Multi-Objective Optimal Management of Building Engineering Based On Ant Colony Algorithm

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Abstract. Under the advanced theory, the traditional construction management mode is optimized. This paper mainly analyzes the multi-objective optimal management of building engineering based on ant colony algorithm. Based on the three indexes of building safety, quality and cost, the optimized management effect is analyzed.

Keywords: Ant Colony Algorithm, Construction Works, Multiobjective Optimization

Introduction
Project management for construction engineering safety, quality, cost, has a significant impact, mismanagement will make construction engineering each index decreased, so in theory to guarantee the project quality, must take into account the above three indicators, but in the midst of traditional architectural engineering project management, most of the construction units in project management, will focus on a certain index, led to the decrease of the level of other indicators, is not conducive to engineering quality evaluation, as well as the necessity of the optimization of traditional project management mode are.

1. Case Overview
In this paper, the reliability of the construction of the second-phase comprehensive pipe gallery project is analyzed by taking an example. The construction period of the project is 135d; this project has a huge structure, including 11 sub-projects in total. FIG. 1 shows the construction relationship diagram among the sub-projects, and according to FIG. 1 and the logical relationship among the projects, the construction reliability block diagram is obtained, as shown in FIG. 2. In addition, according to the figure 1 that the 11 kinds of construction engineering are: earthwork, cushion, floor engineering, the principal part of the project, waterproof engineering, backfill soil engineering, decoration engineering, wrought iron installation engineering, pipeline engineering, embedded parts and casing installation, completion inspection and acceptance, table 1 unit of the project is introduced, the primary data of the table a, m, b represent activities I best, worst, the most likely time.
2. Reliability Calculation of Work Units

2.1 Safety and Reliability of the Work Unit

| The serial number | Work units                        | Duration (days) | Direct cost per unit (yuan) | quantities | The number |
|-------------------|-----------------------------------|-----------------|-----------------------------|------------|------------|
|                   |                                   | a m b           | a m b                       | unit       |            |
| One               | Civil engineering                 | 14 21 28        | 17 19 25                    | m³         | 55350      |
| Two               | Cushion engineering               | 12 15 20        | 180 200 250                 | m          | 500        |
| Three             | Floor engineering                 | 38 45 60        | 1900 2000 2200              | m          | 500        |
| Four              | The principal part of the project | 62 75 90        | 8500 9000 9600              | m          | 500        |
| Five              | Waterproof engineering            | 8 12 15         | 9 12 15                     | m³         | 7325       |
| Six               | Backfill works                    | 6 11 15         | 17 23 25                    | m³         | 41937      |
| Seven             | Rough finishing project           | 5 7 10          | 230 266 300                 | m³         | 190        |
| Eight             | Iron work installation            | 6 8 11          | 150 205 230                 | m          | 50         |
| Nine              | Pipeline installation             | 15 18 22        | 680 742 800                 | m          | 500        |
| Ten               | Embedded parts and sleeves        | 7 11 16         | 6000 6376 6500              | t          | 0.5        |
| Eleven            | Completion inspection and acceptance | 2 2 3         | 4300 4500 4800              | Item       | 1          |
Whether the work unit is safe or not depends on the probability of the occurrence of safety accidents during construction. As there are too many types of safety accidents to generalize, this paper will take the construction electric shock accident as an example to analyze its reliability [1]. In the analysis, this paper first establishes the tree diagram of construction electric shock accident, as shown in FIG. 3. Secondly, it adopts Boolean algebra method to cut the set of accident tree diagram and express its function. Finally, after obtaining the probability of the occurrence of electric shock accident in this project, the probability is put into the above function expression and the reliability is calculated. FIG. 3 tree diagram of electric shock accident in construction site, where T represents electric shock death; E1 stands for direct death after electric shock; E2 stands for indirect death after electric shock; E3 represents normal voltage and current, and the electric shock time is too long. E4 represents other accidents caused by electric shock; E5 represents excessive current and voltage. X2 represents other diseases induced by electric shock; X3 represents failure of timely power failure of electrical equipment; X4 means hit the spot; X5 represents dangerous operations; X6 stands for runaway safety operations.

![FIG 3. Tree diagram of electric shock accident at construction site](image)

The cut set expression of the tree graph by Boolean algebra method is shown in formula (1):

\[
\{ x_1 \} \{ x_2 \} \{ x_3 \} \{ x_4 \} \{ x_5 \} \{ x_6 \}
\]

The structural function expression is shown in formula (2):

\[
f = x_1 + x_2 + x_3 + x_4 + x_5 + x_6
\]

After calculation, the safety reliability of each work unit of the project is shown in table 2. According to the results in table 2, the average safety reliability of the project is 0.68.

| Work units | Safety reliability |
|------------|--------------------|
| One        | 0.8775             |
| Two        | 0.8990             |
| Three      | 0.8760             |
| Four       | 0.9458             |
| Five       | 0.7989             |
| Six        | 0.8760             |
| Seven      | 0.9213             |
| Eight      | 0.9145             |
| Nine       | 0.9689             |
| Ten        | 0.9246             |
| Eleven     | 0.9989             |

2.2 Calculation of Quality Reliability of Work Units

Concrete is mainly used for construction in practical projects. Therefore, in the quality reliability calculation of working units, concrete is taken as an example and the influence of actual concrete
quality nonconformity on the quality of engineering units is analyzed in combination with figure 1 [2]. In terms of method, according to the establishment method of the above fault tree diagram, the unqualified concrete entity tree diagram can be obtained, as shown in FIG. 4. The detailed explanation of figure 4 is given in table 3, and the probability of each event is given by investigation method.

![Failure tree diagram of top event when concrete entity quality is unqualified](image_url)

**Table 3.** Concrete entity quality unqualified fault tree diagram and accident probability

| Symbol | Meaning                                           | Symbol   | Meaning                                           |
|--------|--------------------------------------------------|----------|--------------------------------------------------|
| T      | The concrete is of poor quality                  | X_2      | Uncorrected plumb sag (probability 0.02)         |
| E_1    | The verticality measured is unqualified          | X_3      | Strut instability (probability 0.02)             |
| E_2    | The flatness measured is not qualified           | X_4      | Formwork flatness unqualified (probability 0.01) |
| E_3    | The measured rebound strength is unqualified     | X_5      | Wood square flatness unqualified (probability 0.02) |
| E_4    | Poor workmanship                                 | X_6      | Formwork slurry leakage from joint joint (probability 0.04) |
| E_5    | The turnover material is not up to standard      | X_7      | Unqualified formwork reinforcement (probability: 0.02) |
| E_6    | The method of work is impractical                | X_8      | Sand unqualified (probability 0.01)              |
| E_7    | The raw material proportion of concrete is unqualified | X_9      | Stones fail (probability 0.01)                   |
| E_8    | Concrete maintenance is unqualified             | X_10     | Cement unqualified (probability 0.01)           |
| X_1    | Mold expansion after pouring (probability 0.05)  | X_11     | Failure of curing temperature and humidity (probability 0.02) |
|        |                                                  | X_12     | Failure of curing age (probability (0.01)        |

On the basis of table 3, The minimum cut set in FIG. 4 is obtained by using the above Boolean algebra method, as shown in formula (3).

\[
\{x_1 \cup x_2 \cup x_3 \cup x_4 \cup x_5 \cup x_6 \cup x_7 \cup x_8 \cup x_9 \cup x_{10} \cup x_{11} \cup x_{12}\}
\]

The structural function expression is shown in formula (4).

\[
f = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12}
\]
The probability of each time mentioned above is put into formula (4) to calculate the probability of concrete entity quality qualification of the project: 1-0.24=0.67 (concrete quality qualification represents the reliability of this part) [3-4].

2.3 Calculation of Unit Cost Reliability

Combined with the historical records before the example project, the actual costs of the previous 80 projects were counted. Then, the statistical results were compared with the estimated costs, and the cost overrun rate and frequency were calculated again, as shown in table 4.

Table 4. Cost overruns of 80 example projects

| Cost overrun rate (%) | The frequency of | frequency |
|-----------------------|------------------|-----------|
| -30~25                | 1                | 0.0125    |
| -25~20                | 4                | 0.05      |
| -20~15                | 3                | 0.0375    |
| -15~10                | 8                | 0.1       |
| -10~5                 | 11               | 0.1375    |
| -5~0                  | 17               | 0.2125    |
| 0~5                   | 12               | 0.15      |
| 5~10                  | 9                | 0.1125    |
| 10~15                 | 8                | 0.1       |
| 15~20                 | 4                | 0.05      |
| 20~25                 | 1                | 0.0125    |
| 25~30                 | 2                | 0.025     |

Combined with table 4, the distribution diagram of the over-expenditure rate (or frequency) was obtained according to the cost over-expenditure theory, as shown in figure 5. According to figure 5, it can be seen that there are obvious peaks and valleys in the cost overexpenditure rate of the project, but the overall distribution of overexpenditure tends to be normally distributed, which indicates that the reliability of the project cost is qualified, but it still needs to be improved [5-7].

3. Multi-Objective Optimization under the Constraint of Construction Reliability Based On Ant Colony Algorithm

3.1 Establishment of Relationship Model

Combined with the above three indicators of safety, quality and cost, this part will first establish the relationship model of the three indicators. Firstly, on the basis of table 1, the time units of each unit of work, namely a and m, are obtained, where a represents Tim of the maximum working state. M represents the t10 of the normal construction state of the project; B represents the direct cost under the conditions of a and m. On this basis, combined with unit cost and engineering quantity, the direct cost
of each of the 11 work units of the project is obtained, as shown in table 5, and the quality reliability and safety reliability performance are listed in it [3].

**Table 5.** Direct cost, quality reliability, safety reliability of each item in the work unit

| The unit of work | Duration (d) | Cost (yuan) | The quality of | Internal security | The external security |
|------------------|--------------|-------------|----------------|-------------------|----------------------|
| The name of the  | m a          | Normal      | limit          | Normal limit      | Normal limit         |
| earthwork        | 21 14        | 1100 911    | 1383 750       | 1 0.86            | 1 0.85               |
| Cushion engineering | 15 12      | 1000 00     | 1250 00        | 1 0.93            | 1 0.88               |
| Floor engineering | 45 38        | 1000 000    | 1100 000       | 1 0.91            | 1 0.95               |
| The principal part of the project | 75 62 | 4500 000 | 4800 000 | 1 0.92 | 1 0.90 | 1 0.81 |
| Waterproof engineering | 12 8 | 8790 00 | 1098 75 | 1 0.86 | 1 0.95 | 1 0.87 |
| Backfill works | 11 6 | 9733 58 | 1048 425 | 1 0.88 | 1 0.85 | 1 0.80 |
| Rough finishing project | 7 5 | 5064 6 | 5700 0 | 1 0.90 | 1 0.91 | 1 0.98 |
| wrought iron installation,engineering | 8 6 | 1026 8 | 1150 0 | 1 0.87 | 1 0.92 | 1 0.96 |
| Piping installation engineering | 18 15 | 3713 00 | 4000 00 | 1 0.95 | 1 0.92 | 1 0.96 |
| Embedded parts and casing | 11 7 | 3188 | 3250 | 1 0.90 | 1 0.88 | 1 0.95 |
| Completion inspection and acceptance | 2 2 | 4500 | 4800 | 1 1 | 1 1 | 1 1 |

Based on table 5, to get the cost of each unit of work time function model, the maximum compression time for confirmed that a single unit of work ti0 ~ Tim, then according to the above (2) the reliability of the unit of work) in the formula of three indicators, get a single unit of work quality time function relationship, the safety time function, cost, time function relationship.

### 3.2 Constraint Conditions

On the basis of the above, this paper analyzes the constraint conditions existing in the three index relations of each work unit of the project. Combined with the relevant data of the example project, the total cost of the project is 910 yuan. On this basis, the reliability evaluation model is adopted to take "cost Rt reliability" as the lower limit of the cost reliability of the project (the set value here is: 0.7500,0.8000, where 0.7500 is the lower limit). Combined with the above calculation results of work quality reliability Rq=0.67 and safety reliability calculation Rs0.68, the value is taken as the lower limit of work quality reliability and safety reliability. After the final analysis, the constraint conditions of the three indexes were obtained: Rt was greater than or equal to 0.75; Rq acuity 0.67; Rs 0.68 or higher [8-10].

### 3.3 Ant Colony Optimization Algorithm is Used to Solve the Multi-Objective Optimization Model

In accordance with the ant colony algorithm to solve, first of all around the above calculation results, the parameters setting: ant population size 40, subgroup size 10, pheromone inspired factors,
pheromone expectations, secondly, with the Matlab programming based on parameters of the 18 500 iterations to get the optimal solution, in which every solution is 11 units of work about the optimum combination of cost, quality and safety, this article selects two overview in table 6.

**Table 6.** Optimization model of ant colony algorithm

| Optimal solution (example) | Cost reliability | Quality reliability | Safety reliability |
|---------------------------|------------------|---------------------|-------------------|
| One                       | 0.79             | 0.92                | 0.91              |
| Two                       | 0.81             | 0.87                | 0.88              |

**4. Conclusion**

Through this article analysis, know the construction system reliability depends on safety, quality and cost, on this basis, combining with the instance, through a variety of calculation method, got the project 11 units of work safety, quality and cost of the original data, numerical reliability, constraint condition, finally combined with ant colony algorithm to solve multi-objective optimization model, working unit around solving numerical value of the construction program, when the scheme to achieve the optimal skill value, then optimized effectively.

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