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Constructing a Multi-Objective Optimization Model for Engineering Projects Based on NSGA-II Algorithm under the Background of Green Construction

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ABSTRACT

In the context of Sustainability Development (SD), Green Construction (GC) has become a key direction for optimizing engineering project objectives. In order to improve the management ability of project engineering in GC, an improved NSGA - II algorithm was used in this study to establish a multi-optimization model for engineering projects. In this process, the hill climbing is introduced to improve the search ability of NSGA - II algorithm. Finally, a Multi-Objective Optimization (MOP) model with strong convergence and distribution was obtained. In subsequent validation experiments, the total construction period of the engineering project MOP model based on the improved NSGA - II algorithm was between 190 and 234days. The total cost ranges from 171,473 to 20,461,800 yuan. Its total mass ranges from 90.41% to 92.19%. Its total safety is between 91.30% and 99.32%. The total environment is between 144.54 and 193.58. Its total resources range from 86.21% to 99.91%. The cost of improving the NSGA-II algorithm is 500300 yuan lower than that of the NSGA-II algorithm, with a resource target increase of 0.4% and an environmental target increase of 4.33%. The iteration curves of the improved NSGA - II algorithm in terms of duration, cost, and environmental objective function are lower than those of the NSGA - II algorithm. Overall, the improved NSGA - II algorithm has better MOP performance, can obtain better Pareto solutions, and has better performance.

1. Introduction

In modern society that advocates Sustainable Development (SD), Green Construction (GC) has become the main goal of building construction. When achieving GC, it is necessary to meet three important construction goals: schedule, cost, and quality goals [1-3]. Based on these three objectives, a comprehensive optimization model was established, namely Multi Objective Optimization (MOP) model, which can integrate safety objectives, environmental objectives, and resource objectives. Therefore, it is necessary to establish a MOP model for engineering projects in a green background. Traditional optimization methods such as weighting and intelligent

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optimization algorithms such as multi-objective GA are often used in the establishment of MOP models. Among them, Genetic algorithm (GA) has higher global optimization capability, and this algorithm can solve MOP [4]. GA can find the global optimal solution by selecting coding mode, fitness function, selection strategy, crossover mode, and mutation mode. In the process of continuous improvement of GA, researchers propose a non-dominated sorting GA (NSGA) for solving multi-objective tasks. This method can achieve simultaneous optimization of multiple objectives and ultimately obtain the best multi-objective optimization strategy. As a type of GA, NSGA introduces non-dominated layering. By sorting the non-dominated hierarchy, it can more effectively inherit the obtained superior genetic individuals to the next generation. As an improved version of the NSGA algorithm, the elite strategy has been introduced in NSGA-II. In this method, by introducing an elite strategy to sort non-dominated layers in NSGA, a more efficient sorting effect can be achieved [5]. And the congestion distance was introduced into NSGA-II to maintain its diversity. NSGA-II can use this concept to control the search range of Pareto optimal solution set, thereby effectively improving calculation results accuracy. Usually, in the actual implementation process of green construction projects, the economic benefits of the project are opposed and unified with environmental protection and resource conservation. Therefore, how to find a balance point among the multiple objectives of green construction project management and construct a multi-objective management system for green construction projects is an important research direction in the field of modern engineering project management. This article considers the combination of green construction technology and traditional project management, and proposes a multi-objective management system for green construction projects. This avoids the shortcomings of excessively single objective control and neglecting the influence of other objectives, which leads to biased decision-making, and enriches the theoretical content of multi-objective management in engineering projects. At the same time, an improved algorithm was proposed in the experiment to optimize the multi-objective model of green construction projects, providing new ideas for improving the efficiency of multi-objective optimization of projects. To establish the MOP model for engineering projects in GC context, NSGA-II was used as this study’s basic method. And to improve method search ability, hill climbing is introduced to optimize it. Based on this, a systematic study is conducted on the multi-objective optimization problem of green construction project management. The research results can provide project management suggestions and theoretical guidance for project decision-makers, managers, and various stakeholders, achieving the maximization of overall benefits of engineering projects.

2. Related Works

GC is an important influencing factor that affects the achievement of SD. Compared to traditional construction methods, GC considers building materials and other influencing factors on the environment. And the management methods during construction have also changed, which effectively improve the application effect of GC in engineering projects [6]. To achieve the goals of GC, in engineering projects management, it is necessary to analyze the economic, safety, quality, environmental and other influencing factors of the building. To achieve GC, priority is given to purchasing green building materials with lower carbon emissions such as steel among relevant government departments abroad. To improve the safety of building materials, the installation methods and proportions of other green building materials were also considered when purchasing [7]. The management optimization of project engineering in GC context can affect application effect of GC concept. Researchers have developed a model that can improve optimization ability of project engineering management in GC context by summarizing and analyzing various factors that affect GC [8]. When achieving GC, it is necessary to meet three important construction goals: schedule goals, cost goals, and quality goals. Based on these three objectives, a comprehensive optimization model was established that integrates safety objectives, environmental objectives, and resource objectives.

Through the above research, it is necessary to establish a MOP model for engineering projects to improve their management and optimization capabilities in a green context. This has important practical significance for building an engineering project management system under a green background. Traditional optimization methods such as weighting and intelligent optimization algorithms such as multi-objective GA are often used in the establishment of MOP models. However, traditional optimization methods cannot obtain accurate calculation results, and the calculation is relatively complex. The introduction of intelligent optimization methods has improved the computational accuracy and efficiency of traditional optimization methods [9-10]. Kashani et al. analyzed the external and internal factors that affect the stability performance of walls. They adopted multiple MOPs for scheme design and compared their methods. Different MOPs have good wall reinforcement effects and high operational efficiency [11]. When considering factors such as power supply loss rate in the wind power prediction, decision algorithms based on intelligent MOP methods can establish effective cost optimization models. This decision-making model can accurately predict wind power while solving the MOP problem to improve the accuracy and economy of decision-making [12]. NSGA - II is a commonly used optimization method in intelligent MOP methods, which has high robustness. In transportation equipment structural optimization, researchers use the NSGA-II algorithm to adjust parameters. They established a mapping relationship for optimizing injection pressure, rate, and other related parameters of instrument. After parameter adjustment, the efficiency and safety performance of device were ultimately achieved [13]. The NSGA-II algorithm has also been effectively applied in field of architecture. Dang et al. utilized the improved NSGA-II algorithm to optimize energy consumption in buildings to reduce their carbon emissions. And they optimized the environmental factors and costs that affect building construction, thereby establishing a comprehensive and efficient building plan [14]. When constructing the building method, Xue et al. used NSGA - II to search for building targets. In this process, this method comprehensively considers factors such as carbon emissions that affect the environment, to reduce the impact of the construction process on the environment. This method can promote achievement of environmental goals under SD concept [15]. MOP can promote the improvement of building performance, and the NSGA-II algorithm proposed in the study can effectively establish a MOP scheme in building construction. In simulation results, this method can effectively consider different optimization indicators impact on building construction, while improving the quality of the optimization method [16].

Through the above research, the MOP of engineering projects under a green background is one of the ways to promote SD. To improve the application effect of MOP in engineering projects, intelligent optimization methods can be used to establish models. Given the excellent capability of NSGA-II in architecture, this method was chosen for MOP model establishment in this study. And improvements were made to the method in the experiment to improve the search ability of the model, thereby improving the application performance of the method.

3. Research on Engineering Project MOP Model Based on NSGA - Ⅱ Algorithm

3.1 Research on the MOP Model and NSGA - II Algorithm for Engineering Projects under the Background of GC

SD has put forward new requirements for building construction. GC is an important way to achieve resource conservation and environmental protection [17]. The main impact goals of project management in GC include schedule, cost, quality, safety, environmental, and resource goals. In GC, the overall optimization level is determined by the schedule objectives, cost objectives, and quality objectives of project. Therefore, in this study, we focused on these three factors and constructed an optimized structure for management objectives. Figure 1 shows the goal optimization structure based on schedule, cost, and quality goals.

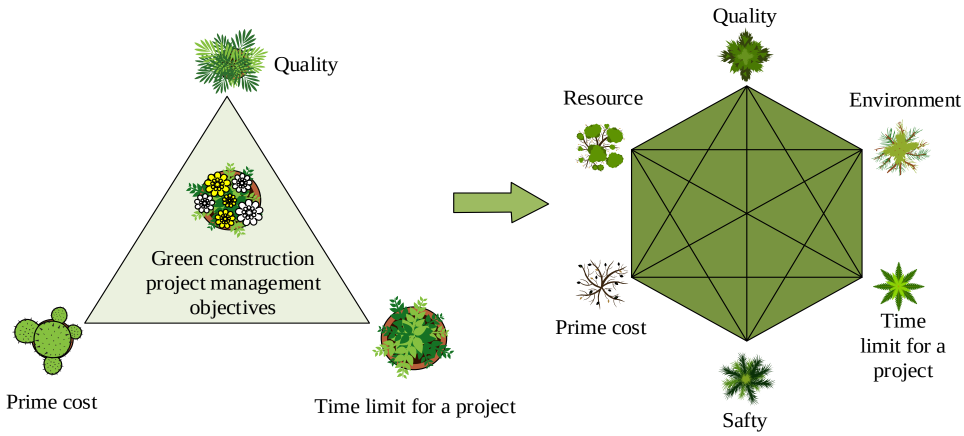


Fig 1. Schematic diagram of optimization relationship structure for green construction project management objectives

The construction period is an important foundation for achieving green engineering implementation, which has a direct impact on the achievement of other goals. And the schedule goal is also influenced by other goals in the GC project. Cost is an important prerequisite for the successful implementation of GC projects. Cost objectives are prerequisites for ensuring project quality, safety, resource conservation, and environmental protection. Quality is an important foundation for achieving green projects, and this goal can meet project functions, services, etc. Safety is the primary requirement of GC, including the overall safety status of construction in green projects. Environmental goals are the embodiment of SD concept in GC projects, including the impact on the environment during the engineering process. The resource goal is a measure to achieve the SD concept, including building water, electricity, land use, etc.

To achieve the above management objectives optimization, multi-objective optimization is necessary. The MOP method mainly includes traditional optimization methods such as linear weighting and intelligent optimization algorithms such as multi-objective GA [18]. Among them, GA has higher global optimization capability, and this algorithm can solve MOP. GA can find the global optimal solution by selecting coding mode, fitness function, selection strategy, crossover mode, and mutation mode. In the continuous improvement of GA, researchers propose the NSGA algorithm for solving multi-objective tasks. This method can achieve the simultaneous optimization of the multiple objectives and ultimately obtain the best multi-objective optimization strategy. As a type of GA, NSGA introduces non-dominated layer. By sorting the non-dominated hierarchy, it can more effectively inherit the obtained superior genetic individuals to the next generation.

As an improved version of NSGA, the elite strategy is introduced in NSGA-II. Figure 2 shows the specific NSGA-II flowchart. In this method, by introducing an elite strategy to sort non-dominated layers in NSGA, a more efficient sorting effect can be achieved. And the concept of congestion distance was introduced into the NSGA-II algorithm to maintain the algorithm diversity. NSGA-II can use this concept to control the search range of Pareto optimal solution set, thereby effectively improving the accuracy of the calculation results [19].

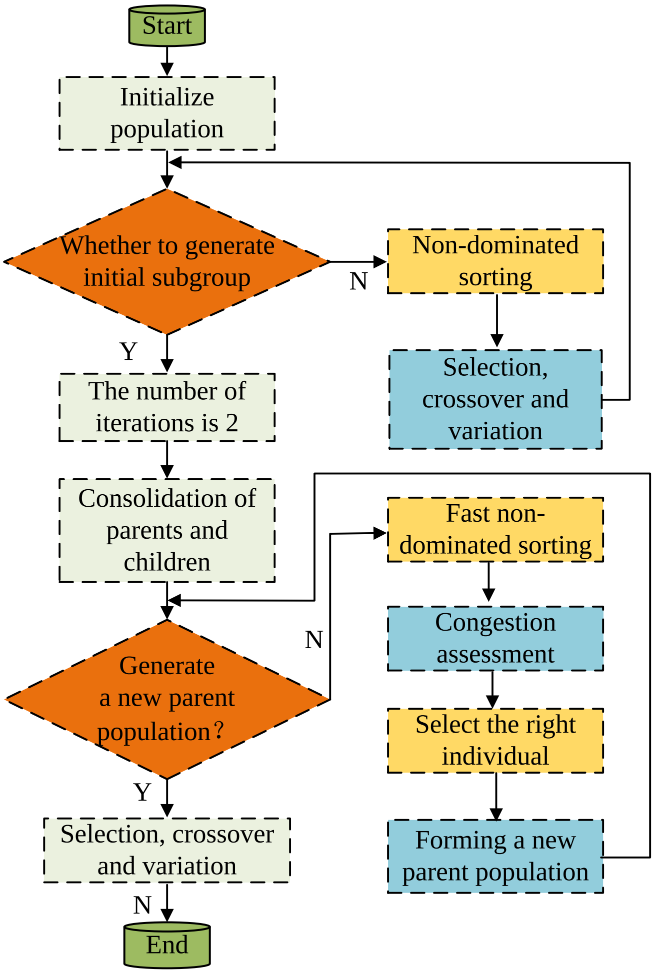


Fig. 2. Flow diagram of NSGA-II algorithm

3.2 Establishment of an Engineering Project MOP Model based on the Improved NSGA - II Algorithm

In the MOP model mentioned above, it is necessary to integrate the optimization models of each objective to conduct global optimization. Firstly, this article elaborates on optimization models for duration, cost, quality, safety, environmental, and resource goals [20]. Among them, Formulas (1) and (2) are the optimization models for the duration goal [21].

$$f_1(x) = \min T = \sum_{ij \in L_m, L_m \in L} t_{ij} \tag{1}$$

$$t_{sij} \le t_{ij} \le t_{lij} \tag{2}$$

In Formulas (1) and (2), T means the total construction period, L is routes set, and L_m is the critical route processes set. t_{ij} is the duration of process j, t_{sij} refers to the shortest duration of j, and t_{lij} is the longest duration of j. Formula (3) is direct expenditure cost in the cost objective optimization model.

$$C_{ij}^{D}=\frac{C_{ij\max}^{D}-C_{ij\min}^{D}}{(t_{lij}-t_{sij})^{2}}(t_{ij}-t_{lij})^{2}+C_{ij\min}^{D} \quad (3)$$

In Formula (3), $C_{ij\max}^{D}$ is the maximum cost of the direct expenditure j, and $C_{ij\min}^{D}$ means the minimum cost of the direct expenditure j. Formula (4) is the indirect expenditure cost in the cost objective optimization model [22].

$$C_{ij}^{I}=\frac{C_{ij\max}^{I}-C_{ij\min}^{I}}{(t_{lij}-t_{sij})^{2}}(t_{lij}-t_{ij}) \quad (4)$$

In Formula (4), $C_{ij\max}^{I}$ refers to the maximum cost of the indirect expenses ij, and $C_{ij\min}^{I}$ represents the minimum cost of the indirect expenses ij. In addition, the economic benefit isan important influencing factor in the cost objective optimization model, as shown in Formula (5).

$$B_{ij}=B_{0}(T_{\max}-T_{ij}) \quad (5)$$

In Formula (5), T_{min} is the shortest total construction period on the critical route. T_{max} represents the longest total construction period on the critical route. T_{ij} is the actual total construction period on the critical route. B_{ij} and B_{0} represent the economic and unit benefits of the early production, respectively. The cost objective optimization model in Formula (6) can be obtained from Formulas (3) to (5).

$$f_{2}(x)=\min C=\sum_{ij\in L}[C_{ij\min}^{D}+\alpha_{ij}(t_{ij}-t_{lij})^{2}+C_{ij\max}^{I}-\beta_{ij}(t_{lij}-t_{ij})-\beta_{ij}] \quad (6)$$

In Formula (6), α_{ij} is the cost increase rate of the direct expenditure ij, and β_{ij} is the cost coefficient of the indirect expenditure ij. Formula (7) is the optimization model for the quality objectives.

$$f_{3}(x)=\max Q=\sum_{ij\in L}[\omega_{ij}^{Q}\times(Q_{sij}+\theta_{ij}(t_{ij}-t_{sij}))] \quad (7)$$

In Formula (7), Q is the process quality, ω_{ij}^{Q} is the weight of the total quality, Q_{sij} is the quality corresponding to the shortest duration of ij. θ_{ij} is the slope of quadratic curve between ij quality and duration. Formula (8) is an optimization model for the safety objectives.

$$f_{4}(x)=\max S=S_{lij}^{out}=[1-\prod_{lki=1}^{n}(1-S_{lki}^{out})]\times S_{lij} \quad (8)$$

In Formula (8), S refers to the overall safety level of project, S_{lij}^{out} is the output safety level of the final process lij, S_{lki}^{out} represents the output safety level immediately before S_{lij}^{out}. S_{lij} is the inherent safety level of lij. Formula (9) is the optimization model for the environmental objectives.

$$f_5(x) = \min E = (L \times W) \times \sum_{ij \in L} (t_{ij} \times e_{ij}) + K \tag{9}$$

In Formula (9), L is the index of distance between the residential area and the project. W is the indicator of the economic development level. e_{ij} is the evaluation value of the direct environmental impact factor. K is the proportion of resource consumption. Formula (10) is the optimization model for the resource objectives.

$$f_6(x) = \max R = \sum_{ij \in L} [\omega_{ij}^R \times (\frac{R_{lij} t_{sij} - R_{sij} t_{lij}}{t_{lij} t_{sij} (t_{lij} - t_{sij})} t_{ij}^2 + \frac{R_{sij} (t_{lij})^2 - R_{lij} (t_{sij})^2}{t_{lij} t_{sij} (t_{lij} - t_{sij})} t_{ij})] \tag{10}$$

In Formula (10), ω_{ij}^R is the resource target weight, R_{lij} is the resource saving degree of ij, and R_{sij} is the worst resource saving degree of ij. The final comprehensive optimization model can be obtained from Formulas (1) to (10), as shown in Formula (11).

$$MinF = f(x) = \{ f_1(x), f_2(x), -f_3(x), -f_4(x), f_5(x), -f_6(x) \}$$

In response to the above comprehensive optimization model, the NSGA-II algorithm was used for the multi-objective optimization in this experiment. NSGA-II has advantages of simple computation, high execution efficiency, and it can reduce the influence of human subjectivity. However, considering that in the actual GC context, engineering projects involve many targets. This has led to an increase in the computational difficulty of the MOP process, a decrease in spatial search ability, and a decrease in the convergence of the algorithm. To solve these problems, hill climbing is introduced to improve NSGA-II. Figure 3 shows the flowchart of the improving NSGA-II.

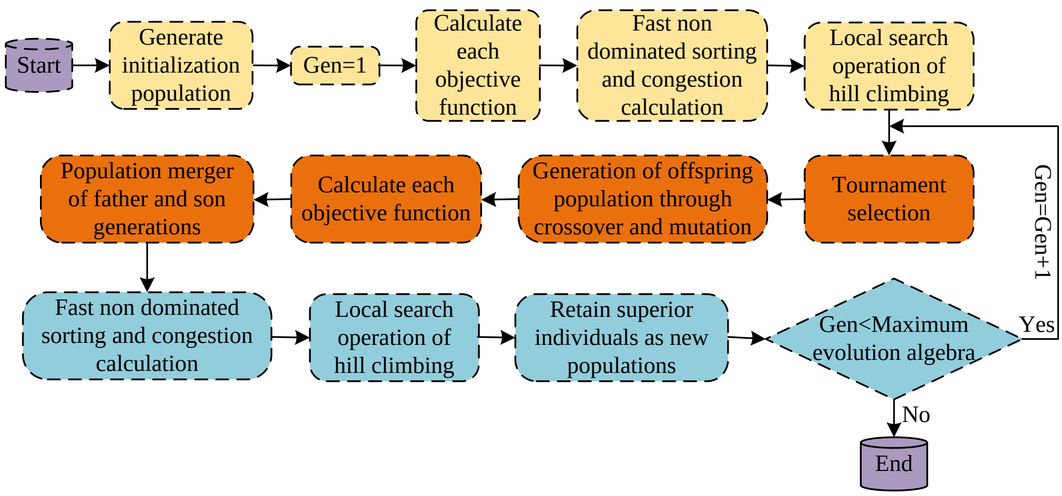


Fig. 3. Flow chart of improved NSGA-II algorithm

In Figure 3, it is first necessary to initialize parameters such as population size, mutation rate, and crossover rate, and randomly generate an initialized population. The second step is to set the evolutionary algebra (Gen) value of the generated initial population to 1, while calculating the objective function of each individual. And fast sorting is carried out through non-domination, crowding degree is calculated, and hill climbing is used for local search. In the third step, the population generated in the second step needs to undergo the tournament selection, crossover operations, and mutation operations to generate offspring. In this process, the individual objective function needs to be calculated and subjected to an elite retention strategy. And fast sorting is carried out through the non-domination, the crowding degree is calculated, and hill climbing is used for the local search. In the fourth step, it is necessary to determine the relationship between Gen and the maximum evolutionary algebra. If Gen is less than the maximum evolutionary algebra, so Gen=Gen+1, then return to step three. If Gen> the maximum evolutionary algebra, then end the algorithm.

To achieve the MOP effect of NSGA - II algorithm in engineering projects, this study will integrate the improved NSGA - II into the comprehensive optimization model mentioned above. In the GC context, an engineering project MOP model based on the improved NSGA - II algorithm mainly includes the initialization stage, the calculation of objective function, and the operation of racial genetic evolution. Figure 4 shows its specific process of an engineering project MOP model based on the improved NSGA - II algorithm.

The test function serves as a test indicator for the performance of the algorithm, and different test functions can be used to test the convergence and other performance of the algorithm. And the algorithm has been set with distribution barriers, which can conduct the comprehensive performance testing in multiple directions. The performance testing of the algorithm can enhance its problem-solving ability in practical applications. In this experiment, ZDT test function was selected as test function for MOP, including ZDT1-3 [23]. Formula (12) is mathematical expression of ZDT1 test function, which is a two-dimensional discontinuous function.

$$\begin{cases} f_1(x) = x_1 \\ f_2(x) = g(x)(\sqrt{\dfrac{x_1}{g(x)}}) \\ g(x) = 1 + 9(\sum_{i=2}^{n} x_i)/(n-1) \end{cases} \tag{12}$$

In Formula (12), $i = 1,2,...,n$ =30, $0 \le x_i \le 1$,and $i = 1,2,...,n$. Formula (13) is the mathematical expression of ZDT2 test function, which is a two-dimensional continuous function.

$$\begin{cases} f_1(x) = x_1 \\ f_2(x) = g(x)(1 - (\dfrac{x_1}{g(x)})^2) \\ g(x) = 1 + 9(\sum_{i=2}^{n} x_i)/(n-1) \end{cases} \tag{13}$$

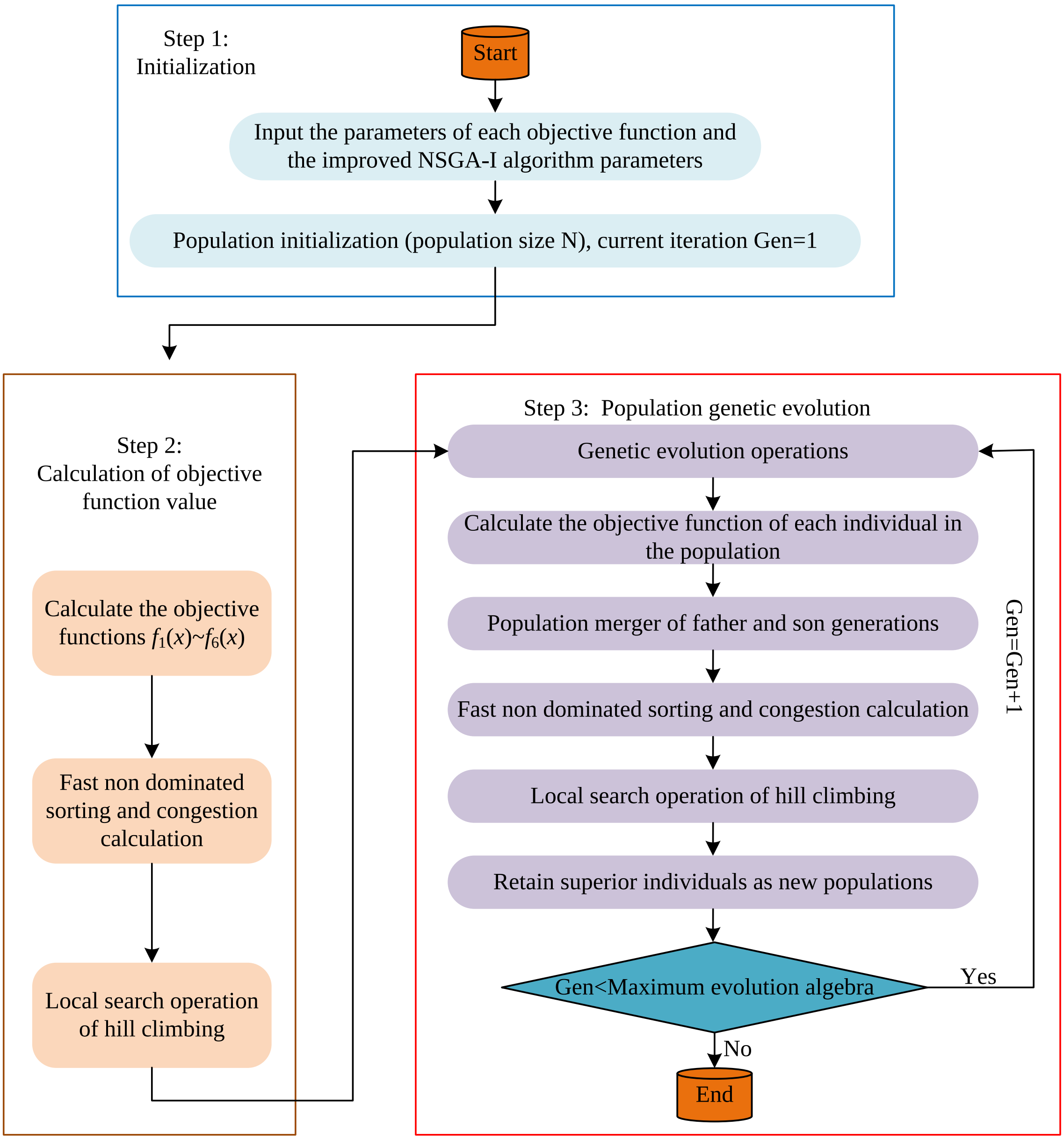


Fig 4. Process of multi-objective optimization model for engineering projects based on improved NSGA-Ⅱ algorithm

Formula (14) is the mathematical expression of ZDT3 test function, which is a two-dimensional discontinuous function.

$$\begin{cases} f_1(x) = x_1 \\ f_2(x) = g(x)\left(1 - \sqrt{\dfrac{x_1}{g(x)}} - \sqrt{\dfrac{x_1}{g(x)}}\sin(10\pi x_1)\right) \\ g(x) = 1 + 9\left(\sum_{i=2}^{n} x_i\right)/(n-1) \end{cases} \tag{14}$$

In the test functions ZDT1-3 above, ZDT1-2 can test whether algorithm has ability to find and generate Pareto frontiers. ZDT3 can test the algorithm search ability in non-connected areas and whether algorithm can maintain the uniform distribution in these non-connected areas. In this study, the improved NSGA - II was used to establish a multi-optimization model for engineering projects. In this process, hill climbing is introduced to improve the search ability of NSGA - Ⅱ. And the improved algorithm performance was tested using the ZDT1-3 test function. Finally, the MOP model with strong convergence and distribution was obtained.

4. Performance Evaluation of Engineering Project MOP Model Based on NSGA - II Algorithm

In the experiment, simulation is needed to conduct performance evaluation before implementing the strategy [24].In the performance evaluation of MOP model, Project S in M city was selected as an example for the validation experiment. The 5th floor construction project in Project S was selected as research object, which included 11 processes such as earthwork excavation and exterior wall decoration, named A~K. Figure 5 shows logical relationship network diagram between A~K processes in Project S.

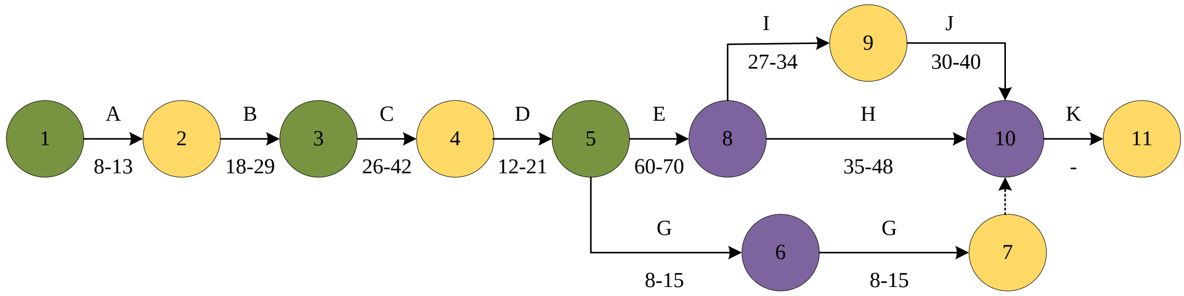


Fig. 5. Double code network diagram of project S

Before conducting the actual case analysis, the relevant data need to be preprocessed. Then, based on the relevant knowledge and a questionnaire survey, the relevant parameters are set. Table 1 shows the settings and ratings of relevant parameters in Project S. This includes optimization model parameters for the total construction period, the total cost, quality, safety, environment, and resource objectives.

Table 1
Setting of relevant parameters

Job name	A	B	C	D	E	F	G	H	I	J	K
Subsequent work	B,C,D	E	G	E	F	G	H, I	J	K	K	-
tsij/day	8	18	26	12	60	7	8	35	27	30	-
tlij/day	13	29	42	21	70	14	15	48	34	40	-
$C^{D}_{ij\min}$ /ten thousand yuan	19.84	413.22	302.26	60.16	336.69	19.34	18.77	19.98	92.27	46.62	-
$C^{D}_{ij\max}$ /ten thousand yuan	23.42	442.82	363.16	73.66	408.73	26.26	20.82	33.21	101.99	55.63	-
$C^{D}_{ij\max}$ /ten thousand yuan	0.84	0.85	0.87	0.9	0.85	0.89	0.84	0.86	0.85	0.88	-
Qlij	1	1	1	1	1	1	1	1	1	1	-
ω^{Q}_{ij}	0.077	0.149	0.134	0.105	0.147	0.067	0.054	0.088	0.092	0.082	-

Job name	A	B	C	D	E	F	G	H	I	J	K
	6	4	6	1	3		7	9	6	8	
ω_{ij}^R	0.079 4	0.071 6	0.083	0.073 5	0.122 1	0.047 4	0.051 3	0.133 7	0.179 3	0.158 7	-
e_{ij}	0.279	0.255	0.248	0.164	0.193	0.102	0.137	0.115	0.161	0.183	-

To better validate the improved algorithm performance, ZDT1-3 function was used to test the algorithm performance. The performance testing can enhance the problem-solving ability of method in practical applications. Multi objective solving will screen out a relatively optimal set of solutions, in which Pareto is used to find the relatively optimal solution or optimal solution. The optimized influence parameters can be obtained from the Pareto frontier [25]. The high degree of similarity between the Pareto frontier value and the true value indicates that the method has ideal distribution and convergence [26]. Figure 6 shows the different function test values for improved NSGA-Ⅱ algorithms. In the results of Figure 6, the improved algorithm can obtain approximate Pareto frontier values in ZDT1-3 function with a high degree of similarity to true values. This indicates that improved NSGA-II has the ideal distribution and convergence.

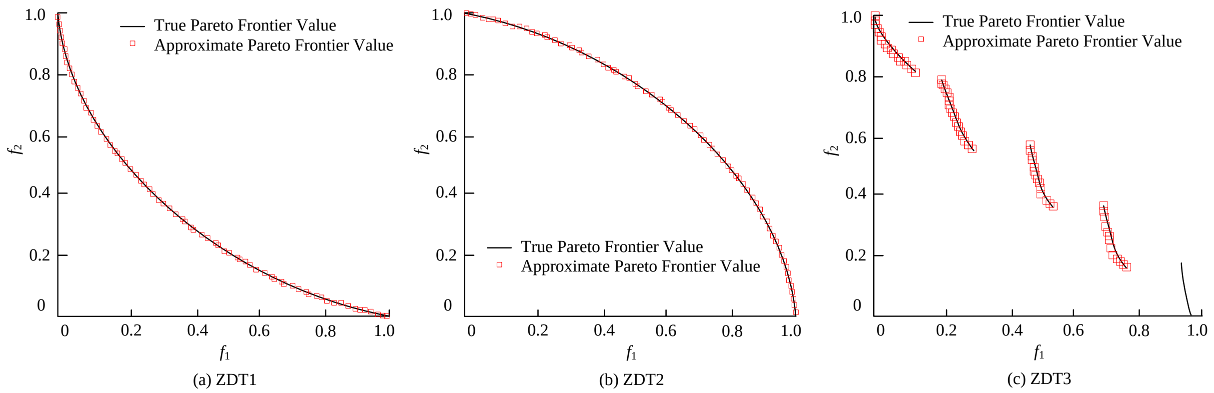
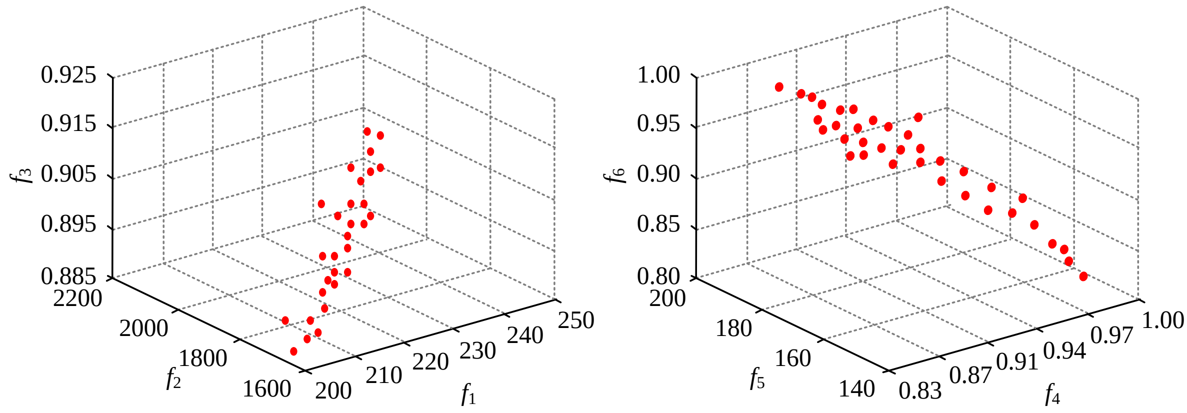


Fig. 6. Different function test values for improved NSGA-Ⅱ algorithms

To verify the performance superiority of the improved NSGA - II, this study compared it with the basic NSGA - II algorithm. According to the parameter settings in Table 1 above, relevant data information is solved in Matlab R2014a software for the engineering project MOP models based on NSGA - II algorithm and the improved NSGA - II algorithm. A total of 500 iterations were conducted, resulting in 40 Pareto solutions. The solution results of the engineering project MOP model based on NSGA - II are shown in Figure 7. From the figure, the total construction period of the engineering project MOP model based on NSGA - II is between 196 and 242. The total cost ranges from 17,677,600 to 21,094,600 yuan. The total mass is between 87.69% and 89.42%. The total safety is between 85.82% and 98.37%. The total environment is between 140.21 and 187.77. The total resources range from 83.62% to 99.51%. The total construction period, total cost, total quality, total safety, total environment, and total resources all meet the requirements of the project.



(a) f_1~f_3 (b) f_4~f_6

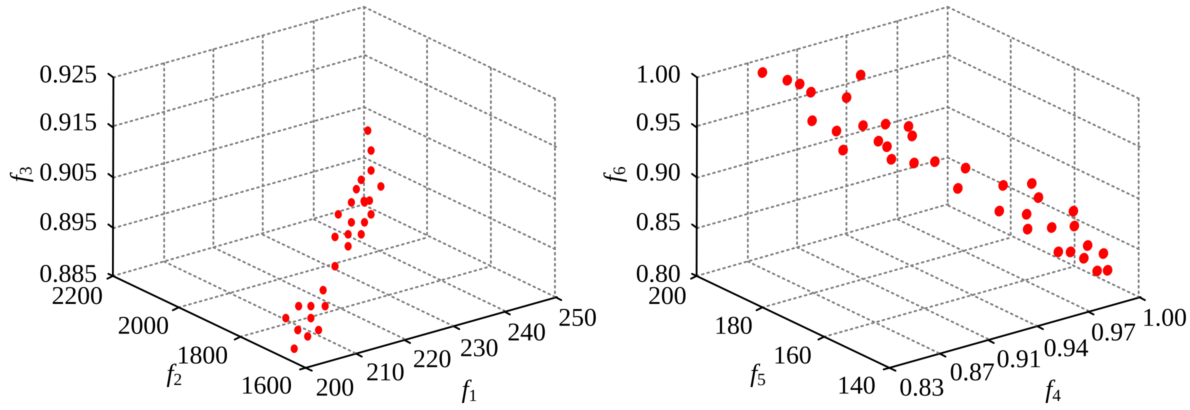
Fig. 7. Pareto solution of multi-objective optimization model for engineering projects based on NSGA-Ⅱ algorithm

The Pareto solutions based on NSGA - II in the above figure are summarized in Table 2. It displays the Pareto optimal solutions for the total duration, cost, quality, safety, environment, and resources. The bold red font represents Pareto optimal solutions of these optimization target models. Based on the content in Figure 7 and Table 2, there are contradictions between the optimization objectives of the plan. For example, the construction period of Scheme 1 is 46 days shorter than Scheme 3. The cost of Scheme 1 is 2.0398 million yuan less than Scheme 3. The environmental impact value of Scheme 1 is 35.54 days lower than Scheme 3. However, the quality of Scheme 1 is 1.63% lower than Scheme 3, the safety of Scheme 1 is 6.96% lower than Scheme 3, and the resources of Scheme 1 are 10.73% lower than Scheme 3.

Table 2
Partial Pareto optimal solutions optimized by NSGA-II algorithm

Scheme	Total construction period/day	Total cost/ten thousand yuan	Total quality/%	Total safety/%	Total environment	Total resource/%
1	196	1793.88	87.79	88.56	143.02	83.92
2	201	1767.76	88.00	94.74	150.27	83.62
3	242	1997.86	89.42	95.52	178.56	94.65
4	221	1886.39	88.51	98.37	160.21	92.17
5	203	1887.29	87.69	95.81	140.21	87.29
6	237	2109.46	89.02	85.82	187.77	99.51

The solution results of the engineering project MOP based on the improved NSGA - II are shown in Figure 8. A total of 500 iterations were conducted, resulting in 39 Pareto solutions. From this figure, the total construction period of the engineering project MOP model based on the improved NSGA - II is between 190 and 234days. The total cost ranges from 171473 to 20461800 yuan. The total mass is between 90.41% and 92.19%. The total safety is between 91.30% and 99.32%. The total environment is between 144.54 and 193.58. The total resources range from 86.21% to 99.91%. The total construction period, total cost, total quality, total safety, total environment, and total resources all meet the requirements of the project.



(a) f_1~f_3 (b) f_4~f_6

Fig. 8. Pareto solution of multi-objective optimization model for engineering projects based on improved NSGA-Ⅱ algorithm

The Pareto solutions based on the improved NSGA - II in the above figure are summarized in Table 3. Based on the contents of Figure 8 and Table 3, there is no contradiction between the optimization objectives of the plan. Based on the results of Figure 7, Figure 8, Table 2, and Table 3, the MOP model based on the improved NSGA - II can achieve better optimization of cost and resource objectives. The cost of the improved NSGA-II is 500,300 yuan lower than NSGA-II, with a resource target increase of 0.4% and an environmental target increase of 4.33%. The data results of these analyses demonstrate that the MOP model based on the improved NSGA - II has better optimization performance.

Table 3
Partial Pareto optimal solutions optimized by improved NSGA-II algorithm

Scheme	Total construction period/day	Total cost/ten thousand yuan	Total quality/%	Total safety/%	Total environment	Total resource/%
1	190	1740.07	90.51	91.30	147.44	86.52
2	195	1714.73	90.72	97.67	154.92	86.21
3	234	1937.92	92.19	98.48	184.09	97.58
4	214	1829.80	91.25	99.32	165.17	95.03
5	197	1830.67	90.41	98.78	144.54	89.99
6	230	2046.18	91.77	88.48	193.58	99.91

The convergence of each optimization objective function is compared in Figure 9. From the graph, quality, safety, and iteration curve of the resource objective function of the improved NSGA-II are higher than those of NSGA-II algorithm. The iteration curves of the improved NSGA - II in terms of the duration, cost, and environmental objective function are lower than those of NSGA - II algorithm. Overall, the improved NSGA - II has better MOP performance, can obtain better Pareto solutions, and has better performance.

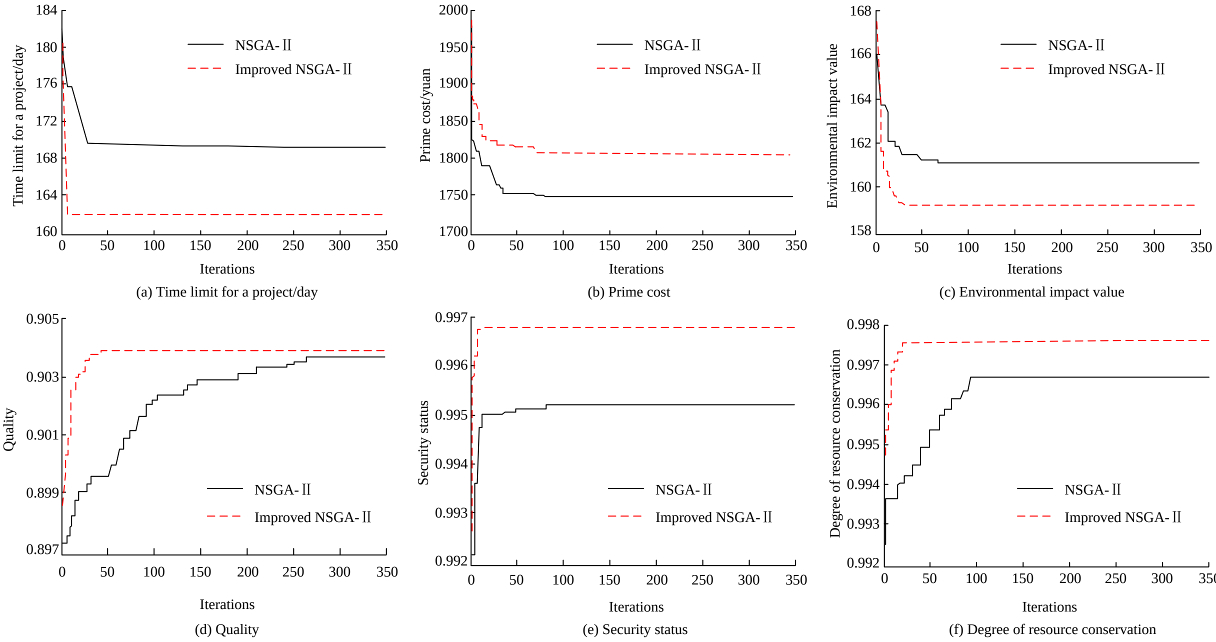


Fig. 9. Comparison chart of iteration curves for various objective functions

In order to more accurately propose green construction project management strategies in the future, this article conducts a detailed analysis of the Pareto solution obtained by optimizing the improved NSGA-II algorithm. The results show that the total construction period, total cost, total quality, total safety, total environment, and total resources all meet the requirements of the project. These results indicate that the improved NSGA-II algorithm has not reduced quality while optimizing and reducing construction time and costs and has achieved a certain improvement in the lowest quality. When using the improved NSGA-II algorithm to optimize the model, there was no reduction in safety status requirements due to reduced construction period, cost, and improved quality. The project will not cause absolute pollution to the environment while reducing construction period, costs, and improving quality and safety levels. Improving the NSGA-II algorithm while meeting the goals of schedule, cost, quality and safety, and environment, does not cause absolute waste of resources. Therefore, the optimization results of the green construction project in this case can be in line with the initial research and construction model to achieve multi-objective optimization of the green construction project. At the same time, this can also provide decision-makers with optimized decision-making solutions when choosing project management solutions.

5. Conclusion

The implementation of MOP for the project engineering in GC context requires the adoption of appropriate optimization methods to improve the management capabilities of engineering projects. In GC, the overall optimization level is determined by the schedule, cost, and quality objectives of project. In many studies, NSGA-II can be applied to solve different multi-objective optimization problems [27-29]. Considering the superiority of this method, this study will apply it to the establishment of multi-objective optimization models for engineering projects. In this study, an optimization structure for the management objectives was constructed centered around these three factors. And the improved NSGA - II was used to establish the MOP model for project engineering. The total duration of the engineering project MOP model based on the improved NSGA - II in results section is between 190 and 234. The total cost ranges from 171,473 to 20,461,800 yuan. The total mass is between 90.41% and 92.19%. The total safety is between 91.30%

and 99.32%. The total environment is between 144.54 and 193.58. The total resources range from 86.21% to 99.91%. The total construction period, cost, quality, safety, environment, and resources all meet the project requirements. The cost of the improved NSGA-II algorithm is 500,300 yuan lower than that of NSGA-II algorithm, with a resource target increase of 0.4% and an environmental target increase of 4.33%. The quality, safety, and iteration curves of the resource objective function of the improved NSGA-II are higher than those of the NSGA-II algorithm. The iteration curves of the improved NSGA - II in terms of the duration, cost, and environmental objective function are lower than those of the NSGA - II. Overall, the improved NSGA - II has better MOP performance, can obtain better Pareto solutions, and has better performance. However, the establishment of objective function did not fully consider resource conservation and environmental protection, and other factors were also taken into account. A more comprehensive impact indicator system needs to be established in subsequent experiments. And no comparison with other MOP algorithms was conducted in the experiment, and further comparative experiments are needed to improve the optimization effect of the improved method.

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Data Availability Statement
The author confirms that the data supporting the findings of this study are available within the article.

Conflicts of Interest
The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical approval
This article does not involve any studies with human participants or animals performed by any of the authors.

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