Multi Objective Optimization Design of Building Construction Period based on BIM and Genetic Algorithm

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Abstract. China's construction industry market competition is becoming increasingly fierce, which requires construction enterprises to gradually enhance the core competitiveness. Therefore, the construction period must be multi-objective optimization (hereinafter referred to as MOO), which will improve the level of project management in the construction process. Through the MOO of construction period, we can achieve the overall cost optimization of construction projects. Through the coordination of construction project scheduling, we can improve the overall efficiency and efficiency of project operation, which will improve the utilization of resources and save the project cost. Genetic algorithm (hereinafter referred to as GA) can solve the adaptive global optimization probability search, which is a method to optimize the model process. By integrating GA into BIM platform, we introduce methods such as virtual construction and collision check, which can reasonably deal with complex MOO problems. The construction schedule and cost can be determined more quickly and reliably through the construction schedule. Therefore, this paper puts forward the MOO design among construction period, quality, safety and cost.

Keywords: BIM, GA, Construction, Multi Objective Optimization

1. Introduction
With the scientific development of project management concept, people have a deeper understanding of project management. In the project management, the construction unit is no longer limited to the three objectives of construction period, cost and quality, which has been extended to the objectives of safety, information and environment [1]. Among different stakeholders, different objectives are interdependent, which will affect the related cost. Therefore, we must deal with the relationship between many objectives, which will better achieve the overall objectives of project management. By coordinating the conflict of interests among different stakeholders, we can achieve the optimal equilibrium of multi-objective. Therefore, MOO in construction management has become a hot research issue [2-4]. At the same time, BIM is the future development direction of the current construction industry, which involves the whole life cycle of construction [5, 6]. Therefore, we can combine the MOO based on GA with BIM, which will be applicable to the construction MOO of life cycle parts [7].
2. Basic operation process of GA
GA is a search optimization method based on molecular genetics theory, which is an adaptive global optimization probability search algorithm. Through the information exchange between individuals in the population, GA has strong macro search ability. At the same time, GA can simulate the reproduction, mating and mutation in genetics, which can produce a new population more adaptable to the environment. However, there are still some problems in different GAs. The basic operation process of GA is shown in Figure 1.

![Figure 1. The basic operation process of GA.](image)

3. Analysis of the relationship between multi objectives in construction

3.1. Duration cost relationship
Direct cost and indirect cost are the main components of construction cost. Among them, direct costs include personnel, materials, machines and measures, while indirect costs include fees for regulations and enterprise management. According to the relevant research, this paper obtains the time cost relationship diagram, as shown in Figure 2. Among them. From $T_i$ to $T_0$, the construction cost is negatively correlated with the construction period; from $T_0$ to $T_n$, the construction cost is positively correlated with the construction period. Therefore, different construction schemes will result in different construction costs.

![Figure 2. Duration cost relationship.](image)

Therefore, we can choose a reasonable scheme to shorten the construction period, which will obtain social and economic benefits. Among them, $T_i$ is the shortest duration of process $i$, $T_0$ is the reasonable duration and $T_n$ is the longest duration under a certain construction scheme.
3.2. **Quality cost relationship**

According to the relevant research, this paper obtains the quality level Q-construction cost C relationship, as shown in Figure 3. From $Q_1$ to $Q_0$, there is a negative correlation between construction cost and quality level. From $Q_0$ to $Q_n$, the construction cost is positively correlated with the quality level. Therefore, the lower the requirement of quality level, the less investment of construction cost. If the quality level is lower than the reasonable quality level, the construction cost will not be reduced. Therefore, we have to choose a suitable point to achieve the lowest cost. Among them, $Q_1$ is the lowest quality level of process $i$, $Q_0$ is the normal quality, and $Q_n$ is the highest quality level.

![Figure 3. Quality Q-COST C curve.](image)

3.3. **Safety cost relationship**

According to the relevant research, this paper obtains the safety level R-construction cost C relationship, as shown in Figure 4. From $R_1$ to $R_0$, there is a negative correlation between construction cost and safety level. From $R_0$ to $R_n$, construction cost is positively correlated with safety level. Among them, $R_1$ is the lowest safety level of process $i$, $R_0$ is the normal safety level and $R_n$ is the highest safety level under a certain construction scheme.

![Figure 4. Safety cost relationship](image)

4. **MOO design in construction period**

4.1. **Construction of MOO model**

In this paper, the construction period, quality, cost, safety synergy target model, which constitutes the construction project multi-objective collaborative optimization model, as shown in Formula 1 and formula 2.


\[ \begin{align*}
\min T &= \sum_{i=1, j \in J} t_i \\
\max Q &= \sum_{i=1}^n \omega_i \left( \omega_{i_1} q_{i_1} + \omega_{i_2} q_{i_2} + \omega_{i_3} q_{i_3} \right) \\
\min R &= \sum_{i=1}^n \omega_i * L_i * E_i * C_i
\end{align*} \] (1)

\[ \begin{align*}
\min T &= \sum_{i=1, j \in J} t_i \\
\sum_{j=1}^n \omega_j &= 1 \\
\omega_j &\geq 0 \\
0 &\leq q_{i_1} \leq 100 \\
0 &\leq q_{i_2} \leq 100 \\
s.t. &\quad 0 \leq q_{i_3} \leq 100 \\
&\quad 0 \leq L_i \leq 10 \\
&\quad 0 \leq E_i \leq 10 \\
&\quad 0 \leq C_i \leq 10 \\
\end{align*} \] (2)

4.2. Fusion of BIM model and MOO design

Time cost optimization is a problem with many factors. GA can check the conflict caused by drawings, types of work and process. Through the introduction of BIM Technology, we can connect the BIM Technology with the algorithm, which can simulate the construction site, sunshine and heat conduction in advance. BIM model can automatically change the specific parameters of GA, which can be re-optimized. Therefore, based on GA, we can carry out BIM schedule management and cost management, which can carry out real-time management of project duration and cost.

4.3. Construction project MOO model GA process

Based on GA, this paper establishes the resource balance optimization process of construction system, as shown in Figure 5.
5. Conclusion

In project management, construction period, cost, quality and safety are important objectives of construction. Therefore, this paper develops a new optimization model based on the principle of GA and BIM Technology, which can be used for MOO design optimization. By considering the construction period and cost, this paper designs a set of algorithm program which accords with the characteristics of construction project, which will make up for the defects of traditional optimization scheme. Through MOO, we can find the best combination of construction activities to meet the requirements of different projects, which will have the function of short construction period, low cost and no collision.

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