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Retraction

Retracted: Multiobjective Optimization Management of Construction Engineering Based on Ant Colony Algorithm

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] X. Liang, "Multiobjective Optimization Management of Construction Engineering Based on Ant Colony Algorithm," *Journal of Control Science and Engineering*, vol. 2022, Article ID 2397246, 8 pages, 2022.

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Research Article

Multiobjective Optimization Management of Construction Engineering Based on Ant Colony Algorithm

Xuejie Liang

School of Architectural Engineering, Huanghuai University, Zhumadian, Henan 463000, China

Correspondence should be addressed to Xuejie Liang; 201914070025@zknu.edu.cn

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In order to solve the problems of extensive management, the construction stage often faces the extension of construction period, excessive cost, and large amount of carbon emission and this paper proposes a multiobjective optimization management method of construction engineering based on ant colony algorithm. Firstly, taking the installation process of laminated plate components as an example, this paper combs the construction process and the consumption types of labor, materials, machinery, or equipment in each process in detail. Then, combined with the idea of multiobjective optimization, the multiobjective optimization mathematical model of construction process is constructed, and the construction data obtained from field investigation are summarized and analyzed to obtain the cost, construction period, and carbon emission of each process under different execution modes. The experimental results show that the ant colony algorithm is used to find the comprehensive optimal process execution mode combination of "cost duration carbon emission." After optimization, the installation cost of laminated plate components is reduced by 1.55%, the construction period is reduced by 3.52%, and the carbon emission is reduced by 7.36%. The feasibility and rationality of multiobjective optimization in this paper are verified by experiments, which can effectively guide the optimization management of construction process.

1. Introduction

With the continuous improvement of people's cultural level, they also have a new pursuit for their own quality of life, which makes the construction engineering encounter new challenges. It is not only necessary to improve the construction quality, but also to meet people's diversified needs. In the process of construction engineering, the process quality control needs to start from two aspects: one is to control the construction process conditions and the other is to control the effect of construction process activities. In terms of condition control, it is necessary to make construction preparations and control various influencing factors in the construction process, so as to lay a good foundation for the smooth development of construction process activities [1]. As relevant managers, they should also recognize the importance of process management, give full play to their own initiative in specific work, comprehensively analyze personnel, materials, equipment, methods, and environment, and adopt targeted management methods in combination with the actual situation, so as to ensure the effective connection between various processes, so as to finally complete the construction task of construction engineering as shown in Figure 1 [2]. With the coordinated development of social economy and science and technology, more and more construction projects are put into construction. With the development of construction technology, the advantages of process management and optimization management in construction are becoming more and more obvious [3]. Therefore, in the specific construction, the relevant units must do a good job in the management of various processes so as to give full play to their technical advantages.

2. Literature Review

Ji and others calculated from the literature, since 2011, the number of articles on the combination of BIM Technology and lean construction has gradually increased. The main reason is that integrated research and application can

Figure 1: Construction project management system.

minimize the waste of engineering change, material, time, and human resources and has high engineering practice value. Among them, BIM plays an important role in information management and information sharing, and the main principles of lean construction are on-site 5S constraint management and just in time production. Both are important management and control concepts in the construction industry. At the same time, it is considered that the industrialization based on both is the key direction of future research [4]. By studying the concept of KanBIM (end planner management system based on BIM), Yang and others prepared a set of guidance scheme for the implementation and operation of lean production management system based on BIM. It provides a powerful platform for the workflow in the visual control system. The platform also supports more in-depth cooperation between on-site and off-site teams. KanBIM covers the maintenance of workflow stability, negotiation and commitment between teams, lean production plan of fine flow control, and effective communication and visualization of processes. It shows that the system has the potential to reduce the waste of work process and improve the evaluation of product through visualization [5]. Ma and others explored the impact of the combination of BIM and lean construction on design. In projects using BIM, the communication practice between personnel roles, design methods, and designers bid farewell to the era of document-based design management. In managing architectural design, the use of lean management tools can be seen as the driving force to enhance customer value, improve operations, and remove activities that do not add value. By means of investigation and interview, the interview content is analyzed, the problems are divided into six categories, the severity of the problems is coded, and the improvement suggestions are put forward for the design team based on the two theories [6].

At present, there is relatively little research on multiobjective optimization of construction process combined with carbon emission factors. Based on this, this paper draws lessons from the relevant research ideas of previous scholars, takes the laminated plate construction process in prefabricated buildings as an example, and deeply analyzes the cost, construction period, and carbon emission of each process under different construction execution modes on the basis of sorting out the construction process flow. Finally, the ant colony algorithm is used to optimize the solution and the construction scheme that can realize the comprehensive optimization of "cost-construction period-carbon emission" is selected.

3. Research Methods

3.1. Construction Process Sorting. There are many processes on the construction site, from basic engineering construction to completion acceptance, in which each subdivisional project contains many subtle processes [7]. At present, the main construction forms include cast-in-situ construction and prefabricated construction. With the continuous development of the construction industry, cast-in-situ construction has been difficult to meet people's requirements for environmental protection. The prefabricated construction can not only effectively improve the construction efficiency, but also effectively reduce the environmental pollution caused by the construction process. Therefore, many countries around the world are promoting the development of prefabricated buildings. In the prefabricated construction mode, each subproject has a relatively fixed process flow, and the relative standardization of the construction process makes the process data more clear and comprehensive. Therefore, this paper selects the prefabricated construction mode process flow to carry out the research, which can not only improve the feasibility of the research, but also comply with the development trend of the construction industry. From the current practice of prefabricated construction, the construction process of laminated plate components is highly standardized and the construction process is relatively standardized. Therefore, taking the installation of laminated plate components as an example, this paper combs the installation process of prefabricated building laminated plate components and establishes a multiobjective optimization model on this basis. Generally speaking, the installation process of laminated plate components can be divided into the following processes: component mobilization and inspection, erection equipment support, base course and construction surface cleaning, embedded parts layout, hoisting and transportation of laminated plate, installation and placement of laminated plate, grouting operation, node protection, on-site cleaning, and other processes. At the same time, through data collection and on-site investigation, the labor, material, and mechanical consumption of each process can be obtained, so as to further calculate the cost and carbon emission of each process. The process duration can also be obtained through on-site investigation [8].

3.2. Multiobjective Optimization Problem. The idea of multiobjective optimization originated in the field of economics is as follows. With people's continuous awareness of the limitation of means of production, how to use the least means of production to obtain the maximum benefit has become the concern of scholars [9]. Based on this idea, the multiobjective optimization process seeks how to optimize the allocation of resources under the condition of the same output, so as to minimize the consumption of means of production in the production process. The theory was first put forward in the 19th century and has been continuously expanded from the field of economics to the fields of system engineering, construction projects, production scheduling, and so on [10]. For engineering projects, the multiobjective optimization problem is the comprehensive optimization of construction period, cost, safety, carbon emission, and other indicators. Using the relevant ideas and methods of multiobjective optimization can effectively solve this problem. Generally speaking, using the relevant principles of mathematical function transformation, the multiobjective optimization problem can be transformed into a mathematical model as shown in the following equation:

$$\begin{cases} \min & Y = \left(f'(x), f''(x), \ldots\right), \quad x \in T^m, \\ \text{s.t.} & g'(x) \leq 0,\ h'(x) \geq 0, \end{cases} \tag{1}$$

where $f'(x)$ and $f''(x), \ldots$ represent each subgoal, and each subgoal has a corresponding mathematical function expression; T^m is the feasible solution space, in which each solution can be applied to the original problem, but not all are optimal solutions. Generally speaking, only a few solutions can make all objective functions relatively minimum; $g'(x)$ and $h'(x)$ are the constraints of the objective function, respectively. Usually, there are multiple constraints. After establishing the multiobjective optimization model, the next step needs to solve the model. Due to the particularity of the multiobjective optimization model, special methods need to be used to deal with it including the following methods.

3.2.1. Objective Programming Method. This method is relatively simple and suitable for multiobjective optimization problems with few parameters and constraints. Firstly, the optimal value of each subgoal is found, and then the optimal value of each subgoal is regarded as the constraint condition of the original problem. Finally, reduce the difference between each subgoal and its corresponding optimal value, and the final optimal solution is the optimal solution of the original problem [11].

3.2.2. Fixed Weight Method. This method uses the weight coefficient to measure the importance of each subgoal to the overall goal, calculates the comprehensive function value through the weight coefficient between 0 and 1 and the subgoal value, and finally compares the comprehensive function value corresponding to each feasible solution. If the comprehensive function value is optimal, it indicates that the corresponding feasible solution is optimal.

3.2.3. Dynamic Weight Method. Similar to the fixed weight method, each subgoal is given a certain weight, but the method adopts dynamic weight, and the weight coefficient will change in each calculation process, which improves the randomness and globality of the solution process. This method is suitable for multiobjective optimization problems with balanced subobjectives and no obvious dominance.

The above three methods are the three most widely used methods in the solution process of multiobjective optimization. Among them, the dynamic weight method has the following advantages compared with the other two methods: first, the weight coefficient is easy to operate and can quickly and reasonably transform the multiobjective optimization problem into a single-objective optimization problem; secondly, the weight coefficient changes dynamically, which avoids falling into local optimization in the solution process and improves the scientificity of the optimization result. In addition, this method is mature and has certain reference experience and can achieve good coordination with computer language algorithm [12]. Therefore, this paper selects the dynamic weight method to solve the multiobjective optimization problem. In the iterative process, the weight coefficient is generated by

$$w_i = \frac{a_i}{a_1 + a_2 + a_3}, \tag{2}$$

where w_i is the weight coefficient of the i-th subtarget and $i = 1, 2, 3$; a_i is a random number between 0 and 1. In each iteration, the algorithm system assigns a value to a_i, then calculates the dynamic weight coefficient, and further calculates the comprehensive objective function value by using the subobjective function value and weight coefficient, so as to realize the transformation from multiobjective optimization problem to single-objective optimization problem.

3.3. Establishment of Optimization Model. In the construction site of prefabricated buildings, the construction period, cost, and carbon emission of the installation process of laminated plate components depend on the input of labor, materials, machinery, and other factors. The process of prefabricated component factory and fabricated building construction site can be divided into normal mode, rush mode, and saving mode for research. Different execution modes correspond to different production resources and consume different costs and construction periods [13]. On this basis, considering the carbon emission factors, the on-site installation process of laminated plate components can also be divided into the above three modes. The same process corresponds to different cost, construction period, and carbon emission under different execution modes. Finding the combination of multiobjective optimal process execution

Table 1: Summary of basic information of construction mode in installation process of laminated plate components.

Serial number	Process name	Normal mode		Rush mode		Saving mode	
		Labor force (person)	Time (min)	Labor force (person)	Time (min)	Labor force (person)	Time (min)
1	Mobilization and inspection of components	1	1	2	0.5	1	1
2	Erection equipment support	3	15	4	13	3	17
3	Cleaning of base course and construction surface	2	6	3	4	2	8
4	Layout of embedded parts	2	10	3	8.5	2	12
5	Hoisting and transportation of laminated plates	3	5	—	—	—	—
6	Installation of laminated plate in place	2	8	2	6	2	10
7	Grouting operation	2	15	3	12	2	17.5
8	Node protection	2	5	2	3	1	7.5
9	Site cleaning	2	3	0	2	2	4

modes can provide guidance for the optimization of on-site construction.

3.3.1. Site Construction Data. Combined with literature and field investigation, the construction mode of on-site installation process of laminated plate components is analyzed. Taking the installation and construction of laminated plate components with a size of 3150 mm × 1250 mm × 60 mm as an example, the basic information of the construction mode is summarized as shown in Table 1.

Combined with the data in Table 1, the cost and carbon emission of 9 processes under different execution modes are further calculated. Among them, the construction cost includes labor cost, material cost, and mechanical cost (such as tower crane shift fee). The labor cost is calculated according to 45 yuan/h, the material cost is calculated according to the actual material consumption and market price of the process, and the mechanical cost is calculated according to the shift fee or discount. Carbon emission sources include workers' respiration, materials, and energy consumption. The carbon emission generated by workers' respiration is calculated by working hours and respiratory carbon emission factors. The carbon emission generated by materials is calculated by the carbon emission factors corresponding to the amount of materials. The carbon emission generated by energy consumption mainly considers the gasoline, electric energy, and other energy used on-site, combined with the energy carbon emission factors [14, 15]. The carbon emission factors used in this paper are shown in Table 2. The calculated cost, construction period, and carbon emission data of each process under different execution modes are shown in Tables 3–5.

Table 2: Carbon emission factors.

Carbon emission source	Carbon emission factor
Water	0.86 kg CO_2/t
Electric energy	0.9987 kg CO_2/(kW·h)
Gasoline	2.93 kg CO_2/kg
Diesel oil	3.10 kg CO_2/kg
Concrete	(C30) 321.30 kg CO_2/m^3
Grouting material	513.56 kg CO_2/m^3
Cement	740.60 kg CO_2/t
Sand	2.79 kg CO_2/t
Worker breathing	1.72 kg CO_2/(person·work day)

3.3.2. Construction Optimization Model. The optimization objective of this paper is the multiobjective optimization of "Cost C-Duration T-Carbon emission E." According to the execution modes contained in different processes, the optimization model is established, as shown in the following equation:

$$\left\{ \min \quad C = \sum_{i=1}^{m} \sum_{j=1}^{q_i} C_{ij}, \min T = \sum_{i=1}^{m} \sum_{j=1}^{q_i} T_{ij} D_{ij}, \min E = \sum_{i=1}^{m} \sum_{j=1}^{q_i} E_{ij} D_{ij}, \text{s.t.} \sum_{j=1}^{q_i} D_{ij} = 1. \right. \tag{3}$$

In the formula, m is the number of construction procedures; q_i is the number of execution modes owned by the i-th procedure; D_{ij} is the decision variable, which takes the value of 0 or 1, and when the i-th procedure adopts the j-th execution mode, its value is 1; otherwise, it is 0.

3.4. Ant Colony Algorithm Process. Because the solving process of multiobjective optimization problem involves complex mathematical model, it is difficult to calculate by manpower, so it needs to be realized with the help of computer algorithm. According to the characteristics of the algorithm, the current algorithms in the research field of

Table 3: Summary of cost data of installation process of laminated plate components (yuan).

Serial number	Process name	Normal mode	Rush mode	Saving mode
1	Mobilization and inspection of components	15.5	16.5	13.9
2	Erection equipment support	22.4	23.5	20.7
3	Cleaning of base course and construction surface	5.2	6.1	4.3
4	Layout of embedded parts	12.5	14.7	10.4
5	Hoisting and transportation of laminated plates	36.4	—	—
6	Installation of laminated plate in place	17.0	18.2.	15.8
7	Grouting operation	43.7	45.5	41.1
8	Node protection	8.4	9.0	7.2
9	Site cleaning	2.4	2.7	1.9

Table 4: Summary of construction period data of installation process of laminated plate components (min).

Serial number	Process name	Normal mode	Rush mode	Saving mode
1	Mobilization and inspection of components	1	0.5	1
2	Erection equipment support	15	13	17
3	Cleaning of base course and construction surface	6	4	8
4	Layout of embedded parts	10	8.5	12
5	Hoisting and transportation of laminated plates	5	—	—
6	Installation of laminated plate in place	8	6	10
7	Grouting operation	15	12	17.5
8	Node protection	5	3	7.5
9	Site cleaning	3	2	4

Table 5: Summary of carbon emission data in installation process of laminated plate components (kg).

Serial number	Process name	Normal mode	Rush mode	Saving mode
1	Mobilization and inspection of components	1.8	1.6	1.5
2	Erection equipment support	2.1	2.6	1.9
3	Cleaning of base course and construction surface	0.8	0.6	0.5
4	Layout of embedded parts	1.2	0.8	0.6
5	Hoisting and transportation of laminated plates	4.5	—	—
6	Installation of laminated plate in place	1.5	1.6	1.3
7	Grouting operation	8.3	8.8	7.1
8	Node protection	0.5	0.5	0.4
9	Site cleaning	0.4	0.4	0.4

multiobjective optimization problems include accurate algorithms and heuristic algorithms [16]. The exact algorithm is suitable for multiobjective optimization problems with small scale and few parameters. Generally, it can get the only optimal solution of the original problem, but the disadvantage is that it consumes a long time. This kind of solution algorithm includes branch and bound method, cut plane method, and integer programming method. With the continuous complexity of multiobjective optimization problems and the continuous development of computer technology, heuristic algorithms have emerged including ant colony algorithm, simulated annealing algorithm, tabu search algorithm, genetic algorithm, and other common methods. This kind of algorithm is suitable for complex multiobjective optimization problems with large scale, many parameters, difficult to find the optimal solution, or the optimal solution is not unique. Through repeated iteration, it continues to approach the optimal solution and finally obtains the optimal solution set of the original problem [17]. Because ant colony algorithm has good universality, operability, and robustness and is suitable for multiobjective optimization problems with medium complexity, ant colony algorithm is selected to solve the multiobjective optimization model of construction process in this paper. Specifically, the ant colony algorithm in this paper includes the following steps:

Step 1: variable definition. The iterative process of ant colony algorithm includes many important parameters to control the iterative process of the algorithm including cycle times N, number of ants m, pheromone importance α, heuristic factor importance β, pheromone strength Q, pheromone volatilization rate p, and other parameters [18]. Among them, N depends on the scale of the original problem, which is usually between 200 and 500. In this study, the scale of the problem is small but in order to ensure the optimization effect, $N = 300$; the number of ants affects the convergence speed of the algorithm. According to the empirical practice, $m = 20$; α and β affect the randomness of the algorithm process. In order to ensure the randomness of the algorithm and take into account the operation efficiency of the algorithm, $\alpha = 1.15$, $\beta = 0.8$; Q and p

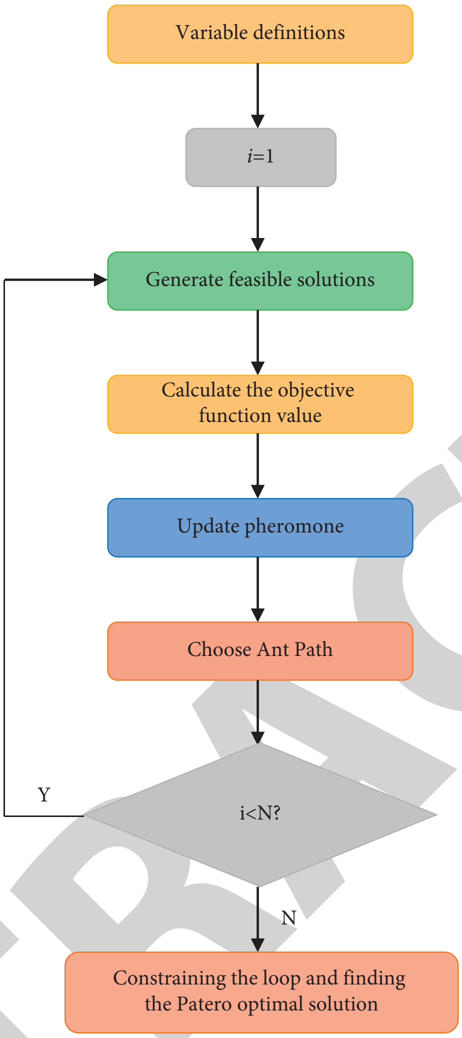

Figure 2: Ant algorithm flow.

are set to avoid the algorithm falling into local optimization. According to empirical practice, $Q = 10$ and $p = 0.3$ are taken.

Step 2: initial feasible solution. As the beginning of the algorithm, it is necessary to randomly generate a set of feasible solutions that meet the constraints, that is, generate 20 ants, in which each ant represents a feasible solution, and the construction period and cost corresponding to the feasible solution are not exactly the same as the carbon emission [19].

Step 3: generate the weight coefficient and calculate the value of the comprehensive objective function. According to equation (2), the weight coefficient is randomly generated for each subobjective function, and the comprehensive objective function value f is calculated. When f is smaller, it indicates that the construction period, cost, and carbon emission of the corresponding feasible solution are smaller, and the feasible solution is better.

Step 4: pheromone update. According to the pheromone intensity and the corresponding comprehensive objective function value of each ant, calculate the pheromone concentration left by ants on each path, that is, Q/F. In addition, the pheromone concentration on each path is equal to the sum of the pheromone retention value before the beginning of the cycle and the pheromone released by ants during the cycle.

Step 5: judge the path choice of ants. The higher the pheromone concentration on the path, the higher the probability of ants choosing the path. According to this principle, the probability of ants choosing each path is calculated, respectively.

Step 6: select the path for the ant. The path selection of each ant is based on the path selection probability of each ant and the path selection function of each ant.

Step 7: repeat the above cycle process until the number of cycles reaches 300.

Step 8: find the optimal solution. After the number of cycles reaches the preset value, the relative optimal solution is found in the generated solution set, so as to determine the global optimal solution of the original problem. Since the solutions obtained in the

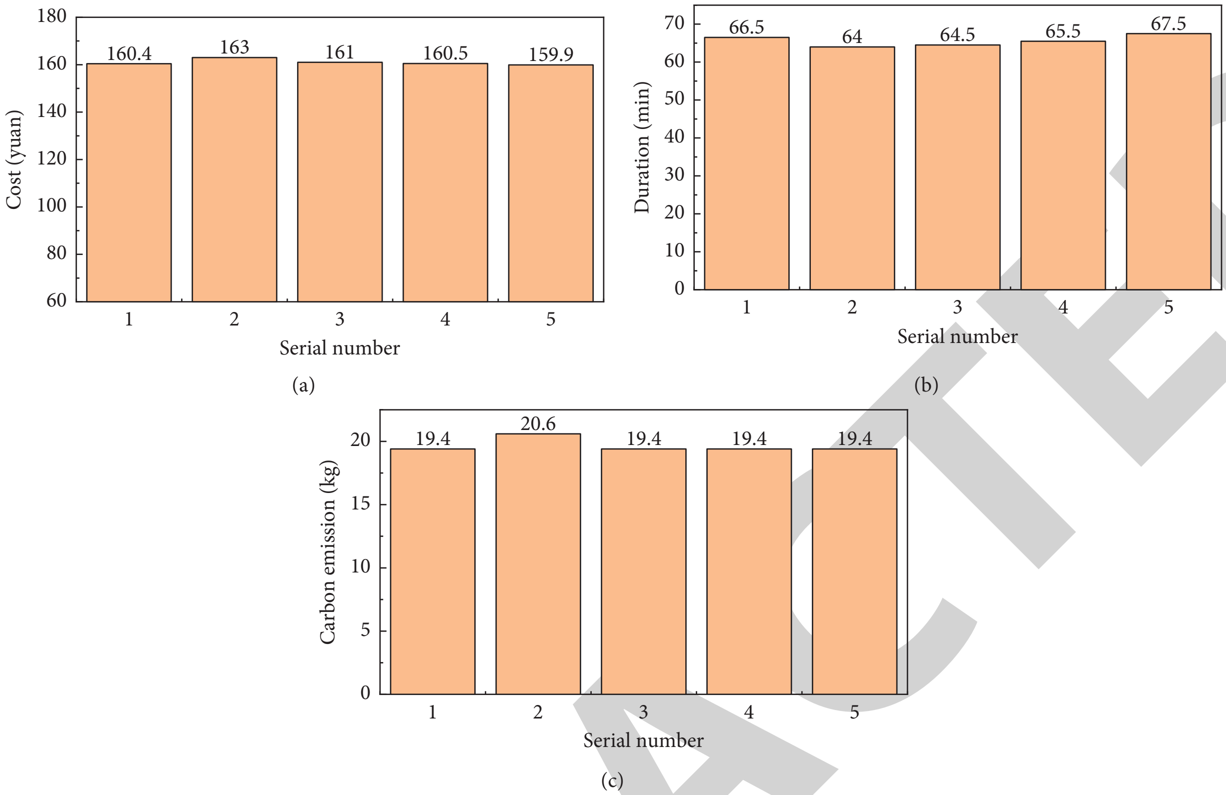

Figure 3: Optimal solution set of the original problem. (a) Cost. (b) Construction period. (c) Carbon emission.

preliminary cycle are the optimal solutions in the corresponding field rather than the global optimal solutions, it is necessary to compare each solution to screen the global optimal solutions [20, 21]. The specific algorithm flow is shown in Figure 2.

4. Result Analysis

The ant colony algorithm is realized by computer programming, and finally five relatively optimal solutions are obtained, as shown in Figure 3. These solutions constitute the optimal solution set of the original problem. At the same time, the algorithm can also obtain the process construction mode corresponding to each feasible solution, and the process mode selection corresponding to the optimal feasible solution can be obtained from this table, which can effectively guide the construction process [22, 23]. As can be seen from Figure 3(a), the average cost of the feasible solution of the optimized laminated plate installation process is 160.96 yuan. As can be seen from Figure 3(b), the average duration is 65.60 min. As can be seen from Figure 3(c), the carbon emission is 19.64 kg. Before optimization, if all processes are executed in normal mode, the cost is 163.5 yuan, the construction period is 68 min, and the carbon emission is 21.2 kg. Therefore, after optimization, the installation cost of the laminated plate component is reduced by 1.55%, the construction period is reduced by 3.52%, and the carbon emission is reduced by 7.36%.

5. Conclusion

With the continuous attention to carbon emissions, as a major carbon emitter, the construction industry is facing the important task of carbon emission optimization. Compared with traditional buildings, prefabricated buildings, which have been widely implemented in recent years, have better environmental friendliness. Many scholars have also studied the cost, construction period, and carbon emission of prefabricated buildings. On the basis of previous research, this paper comprehensively considers the multiobjective optimization of cost, construction period, and carbon emission in the construction stage of prefabricated buildings and strives to realize the multiobjective optimization of construction process from the microlevel through the reasonable selection of process construction mode. In the research process, taking the installation process of laminated plate components as an example, this paper first combs the construction process flow and divides the process into three execution modes: normal, expediting, and saving. Under different execution modes, each process has different cost, construction period, and carbon emission. On this basis, this paper constructs a multiobjective optimization model and uses ant colony algorithm to solve it. The final optimization result reduces the cost by 1.55%, the construction period by 3.52%, and the carbon emission by 7.36%. At the same time, the algorithm also obtains the process mode selection corresponding to each optimal solution, which can provide more guidance for the construction process. In the future, the optimization idea and method can be applied to the optimization of more processes on the construction site so as to further realize the overall optimization of the whole construction site.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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