small, the particles may not be able to fully explore the region outside the local optimal region. The dynamic adjustment of the velocity requires experimentation. If the particle exceeds the boundary after iteration, a speed is set for the particle to translate to the boundary. Slow down the speed of particles to make them search in opposite directions.

(3) *The Pruning of Nondominated Solution.* In the iterative process of the algorithm, the number of nondominant solutions will often exceed the maximum storage of the external set. When the number of generated nondominant solutions is larger than the maximum storage capacity, the redundant solutions need to be deleted. The external set needs to be enveloped and clipped to get rid of duplicate solutions. Update the external storage space to facilitate the smooth operation of the algorithm.

3.3. Synergy Efficiency Coefficient Method. To make the owner make the best decision from the Pareto optimal solution, the paper proposes to use the power factor method to calculate the degree of satisfaction of each target and to determine the score of each target. Because the project management comprehensive optimization objectives have a unity of opposites and only evaluate a single target, it is impossible to select the best solution for the construction unit from the Pareto optimal solution. To realize the Pareto optimal decision among project investment, time and quality, the multiobjective function needs to be weighted according to the importance of each objective.

Assume the contract time limit of the project as T_nT_n that is set as the upper limit of the construction period. The sum of the minimum time limit of each process on the critical route in the project is taken as the lower limit T_c of the construction period. The efficiency coefficient of the time limit target is $U_T = T_n - T_k/T_n - T_c$, where T_k is the actual time limit of the construction period.

The highest quality level of the project is 1, and the upper limit of the quality target is set to $Q_n = 1$. The average value of the lowest quality level of each working procedure of the project is taken as the lower limit of the quality target. Then the efficiency coefficient of the quality target is $U_Q = Q_n - Q_k/Q_n - Q_c$, where Q_k is the actual value of the quality target.

The investment target of an engineering project is a series of parameter values obtained by continuous optimization. Take the maximum value as the upper limit I_n of the investment target and the minimum value as the lower limit I_c of the investment target. The efficiency coefficient of the project investment target is $U_I = I_n - I_k/I_n - I_c$, where I_k is the actual value of the investment target.

The multiobjective programming model is established according to the formula of investment, time limit, and quality efficiency coefficient of the project, as in

$$\begin{cases} \max Z = \omega_I * U_I + \omega_T * U_T + \omega_Q * U_Q, \\ U_I = \dfrac{I_n - I_k}{I_n - I_c}, \\ U_T = \dfrac{T_n - T_k}{T_n - T_c}, \\ U_Q = \dfrac{Q_n - Q_k}{Q_n - Q_c}. \end{cases} \tag{2}$$

Here, Z is the multiobjective synergy degree of engineering projects, and $\omega_I, \omega_T, \omega_Q$ are the preference weight of project investment, time limit, and quality objectives, respectively.

4. Construction of the Multiobjective Optimization Model for Engineering Project Management

The realization of investment, duration, quality, safety, and environmental objectives plays a leading role in the progress of the project. With the mutual influence between goals, there is a dialectical relationship between opposites [24]. Only in the pursuit of the optimal value of a single target, while ignoring the relationship between the objectives, the construction unit is more difficult to comprehensively optimize the management of multiobjective projects.

The owner is driven by comprehensive optimization management to carry out project construction. Its main purpose is to optimize the optimization of the objectives of the project, meet the requirements of quality, safety, and environmental level in the contract, shorten the construction period reasonably, minimize the investment of the project, and optimize the quality.

Condition 1. Functional relationship between the time limit and investment objective.

The construction investment mainly includes costs of construction and installation, equipment-and-tool buying, other construction, storage, value-added tax, fundraising, and working capital. According to the relationship between investment and time limit, project investment falls into two categories: One is a direct category, and the other is an indirect category. For the direct investment, shortening the construction period requires increasing the corresponding labor force, turnover materials, and construction machinery usage. Therefore, the shorter the project time, the greater the direct investment. However, for indirect investment, short construction period will reduce the salary expenditure, travel expense, and risk of management personnel. Therefore, short construction time will lead to the reduction of indirect investment.

When calculating the direct investment, the thesis proposes the marginal cost growth factor concerning the marginal utility theory. When the conditions such as process, construction environment, and labor force are used for construction, the value of the marginal growth factor is low; otherwise, the value is high. Direct investment is calculated based on the minimum investment, duration, and marginal growth factor of each process; unit indirect investment is calculated at the contracted price. To simplify the calculation, it is postulated that construction investment is equal to the sum of direct and indirect investment. Then, the function between the construction investment and time limit can be expressed as in

$$\begin{aligned} &I = I^d + I^p = \sum_{(i,j\in R)} \left[b_{ij} + r_{ij}\left(t_n - t_{ij}\right)^2 \right] + t_{ij} \times i^p, \\ &st.D_c \le t_{ij} \le D_l, \end{aligned} \tag{3}$$

where I is the construction investment, I^d is the direct investment of the engineering project, I^p is an indirect investment, I^p is the minimum investment of the process (i, j), r_{ij} is the marginal increasing factor of the process (i, j), t_n is the normal time limit of the process (i, j), t_{ij} is the actual time limit of the process (i, j), D_c is the shortest time limit of the process, D_l is the longest time limit of the process, i^p is the indirect investment of the company during the contract period, and R is all the procedures of an engineering project.

Condition 2. Functional relationship between the time limit and quality.

In the traditional time limit-quality curve model, the time limit of work has a linear relationship with the quality. However, in the actual project, the quality level will not increase indefinitely with the increase of the time limit. There is an upper limit to the project quality level; when the project quality reaches this upper limit, the project quality will tend to a fixed value with the extension of the time limit. That is to say, there is a nonlinear curve between the time limit of each process and the quality level. When the time limit is relatively loose, the compression time limit has little impact on the project quality, while for the project with a tight project schedule, the engineering quality may be affected by the phenomenon of rush work.

The total quality of the engineering projects is determined by the quality level of each process. Different processes have different influences on the total quality of the project. When certain processes occupy a key position in an engineering project, the reduction of their quality level will have a greater impact on the project. Therefore, greater weight should be set for such processes. All process quality levels can be weighted to obtain the whole project quality level.

To obtain the quantitative model of quality level, quantitative treatment was adopted for engineering quality in this paper: The engineering quality level was quantified as a continuous value from 0 to 1, and the closer to 1, the higher the work quality level is. The functional relationship between the construction period and quality level proposed by Jiang et al. [35] was adopted as in

$$\max Q = \sum_{(i,j\in R)} w_{ij} * \ln\left(\varphi_{\mathrm{ij}} * t_{ij} + \phi_{ij}\right),$$
$$st.\begin{cases} w_{ij} > 0, \sum\limits_{ij\in A} w_{ij} = 1, \\ 0 \le Q_{ij} \le 1, \end{cases} \tag{4}$$

where the parameter $\varphi_{ij} = e - e^{q^{ij}}/D_{m_{ij}} - D_{c_{ij}}$, $\phi_{ij} = e^{q_{ij}} * D_{m_{ij}} - e * D_{c_{ij}}/D_{m_{ij}} - D_{c_{ij}}q^{ij}$, is the minimum quality value required by the process (i, j), e is a natural constant, D_m means that the quality level of the process is 1 under the continuous-time, $D_{c_{ij}}$ is the shortest time limit of the process, t_{ij} is the actual time limit of the process, Q is the actual quality level of the project, and w_{ij} is the proportion of the quality of process (i, j) in the whole project quality.

Condition 3. Functional relationship between the security and investment.

In the management of engineering projects, safety accidents will not only increase the investment but also lead to the extension of the project time limit, and even have a bad impact on the quality of the project and the environment in a serious case. The safety level of engineering projects is directly related to the size of the engineering investment. Reasonable safety investment can largely avoid or reduce the occurrence of safety accidents and the losses caused by safety accidents. The influence of safety on a time limit, quality, and environment can be recovered through investment in the later period of construction.

The influencing factors of building safety can be divided into human insecurity, material insecurity, and organizational insecurity. For the project owners, the unsafe factors of builders can be divided into the unsafe factors directly related to construction personnel, as well as the unsafe factors that are indirectly related to management personnel. The unsafe factors of objects can be divided into those directly related to the construction of engineering entities and those indirectly related to the construction of engineering entities. Organization and management refer to the necessary preparation, organization, and management for the safe implementation of the project, which is indirectly related to the construction of the project.

Therefore, safety factors can be divided into two categories: One is directly related to the project, and the other is indirectly related to the project. Among them, the safety factors directly related to the project are related to the direct investment in the project, and the safety factors indirectly related to the project are related to the indirect investment in the project. Considering the proportion of safety measures in project investment, the functional relationship between security and investment is obtained as in

$$I_s = s^d \cdot I^d + s^p \cdot I^p, \tag{5}$$

where I_s is the engineering safety investment; s^d and s^p are the proportion of security investment in direct investment and indirect investment of engineering projects, respectively, which are obtained through national security big data; and I^d and I^p are the direct and indirect investments.

Condition 4. The functional relationship between the environment and investment.

In the process of project implementation, improper operation or unavoidable activities will have adverse effects on the environment. Environmental goals have an impact not only on engineering quality but also on the safety of construction personnel. Therefore, more attention should be paid to environmental problems to reduce the negative effects of environmental pollution. In the process of engineering construction, it is impossible to eliminate the destruction of the environment; therefore, strengthening the prevention of pollution is the best way to solve environmental problems.

Through analysis, the influence of the environment on engineering can be translated into an increase in the project investment. Among them, the environmental investment includes the prevention investment and governance investment.

Thus, the environmental investment is divided into two parts: environmental prevention investment and environmental governance investment. The functional relationship between the environment and investment is as in

$$I_e = I_e^p + I_e^g = E^c \times I, \tag{6}$$

where I_e is the engineering environment investment, I_e^p is the investment in environmental prevention, I_e^g is the environmental governance investment, and E^c is the coefficient (obtained through the analysis of historical data).

The multiobjective optimization model is a combination of the above four functional relationships. The ideal point method is used to establish the fitness function. The smaller the value of the fitness function, the higher the degree of comprehensive optimization. The constraints in the model indicate that the project should meet the contract duration, contract quality, and contract cost requirements, and the duration of each process should be kept within the shortest duration and the longest duration. The quality of the optimized project should be higher than or equal to the quality requirements in the contract. Pursue the comprehensive optimization objectives of engineering construction period as short as possible, engineering quality as high as possible, and engineering investment as low as possible. The multiobjective optimization model of the project is represented as in

$$\min F(x) = \sqrt{\left(\min I_t - I_t^*\right)^2 + \left(\min T - T^*\right)^2 + \left(\min Q - Q^*\right)^2}, \quad (7)$$

$$\begin{cases} \min I_t = I + I_s + I_e, \\ \min T = \sum\limits_{(i,j)\in L_m} t_{ij}, \\ \max Q = \sum\limits_{(i,j)\in R} \omega_{ij} \times \ln\left(\varphi_{ij} \times t_{ij} + \phi_{ij}\right), \end{cases}$$
$$st. \begin{cases} w_{ij} > 0, \\ \sum\limits_{(i,j)\in R} w_{ij} = 1, \\ 0 < Q_{ij} \le 1, \\ D_c \le t_{ij} \le D_l, \end{cases} \quad (8)$$

where I_t is the total investment of the project, I is the construction investment, and L_m is the key work of the project.

5. Application Analysis of Multiobjective Comprehensive Optimization Algorithm

5.1. Introduction to the Example. Basic information about the project: According to the construction plan of a wind power project, the wind power project is located in Ruoergai County, Aba prefecture, Sichuan province. It is located on the northeastern edge of the Qinghai–Tibet Plateau, in the northern part of Sichuan Province. Ruoergai County has a humid monsoon climate in the plateau cold temperate zone, with an average altitude of 3500 m. To speed up the development of Ruoergai County and drive the economy, it was decided to build a wind power project in the county. This construction scale is to install 33 1500 kW wind power generating units. The contract period of the wind power project is 45 weeks long construction period. The total investment is 500 million yuan, among which the indirect investment I^P is 20,000 yuan/day, which is a large amount of investment. The case project consists of 13 processes, and the sequence number of the key route is 1—5—6—10—12.

Wind power projects are new energy industry projects encouraged by China, which require high quality. It will improve Ruoergai County's energy and power structure and meet the needs of Ruoergai County's sustainable development and economic development by putting wind power projects into use in advance. First, Ruoergai County is a national key scenic spot, which has abundant natural resources and higher requirements for an ecological environment. The local ecological environment is likely to be under threat during the construction of wind power projects, which leads to the destruction of vegetation, change of topography, and soil erosion. In the construction of wind power projects in Ruoergai County, environmental protection factors must be met first, and the construction should be carried out based on not destroying the original ecological conditions. Second, the wind power project has a long construction cycle, large investment amount, high-quality requirements, and high social benefits. Finally, there is a lot of equipment in the wind power project, such as fan blades, wind turbines, rotating mechanisms, and rotating mechanisms. The installation, operation, and containment of this project require high-altitude work, which adds a safety risk factor for builders. In conclusion, comprehensive optimization management should be carried out on the project investment, construction period, quality, safety, and environmental goals.

5.2. Data Analysis in Example Algorithm. The proportion of $s^d s^p$ and in direct and indirect investment in engineering projects obtained through Chinese security big data are 56% and 58%, respectively. Fifteen experts were invited to score the lowest quality level q_{ij} of each process in the engineering project, and the quality level interval of each process was set as [0.9, 1], and the weight value W_{ij} of each process quality in the engineering project was determined. The minimum investment b_{ij} and marginal increasing factor r_{ij} of each process are obtained according to the analysis of the tender offer data of the project. After consulting the construction quota of the construction industry, the shortest time limit D_c, the longest time limit D_l, the normal time limit t_n of each prose, and the time limit D_m with the quality level of 1 are obtained. Specific data of engineering project-related parameters are shown in Table 1.

Parameters φ_{ij} and ϕ_{ij} are calculated according to the relationship between the time limit and quality in the aforementioned Condition 2 and the data in Table 1, as shown in Table 2.

5.3. The Model Solution in the Example Algorithm. According to the previous data conditions, the multiobjective optimization model of the calculation example is constructed by combining formula (10).

The comprehensive optimization problem of the example can be expressed as a multiobjective decision vector $t = [t_{1,3}, t_{1,2}, t_{3,4}, , , t_{11,12}]$ for a given engineering project, which meets the following constraints:

Table 1: List of related parameters of the project.

No.	Process name	D_c (week)	t_n (week)	D_l (week)	D_m (week)	b_{ij} (ten thousand yuan)	r_{ij}	q_{ij}	w_{ij}
1	Construction preparation	6	8	10	11	2300	0.21	0.9221	0.0863
2	Field leveling of each wind power equipment hoisting platform	7	9	12	12	2500	0.18	0.9324	0.0772
3	Field leveling of management area and booster substation	5	7	8	8	1700	0.31	0.9351	0.0768
4	Fan foundation reinforced concrete project	4	7	8	9	2900	0.20	0.8143	0.0639
5	Fan foundation installation project	9	10	11	11	4400	0.42	0.9121	0.0901
6	Box type transformer foundation	7	9	10	10	5500	0.43	0.8754	0.0726
7	Production building, comprehensive distribution room	5	6	7	8	4500	0.21	0.8745	0.0856
8	110 kV booster substation equipment foundation project	2	5	7	7	3300	0.25	0.8034	0.0512
9	Construction of booster station	4	7	8	9	2500	0.24	0.8153	0.0701
10	Fan installation	8	11	13	13	4900	0.31	0.9168	0.0737
11	Exterior components	9	13	15	15	5600	0.21	0.9134	0.0975
12	External traffic highways and traffic highways in administrative areas	7	9	10	11	4300	0.27	0.9056	0.0719
13	Closure and acceptance hand over	6	7	10	11	4400	0.47	0.9103	0.0831

Table 2: Values of parameters φ_{ij} and ϕ_{ij}.

φ_{ij}	0.04	0.04	0.06	0.09	0.11	0.11	0.11	0.10	0.09	0.04	0.04	0.06	0.05
ϕ_{ij}	2.27	2.29	2.26	1.89	1.46	1.66	1.86	2.04	1.89	2.15	2.15	2.04	2.21

$$\begin{aligned} &6 \le t_{1,3} \le 10, 7 \le t_{1,2} \le 12, 5 \le t_{3,4} \le 8,\\ &4 \le t_{4,9} \le 8, 9 \le t_{3,5} \le 11, 7 \le t_{5,8} \le 10,\\ &5 \le t_{2,6} \le 7, 2 \le t_{6,7} \le 7, 4 \le t_{7,11} \le 8,\\ &8 \le t_{8,10} \le 13, 9 \le t_{9,10} \le 15, 7 \le t_{10,12} \le 10,\\ &6 \le t_{11,12} \le 10. \end{aligned} \quad (9)$$

The six contradictory optimization objectives of the example are shown as in

$$\min F(x) = \sqrt{(\min I_t - 49461.96)^2 + (\min T - 37)^2 + (\min Q - 0.9896)^2}. \quad (10)$$

Seek $t^* = [t^*_{1,3}, t^*_{1,2}, t^*_{3,4}, , , t^*_{11,12}]$ to make the optimization function f reach the optimal condition while satisfying the constraint conditions.

5.4. The Solving Process of the Example. Programming of the MOPSO algorithm on computer with Matlab2017a [36].

Step 1. Initialization Settings. The parameters required for the operating environment of the MOPSO algorithm are defined, including the dimensions of the problem: 13 dimensions, iterations 200, randomly generated particles 100, acceleration constant $C_1 = C_2 = 2$, and inertia weight $\omega = 0.6$ parameters. The particle initializes and randomly generates a matrix with 100 rows and 13 columns.

Step 2. Fitness Value Calculation. This calculation process begins with initialized particle position and velocity, and then the fitness value of the initial population was obtained by substituting the particle position into the fitness function. The obtained initial population diagram is presented in Figure 2.

In this stage, 100 sets of initial solutions are formed, that is, 100 sets of basic data are formed, which provides the data basis for the next preliminary screening of noninferior solutions.

Step 3. First-Time Screening of Noninferior Solution. In the project optimization, the initial population is first selected according to the dominant relationship and constraint conditions of the target. Meanwhile, by adopting the method of quicksort, the nondominant set can be constructed. The dominant relation demonstrates the situation when initial particles are supposed to be stored in set R. Let x_1, x_2 denote two random variables in R. Suppose particle x_1 govern x_2, and only if $\forall i$, $f_i(x_1) \le f_i(x_2)$ exists and there is at least one $i \in \{1, 2, 3\}$ making $f_i(x_1) < f_i(x_2)$, it is denoted as $x_1 < x_2$.

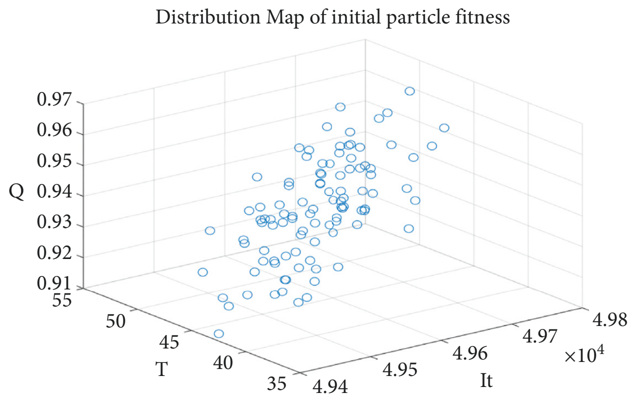

FIGURE 2: Distribution map of initial particle fitness.

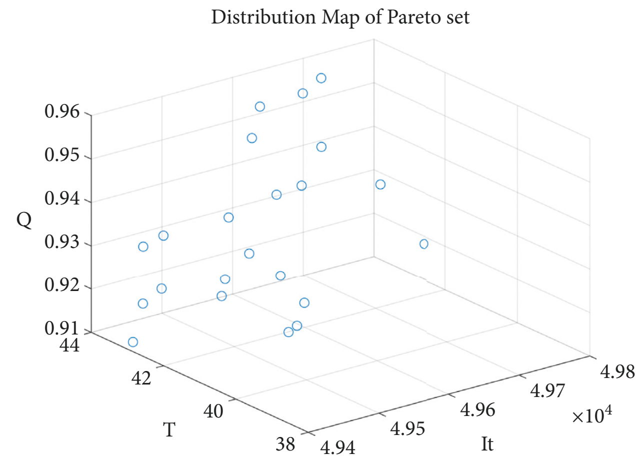

FIGURE 3: Distribution map of the Pareto set.

The particle distribution after preliminary screening is shown in Figure 3.

The preliminary screening of noninferior solutions shows that if a particle is not under the control of other particles, it will be put into the noninferior solution set. As a result, the best particles found in this iteration are stored in the set.

Step 4. Loop Iteration. Let the number of iterations set to 200. A particle is randomly selected from the pair as the best particle of the population.

Step 5. Swarm Regeneration. By using the updating formula, the velocity and position of the particles at the previous moment are substituted into the updated formula to obtain the velocity and position of the particles at the next moment to achieve the purpose of updating the swarm.

When updating the above running particle position and velocity, the particle position may exceed the defined boundary range so that the optimal value obtained is beyond the defined domain. Therefore, it is necessary to conduct boundary processing on the particles beyond the boundary so that the particles beyond the boundary return to the search range to continue the search. The boundary processing method is as follows:

$$X_{ij} = \begin{cases} X_{\min,j} & X_{ij} < X_{\min,j}, \\ X_{\max,j} & X_{ij} < X_{\max,j}, \end{cases} \tag{11}$$

where $[X_{\min,j}, X_{\max,j}]$ is the value range of particles defined in the j dimension.

If the particle exceeds the boundary after iteration, a speed is set for the particle to translate to the boundary. Slow down the speed of particles to make them search in opposite directions, as shown in Figure 4.

Step 6. The fitness values of 100 particles after updating were calculated. The swarm distribution map after particle updating is shown in Figure 5.

Step 7. Update particle position. Dynamically update the particle's best position based on the dominance relationship.

Step 8. Update the Pareto set. It consists of two steps. First, a new Pareto set is obtained, which is generated by combining the Pareto set with the updated historical best particle set. Second, according to the screening process under the domination relation of Pareto sets, a new Pareto set is selected. The schematic diagram is shown in Figure 6.

Step 9. Remove duplicate particles. To ensure that the size of the Pareto set does not exceed the carrying capacity, duplicate particles in the new Pareto set need to be removed.

According to the above calculation steps and related data, the multiobjective optimization model of the project is solved, and the three-dimensional scattergram of investment, time limit, quality, and the convergence curve of the function are obtained, as shown in Figures 7 and 8 and Table 3.

To verify the effectiveness of the multiobjective particle swarm optimization algorithm, the article first uses Matlab2017a software to run 1000 optimization paths and stores Pareto optimal solutions for 1000 paths. Then, 1000 sets of optimal solutions are imported into the SPSS23 software, and the optimal value, the worst value, the average value, and the standard deviation of each target in the optimization results in the 1000 paths are calculated. The calculation results are shown in Table 4.

5.5. The Choice of the Best Scheme. To make the owner make the best decision from the Pareto optimal solution, the paper proposes to use the power coefficient method to calculate the degree to which each target reaches the satisfaction of the construction unit and to determine the score of the total investment, construction period, and quality target, and then the weighted average is combined to evaluate the Pareto optimal solution.

According to the known conditions of the example, the lower limit of the project time limit is 37 weeks, and the upper limit of the project time limit is the contract, which is 45 weeks. The upper-quality limit is the highest quality level

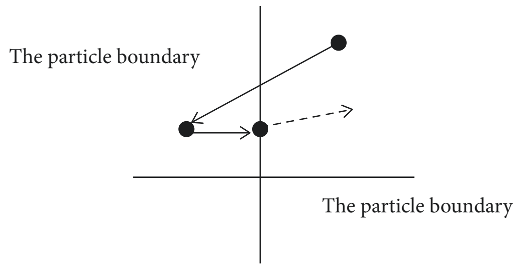

Figure 4: Schematic diagram of the individual particle velocity and position beyond the boundary.

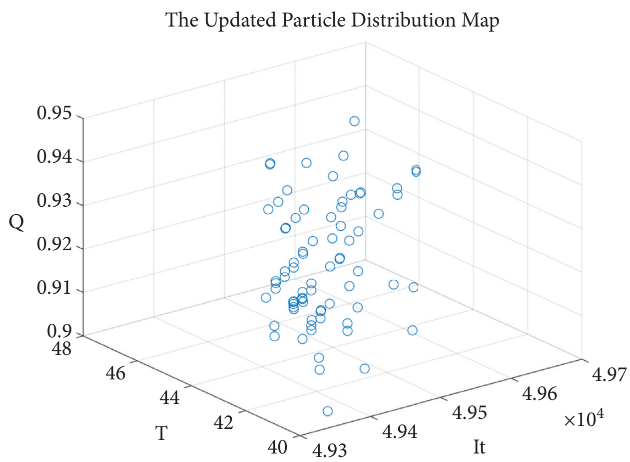

Figure 5: The updated particle distribution map.

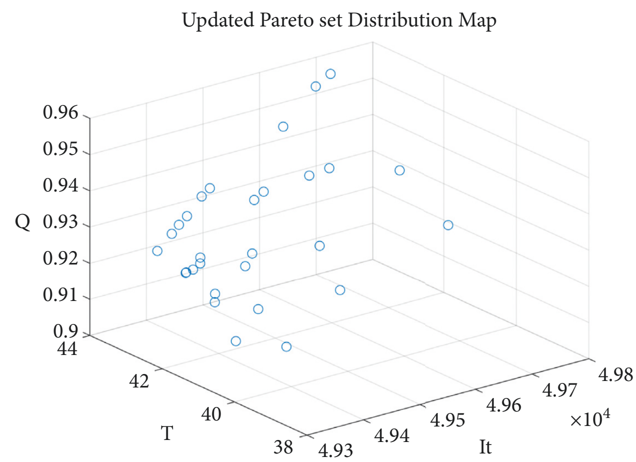

Figure 6: Updated Pareto set distribution map.

1. The lower limit of quality is the average value of the lowest quality level of each process, that is, the lower limit of engineering quality is

$$Q_c = \frac{1}{13} * (0.9921 + 0.9324 + 0.9351 + 0.8143 + 0.9121 + 0.8754 + 0.8754 \\ +0.8034 + 0.8153 + 0.9168 + 0.9134 + 0.9056 + 0.9103) = 0.892. \quad (12)$$

According to the requirements of the construction unit on the total investment, time, and quality objectives of the project, and following the principle of balance optimization, set the weight of preference of each target as $\omega_{I_t}, \omega_T, \omega_Q = (0.35, 0.35, 0.3)$.

In the example, 23 sets of Pareto optimal solutions were obtained, and the efficiency coefficient method was used to decide on the scheme. Since the investment and construction period are cost-oriented attribute indexes, and the quality level index is cost-oriented, the positive ideal solution is $A^+ = (49460.52, 37, 1)$, and the negative ideal solution is $A^- = (49566.82, 45, 0.892)$. The efficiency coefficient of Pareto's optimal solution is shown in Table 5.

Through the comparative analysis of 11 schemes, it can be seen that the total investment utility coefficient of 1.25 and the time limit utility factor of 0.625 of the project's optimal plan 5 are both larger than the utility coefficient of the other plans. The quality efficiency coefficient is 0.35,

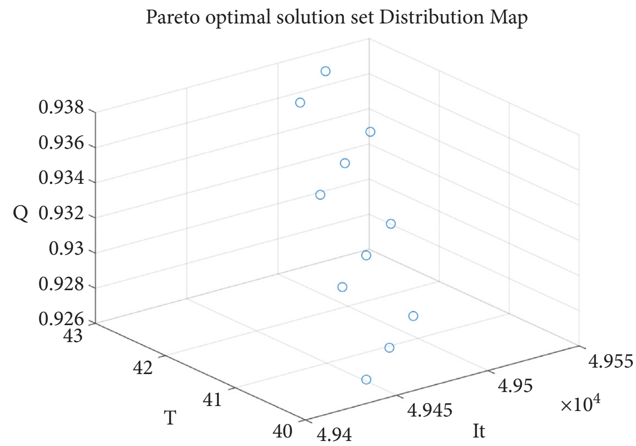

Figure 7: Pareto optimal solution set distribution map.

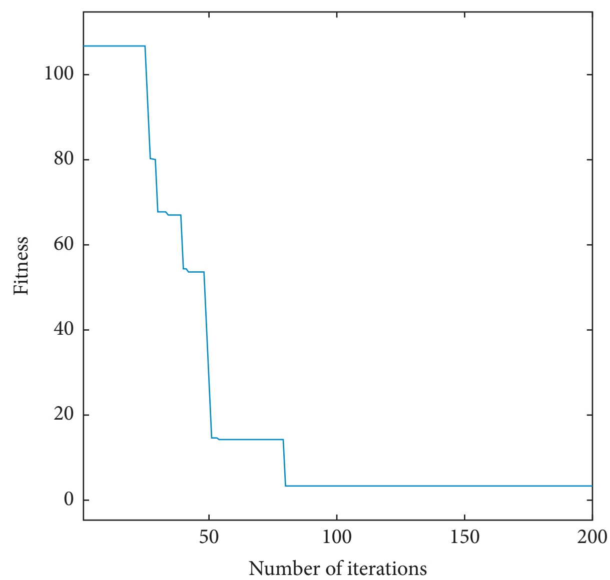

Figure 8: Optimal path iteration curve.

Table 3: Pareto optimal solution.

Serial number	Total investment I_t	Construction investment I	Safety investment I_s	Environmental investment I_e	Time limit T	Quality Q
1	49459.08	48973.98	274.51	210.58	40	0.930
2	49446.00	48961.03	274.44	210.53	40	0.928
3	49484.86	48999.50	274.66	210.69	42	0.932
4	49498.36	49012.87	274.74	210.75	42	0.934
5	49433.34	48948.50	274.36	210.47	40	0.927
6	49471.66	48986.43	274.59	210.64	41	0.931
7	49485.16	48999.80	274.66	210.69	41	0.932
8	49512.29	49026.66	274.82	210.81	42	0.935
9	49526.12	49040.35	274.90	210.87	43	0.936
10	49458.58	48973.48	274.51	210.58	41	0.930
11	49512.19	49026.56	274.82	210.81	43	0.935

Table 4: Multiobjective particle swarm algorithm 1000 path result statistics.

Algorithm	Number of runs	Optimize the target	Best value	Worst value	Average value	Standard deviation
Multiobjective particle swarm optimization	1000 times	Investment	49326.20	49595.03	49465.85	46.34
		Duration	37	44	39	1.56
		Quality	0.942	0.902	0.927	0.007

Table 5: Pareto solution's efficiency coefficient.

Program	U_I	U_T	U_Q	Z
1	1.01	0.625	0.38	0.68
2	1.13	0.625	0.37	0.72
3	0.77	0.375	0.40	0.52
4	0.64	0.375	0.41	0.47
5	1.25	0.625	0.35	0.76
6	0.89	0.50	0.39	0.60
7	0.76	0.50	0.40	0.56
8	0.51	0.375	0.42	0.43
9	0.38	0.25	0.44	0.35
10	1.01	0.50	0.38	0.64
11	0.51	0.25	0.42	0.39

while the quality efficiency coefficient of other schemes is all greater than that of scheme 5. However, the synergy degree of the three targets in scheme 5 is 0.76. Therefore, this scheme has the highest degree of coordination and is the best scheme.

6. Conclusion

Multiobjective particle swarm optimization (MOPSO) initializes a group of random particles and then finds the optimal solution according to the domination relation and iteration. In each iteration, the particle updates itself by tracking the individual extremum and global extremum. In the process of updating the velocity and position of the particle swarm, the particle swarm constantly seeks individual extremum states around the global optimal particle. The particle swarm also gradually converges to the optimal location. This process verifies the feasibility of the algorithm:

(1) Optimization is run 1000 trails. From the 1000 trails, the best and worst results are given in the paper. The optimum value is (49326.20, 37, 0.942), which is similar to the final selected option 8. The feasibility of the algorithm is verified by the process.

(2) In the three-dimensional solution space, the Pareto solutions sought by MOPSO to solve the equilibrium optimization model are relatively scattered; the quality level is generally high, and the optimization values of investment and time limit fluctuate relatively greatly. This also reflects that the algorithm can reflect the mutual restriction between the total investment, time limit, and quality objectives of the project.

(3) Project decision-makers can choose the best plan according to the specific requirements of the total investment, time limit, and quality objectives and allocate resources for the reasonable implementation of each process. The final Pareto optimal solution can be used as an alternative to the project. Project decision-makers can choose the best plan according to the specific requirements of the project for each goal, fully and effectively allocate project resources, achieve multifactor coordinated development, and improve management efficiency.

A multiobjective equilibrium optimization model for an engineering project is proposed from the perspective of the construction unit in this paper, and the objective comprehensive optimization management of a wind power project in Sichuan province is taken as an example to calculate, which has certain theoretical and practical significance. However, there are still some problems in this paper that need further study. (1) At present, there is no definite optimal quantification method for the difficult quantified objectives such as quality and safety of engineering projects, and how to construct a more suitable objective optimization model of quality and safety has not been solved. (2) The relationship between the time limit and environment, quality, and safety objectives is not considered in this paper. Meanwhile, the problem is simplified when constructing the equilibrium optimization model, which is a little insufficient in solving practical engineering projects. Enrich model content in future research to make the model close to the actual engineering situation [37].

Data Availability

The data underlying the results presented in the study are included within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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