Engineering Cost Estimation Model Based on an Improved Artificial Fish Swarm Algorithm

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Abstract — In order to improve the reliability and accuracy of cost analysis of engineering project, a rapid estimation model of project cost based on improved artificial fish swarm algorithm is put forward. Firstly, the quantitative index of project evaluation result is built through Building Information Modelling (BIM) method as the optimization objective of rapid estimation of project cost. Second, we achieve this objective by using an artificial fish swarm algorithm. Furthermore, to improve the local search capability and performance of the artificial fish swarm algorithm, the simulated annealing method is used to realize a comprehensive improvement of the algorithm performance. Finally, the simulation comparison between BIM project software of Thsware, Glodon, Luban shows that the proposed algorithm is of higher estimation accuracy and efficiency.

Keywords- artificial fish swarm algorithm; bim project; cost analysis; simulated annealing

I. INTRODUCTION

With the rapid development of economy and society, more and more tunnels are constructed in mountainous area [1]. But for the complexity of mountainous terrain, it is difficult to avoid building bias tunnel, especially in portal section, along the river area, along the mountain area, etc. Because the unsymmetrical load of bias tunnel, it is necessary to study the construction technology in such condition.

The cost analysis of construction project involves various links of purchasing, transportation, recycling and maintenance of raw materials. Using BIM model to conduct cost analysis of engineering construction and tracing control has become one of hotspot directions in current construction cost control field.

Literature [3] conducts the research analysis for the components related to the construction cost by using BIM model, which forms the construction component of simplified form. Literature [4] evaluates the cost of construction project by using BIM model. Literature [5] constructs the evaluation system for life cycle of building and research on building environment interference in life cycle. Literature [6] constructs building evaluation model under the influence of cost based on construction cost evaluation model and acquires the environment interference factors of building example. The construction method of building model based on BIM has obvious advantages, which is widely applied in application occasion of building evaluation. Current relevant research on construction cost model applies the 3D model evaluation framework of project BIM technology, which is the practical method of cost factor influence.

Figure 1. Project cost management
This paper is mainly intended to construct the model relations between construction materials and BIM elements from the cost analysis angle of construction project based on BIM technology and improved artificial fish swarm algorithm so as to form the systematic evaluation method of quantization component of building and improve the reliability of cost evaluation.

II. DEFINITION OF REFINED PROJECT COST

A. Definition Description

The refined management of cost means to conduct refining management for each project stage and realize the phased strengthening management of the cost. For all stages of project implementation, the resources shall be optimized for configuration and the “three excesses” phenomenon shall be avoided. The management links of refined project cost mainly include: design, decision, construction, bidding and completion. The cost management and relevant subject involved in these five stages are shown as Fig. 1.

Refined project cost management is the premise of determination and control of reasonable cost. In order to realize the reasonable evaluation of investment, it shall be determined within the control limit range of total cost. Particularly in the cost evaluation stage of design, it shall be guaranteed that the cost evaluation value is more reasonable than the cost evaluation value in investment stage and it is affected by cost evaluation in investment stage. For the cost evaluation in design stage of construction drawings, the refining evaluation shall be conducted according to the design thought of construction drawings and materials. For construct cost management, the key point of cost evaluation is to deal with the bidding cost between construction unit and contractor. For the schedule of process construction project and management of advance funding matters, it shall combine the two key links of construction actual design and earlier stage design of program. For the final settlement and settlement management link of construction project, the actual project cost shall be summarized and the cost in each project stage shall be controlled.

B. BIM Quantitative Evaluation Model

Here the cost management process of research building project of certain university in China is taken as the research object. And the cost analysis is conducted through researching on the cost management process of the construction project. After determining the cost evaluation section, the model relation between construction materials and BIM elements shall be constructed.

The main evaluation indexes of construction project include: technology, environment and cost. According to the above factor features, the unique correlation model between index and subsystem can be built and the hierarchical structure evaluation model of multi-complex factors cost management of project can be built. The model is divided into three groups of different levels: (1) comprehensive influencing parameters of environment; (2) Economic index, project index and environment index; (3) Specific evaluation index, shown in Table 2.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Name of material</th>
<th>Nomen of model</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FA_concrete_fine stone</td>
<td>100+150</td>
<td>74.168</td>
</tr>
<tr>
<td>2</td>
<td>FA_concrete_rebar</td>
<td>100+150</td>
<td>18.532</td>
</tr>
<tr>
<td>3</td>
<td>FA_concrete_fine stone</td>
<td>100+200</td>
<td>19.918</td>
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<td>4</td>
<td>FA_concrete_rebar</td>
<td>150</td>
<td>5.974</td>
</tr>
<tr>
<td>5</td>
<td>FA_concrete_rebar</td>
<td>FW-150</td>
<td>0.218</td>
</tr>
<tr>
<td>6</td>
<td>FA_concrete_rebar</td>
<td>JT-150</td>
<td>118.156</td>
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<td>7</td>
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<td>SH-150</td>
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</tr>
<tr>
<td>8</td>
<td>FA_concrete_rebar</td>
<td>0.218</td>
<td>290.128</td>
</tr>
</tbody>
</table>

Complete cost evaluation process usually involves the stages of production, operation construction and maintenance. Based on 8 groups of unit component of floor slab production shown in Table 1, the influence of production process on cost evaluation is evaluated. The solution result of relevant index involves the economic index, namely the environment governance input and construction material price. The rest index is calculated by setting these two factors as the variable and taking advantage of the BIM model. The specific situation is shown as Table 3.

III. SIMULATED ANNEALING ARTIFICIAL FISH ALGORITHM (SA-AFSA)

A. Basic Artificial Fish Algorithm

Artificial fish swarm algorithm is a kind of swarm intelligence algorithm, which has rapid rate of convergence and strong global optimization capability with not high requirement for initial value and objective function. It simulates the behavior of foraging, bunching and tailgating of fish swarm in nature so as to realize the global
optimization and find the optimal solution of the problem [10].

(1) Foraging behavior. Suppose that the current status of artificial fish is $X_i$, and select a status $X_j$, in its sight range. If $Y_i < Y_j$, make a step forward towards this direction. See details in Formula (1); If it does not meet the condition, move a step randomly. See details in Formula (2).

$$ X_{i+1}^t = X_i^t + \frac{X_j^t - X_i^t}{|X_j^t - X_i^t|} \cdot \text{Step} \cdot \text{Rand}() $$(1)

$$ X_{i+1}^{t+1} = X_i^{t+1} + \text{Step} \cdot \text{Rand}() $$ (2)

In the formula, $Y_i$ represents the concentration of food in $X_i$ status, Step is the step length of movement, Rand() represents the random number within the scope of (0,1).

(2) Bunching behavior. Currently, artificial fish $X_i$ explores the partner number $n_f$ and central position status $X_c$ in its right range. If $Y_c/n_f > \delta Y_i$, it shows that there are many foods in partner center and it is not crowd, and make a step towards the partner center. See details in Formula (3), otherwise execute foraging behavior.

$$ X_{i+1}^{t+1} = X_i^{t+1} + \frac{X_c^t - X_i^t}{|X_c^t - X_i^t|} \cdot \text{Step} \cdot \text{Rand}() $$ (3)

(3) Tailgating behavior. Currently, artificial fish $X_i$ explores the partner $X_j$ with the maximum food concentration value in its sight range. If $Y_j/n_f > \delta Y_i$, then make a step forward towards the artificial fish $X_j$ with the maximum food concentration, otherwise execute the foraging behavior.

(4) Random behavior. The artificial fish select a status randomly in sight range and move towards the direction, its foraging behavior is the default behavior.

(5) Billboard. The billboard is used to record the status of optimal artificial fish. After the behavior of each artificial fish, the artificial fish status at that time will be compared with the status recording on the billboard. If current status is more superior, the billboard shall be updated. After the completion of algorithm, the element value on billboard is the optimal value and it corresponding status is the optimal solution.

B. Introducing Annealing Operation

The AFSA local search capability with mutation operator is not strong and it is hard to acquire the globally optimal solution. SA has strong local search capability, therefore, the optimal solution acquired form AFSA with mutation operator is abandoned and left according to Metropolis criterion. In each iteration process of SA, if the fitness function of optimal solution increases, it will be accepted, otherwise it is judged whether to be accepted according to Formula (4).

$$ Q(T_{i+1}) = \begin{cases} 
1 & f_{i+1} < f_i \\
\min \left[ 1, \exp \left( \frac{f_i - f_{i+1}}{\text{random}(0,1)} \right) \right] & \text{otherwise}
\end{cases} $$ (4)

In the formula, $f_i$ is the fitness value of optimal solution acquired in $i$ iteration, $Q(T_{i+1})$ is the probability of acceptance in the temperature of $T_{i+1}$, $T_{i+1}$ can be expressed as:

$$ T_{i+1} = \alpha \times T_i $$ (5)

In the formula, $\alpha$ is the temperature cooling coefficient.
Figure 2. Workflow of SA-AFSA
Because AFSA with mutation operator is affected by random step length, sight range and random behavior, etc, the accuracy of optimal solution acquired when it initializes the weight vector of equalizer is not high. Therefore, after the AFSA with mutation operator acquires the optimal solution and cascades the SA with strong local search capability, the globally optimal solution with “high accuracy” can be acquired. SA-AFSA introduces the SA algorithm with mutation operator and local search capability, and its working process is shown as Fig. 2.

C. Algorithm Step

when conducting project cost evaluation, the procedure of rapid estimation model of project cost based on improved artificial fish swarm algorithm is:

Step 1: Using BIM technology to construct the process cost model in different periods of construction, the cost feature in certain period of construction is selected. The feature is divided according to time and the cost feature in independent period is acquired. \( C_j (j = 1, 2, \ldots, n) \) is selected according to criterion;

Step 2: According to specialist discrimination, the entropy conducts the weight assignment according to the decision criterion in cost management process and the criterion \( C_j (j = 1, 2, \ldots, n) \) is acquired;

Step 3: The rapid estimation model of project cost based on improved artificial fish swarm algorithm conducts optimization decision for the project cost features in different periods and acquires the optimal cost combination evaluation;

Step 4: The feature vector acquired by optimal solution is normalized. And the consistency verification is conducted to acquire it direct ratio and inverse ratio index.

IV. EXPERIMENTAL ANALYSIS

A. Index Analysis

Here BIM project cost software of Thsware, Glodon, Luban are taken as the basic modeling software. And conduct index evaluation combining the proposed algorithm in the Paper. The evaluation index selection is shown as followings: software installation, safety evaluation, function universality. Select Literature [11] algorithm compared with settlement algorithm.

According to the process demand of decision evaluation, the criterion is divided into such five criterion levels as "totally poor" "poorer" "ordinary" "very well" "extremely well". Based on this, the remark set can be acquired: \( V = \{ v_1, v_2, v_3, v_4, v_5 \} = \{ \text{totally poor, poorer, ordinary, very well, extremely well} \} \). For the poorest level \( v_1 \), its assignment is 50 scores. For the best level \( v_5 \), its assignment is 100 scores. The quantitative level vector can be acquired:

\[
B = \{ 50, 60, 80, 90, 100 \}
\] (6)

Literature [11] is the project cost analysis conducted on the basis of specialist evaluation form. First, the specialist evaluation is conducted according to defined level and evaluation data statistic analysis is realized based on mathematical statistics. The membership value is acquired. For example, 10 specialists in different fields evaluate the project cost index. If nobody selects \( V_1 \) and \( V_2 \) evaluation level, 2 persons select \( V_1 \) evaluation level, 5 persons select \( V_2 \) evaluation level and 3 persons select \( V_3 \) evaluation level, the vague evaluation value of the cost software index is \( (0,0,0.2,0.5,0.3) \).

B. Result Analysis

The vague evaluation value of index of algorithm in the Paper + Thsware, Glodon and Literature [11] + (Thsware, Glodon, Luban) is shown as Table 3.

| TABLE 3. COMPARISON BETWEEN OPTIMAL EVALUATION RESULTS |
|-----------------------------------------------|-----------------|-----------------|
| Evaluation index | Software | Algorithm in the Paper | Numerical value |
| Software installation | Glodon | Algorithm in the Paper | 91.2 |
| | Thsware | Algorithm in the Paper | 89.7 |
| | Luban | Algorithm in the Paper | 88.6 |
| Safety evaluation | Glodon | Algorithm in the Paper | 86.2 |
| | Thsware | Algorithm in the Paper | 86.3 |
| | Luban | Algorithm in the Paper | 92.7 |
| Function applicability | Glodon | Algorithm in the Paper | 86.9 |
| | Thsware | Algorithm in the Paper | 84.3 |
| | Luban | Algorithm in the Paper | 85.4 |
| Comprehensive evaluation | Glodon | Algorithm in the Paper | 89.9 |
| | Thsware | Algorithm in the Paper | 88.2 |
| | Luban | Algorithm in the Paper | 86.7 |
algorithm in the Paper + (Thsware, Glodon, Luban) is superior to that of Literature [11] + (Thsware, Glodon, Luban). It reflects the validity of proposed algorithm. As for three BIM software of Thsware, Glodon, Luban, the score of Glodon is the lowest, the scores of Thsware and Luban are much better. Generally, the cost quality of Thsware and Luban is better.

The operation time of algorithm in the Paper + Thsware, Glodon, Luban and Literature [11] + (Thsware, Glodon, Luban) is shown as Fig. 3.

![Fig. 3. Comparison of algorithm operation efficiency](image)

It is shown from Fig. 3 Comparison of Algorithm Operation Efficiency that algorithm in the Paper is superior to the comparison algorithm in Literature [11] in the aspect of calculation efficiency. Meanwhile, comparing the software of Thsware, Glodon, Luban, it is shown that the operation efficiency of Luban and Thsware is higher and the operation efficiency of Glodon is lower.

Standardized comprehensive weighted analysis is conducted for economic index according to the indicated results of algorithm model in the Paper, under the setting condition of price variable \( P \); the cost influence evaluation result of 1–8 component element in Table 3 can be acquired:

\[
D_1 = 0.132P_1 + 0.013, \quad D_2 = 0.132P_2 + 0.026
\]

\[
D_3 = 0.132P_3 + 0.0173, \quad D_4 = 0.132P_4 + 0.0068
\]

\[
D_5 = 0.132P_5 + 0.0007, \quad D_6 = 0.132P_6 + 0.1876
\]

\[
D_7 = 0.132P_7 + 0.0246, \quad D_8 = 0.132P_8 + 0.4876
\]

Based on the above analysis result, the corresponding cost influence of 8th group of component in 8 groups component is the biggest, the reason is that the structure mass of the component is bigger that that of other components. For 2, 3 and 7 component, their cost evaluation influences are close, showing the difference of influence of different construction material selection on cost evaluation. Moreover, the environment influence factor based on above analysis result shall be emphasized and the calculation difference for different component element shall be refined.

V. CONCLUSION

The Paper puts forward a rapid estimation model of project cost based on improved artificial fish swarm algorithm, constructing quantitative index of project evaluation result by using BIM model as the optimal objective of rapid estimation of project cost, conducting objective optimization of rapid estimation for project cost by using artificial fish swarm algorithm and verifying the effectiveness of algorithm through comparison among the project software of Thsware, Glodon, Luban.

REFERENCES

