Study on trade-off of time-cost-quality in construction project based on BIM

XU Yongge [1, a], Wei Ya [1, b]

[1] Xi'an Univ.of arch. & Tech., Xi'an 710055, China;

[a]15829690177@163.com, [b]631931577@qq.com

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Abstract. With the development of BIM technology, BIM provides a new direction for the project management of three objectives. Based on the current situation of the project time cost-optimized mass balance studies, pointing out the implementation mechanism of achieving the trade-off of time-cost-quality in construction project based on BIM mainly oriented components of the BIM model based; the use of Structured Query Language query statistics data information needs combined bill of quantities calculation method for the specification, preliminary engineering scale generation; establishment of Project relations system model. In the process duration is subject, for the construction of uncertainty factors such as interest rates and prices, through the establishment of quality, cost and schedule function, the establishment of quality balanced schedule cost optimization model, using genetic algorithm model of the optimal solution are obtained. With BIM case finally proves the rationality of the model and the effectiveness of the proposed genetic.

1. Introduction

Balance between the three objectives of the optimization problem has also been a research scholar in the field of project management focus at home and abroad, as early as 2005 EI-Rays on the proposed project schedule cost optimization of the quality of discrete model (TCQTP), 2008 Mr Yeung Hung et al. Taking into account the uncertainty of the project, presented the project duration cost quality Fuzzy Tradeoff Optimization model (FTCQTP), and the use of adaptive genetic algorithm to obtain the optimal solution of the model, in 2013 camp Lian [1]and others to step duration of decision variables to establish a balance of the three fuzzy optimization model, genetic immune particle swarm optimization algorithm with fuzzy multiple Pareto optimal solutions and draw a three-dimensional scatter plot. But previous studies, there are two problems: first, the quality of the project cost optimization model schedule some parameters by the policy makers need to give their weights, but often the actual situation of the project is very complex, limited experience of policy makers, leading to right in the weight value is not enough objective factors affecting the scientific model[2]; and second, the above model is based on a comprehensive CAD-based optimization, the use of related management software to the CAD model and cost, schedule software integration to give 4D model, then with manual or semi-manual mode will cost data, schedule data and CAD models linking the lack of interoperability in this way, but also very complicated, to some extent, hinder the smooth progress of the project management [3].

The main goal of the project is to control time, cost and quality, and these three mutual unity of opposites. In the project management process, in order to achieve the project's economic and social benefits, usually we need to study how to optimize the combination of the three, the rational allocation, in order to achieve the quality requirements of the project goals and schedule targets within budget limits. To achieve a balanced optimization of the three means of construction resources to the project, construction materials and installation costs dynamic,, and other complex information have a definite to control. Parametric BIM technology through the establishment of a multidimensional model of Participation parties to establish information platform, a collection of information can be highly utilized to achieve visual effects, optimize the construction schedule,

improved construction methods, cost savings, to achieve a balanced schedule optimization project cost quality[4].

2. The optimization mechanism of trade-off of time-cost-quality in construction project based on BIM

Building Information Modeling BIM (Building Information Modeling, called BIM) is a three-dimensional digital imaging technology, the integration of multiple modeling tools, a digital representation of the building to achieve physical and functional characteristics. Currently BIM technology research and application resource consumption in the largest construction phase is not yet mature, in the project management of the above studies most scholars of BIM only independent research for the time, cost and quality, but as the project management key elements of the project schedule, there is a dialectical relationship between cost and quality, the three unity of opposites, and can't focus only on the use of BIM to achieve optimization of project management from the actual purpose of the work schedule, cost or quality is unreasonable. In fact, BIM has the following three characteristics can be achieved cost-quality balance project schedule optimization:

First, based on the components of the BIM model-oriented, relational database objects for each component in order to "record" in the form generated corresponding table, and can be transferred via structured query language of the data in the table, with the final form by Graphic Converter building models reasonable properties, provide timely and effective data base for the BOQ, project cost, schedule and so on.

Secondly, the use of Structured Query Language queries require statistical data combined with the construction bill of quantities calculation specification (GB50500-2013) to generate preliminary engineering scale. For the Bill of Quantities not automatically generated can be incorporated into sporadic work items table based pricing norms, the list of measures project, other projects within the list.

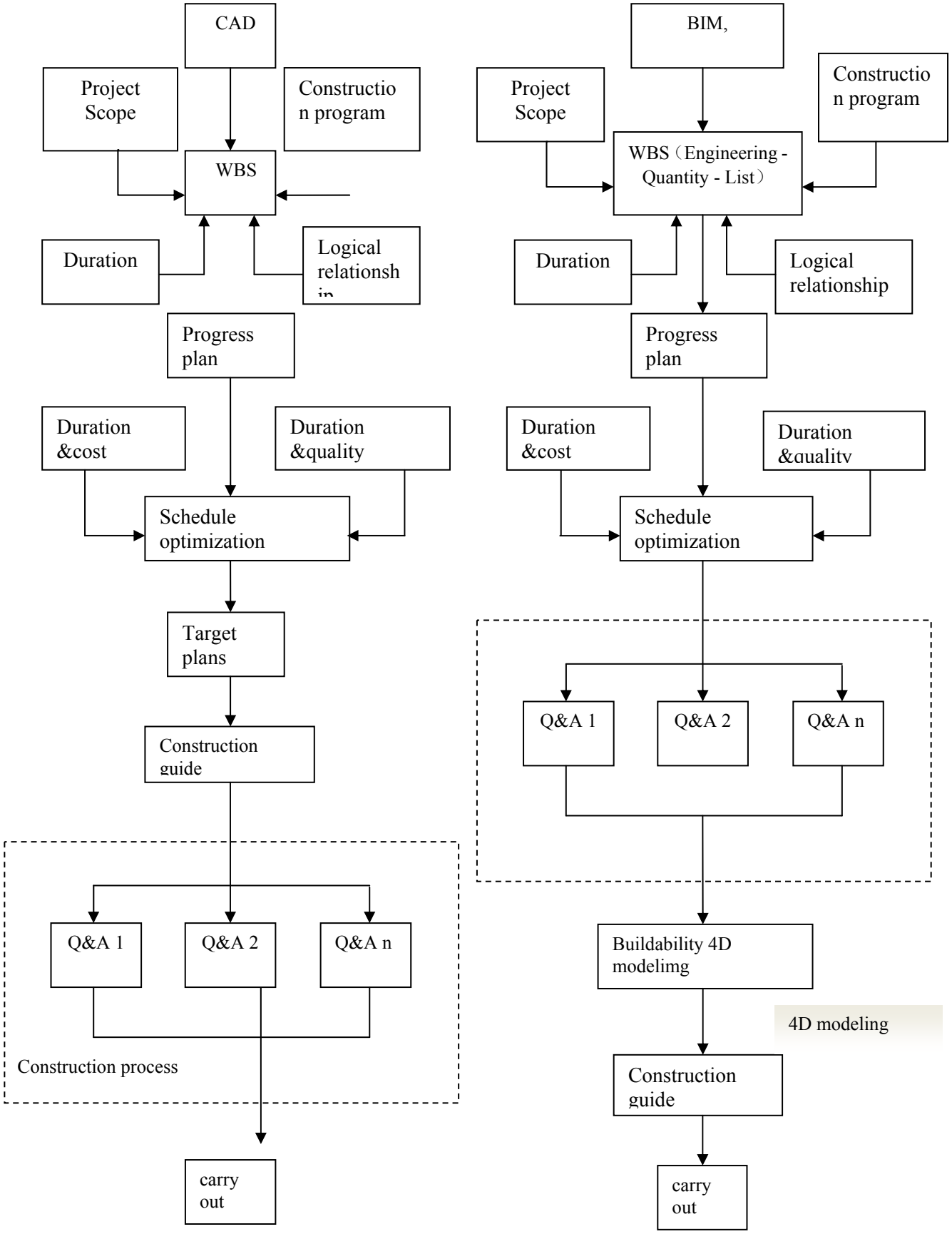

Fig 1. Comparison of traditional and BIM based three target equilibrium optimization process

Finally, based on the BIM model and relational databases, in order to establish the relationship between the project system model as the core. The model project components, project schedule, BOQ item associated with the model by associating the three, for engineering scale each component has unique Structured Query Language query commands, through the query associated with the project list of items corresponding amount, when the inquiry is completed, the components associated with the BOQ items also completed [5].

Through the above analysis, the three major objectives of the traditional balancing optimization processes and optimizing processes were compared based on three objectives balanced BIM, shown in Figure 1. Can be visualized by the following diagram shows the difference between them[6].

3.Construction of equilibrium optimization modeling

3.1 Basic assumption

Hypothesis 1: the project has no other resources except the funds

Hypothesis 2: each job is composed of a finite number of jobs and is independent of each other, and the duration of each job is subject to normal distribution.

Hypothesis 3: the uncertainty in the construction process of the engineering project is expressed with hesitation.

Definition 1: project cost includes direct cost and indirect cost of two parts. Direct costs include labor costs, material costs, construction machinery and construction costs, etc., indirect costs, including the cost for the project management, etc.

Definition 2: the total quality of the project for the work is the average value of the quality of the

3.2 The restricting relationship among the duration /cost / quality

1. The restricting relationship between the duration and cost

This paper assumes that the indirect cost is linear with the project duration. Because of the long term and the time value of the project, the project cost is in the process of the project.

With the continuous compound interest method to calculate the time value of money, the function relationship between time and cost for:

$$MinC = \Delta C^{i}\left(P/A,\ i_0,\ T\right)+\sum q_j e^{\left[-i_o\left(t_j+d_j\right)\right]\left[1+\frac{r}{T}\left(P/A,\ i_0,\ T\right)\right]}$$

Among them, ΔC^{i} is the fixed value, expressed as a unit of time within the connection fee. P / A is the present value of the annuity factor. i_0 is the discount rate for the benchmark. q_j is the cash flow for the direct cost of work j. t_j is the finish time for the pre work. d_j is the duration of work j. r is as a unit of time price increases, the project started construction on the average value of a year building materials prices.

2. The restricting relationship between the duration and quality

In the process of engineering construction, if the project duration less than or close to normal period may lead to shoddy, reducing the quality of the project. If the project duration is too long will appear "student syndrome" effect, leading to tardiness, cost, project quality decline[7]. According to the above characteristics, too short and long duration can reach the optimal project quality, which is in line with the characteristics of the bell curve. In this paper, a bell shaped curve expression of the function relation between the duration and quality:

$$Q_i = \frac{1}{1+\left|\frac{T_{in}-T_{io}}{a}\right|^{2b}} \quad \text{i=1,2,……n} \quad : \quad Q=\frac{1}{n}\sum\nolimits_1^n Q_i = \frac{1}{n}\sum\nolimits_1^n \frac{1}{1+\left|\frac{T_{in}-T_{io}}{a}\right|^{2b}}$$

Among them ,Q is the total project's quality, Q_i is the quality of work i, T_{io} is the shortest time of i,a is the difference between the minimum time and maximum time of i.b generally taken to be 1.5.

3. The probability of completion

This paper evaluate the probability of completing the project according to the size of the planned duration of the use of probability of completion. PERT network analysis assumed that the duration of the work of obedience β distribution is approximated by a third estimation method to estimate the value of three times, that is the shortest, longest, and most likely duration, this method is certainly the type of problems into non-calculated with definite problem with the variance estimated time deviation analysis, correlation formula is as follows:

$$T_i = \frac{T_{io} + 4T_{in} + T_{ip}}{6} \qquad \sigma_i = \frac{T_{IP} - T_{io}}{6} \qquad \lambda = \frac{T - T_m}{\sigma}$$

Among them , T_{io} is the minimum duration of work i, T_{in} is the normal duration of i. T_{ip} is the longest duration of i , σ_i is the standard deviation duration of i , λ is the project's probability of completion , T_m represents the sum of the average duration of the work on the critical line, σ is the standard deviation of critical line .

4. The equilibrium optimization model

Taking the project construction period as the research object, considering the quality and cost of the project, the construction project cost and the quality of the project is built.

$$Z = \min\{C, -Q, 1-\lambda\}$$

4.Model solving

Equilibrium optimization modeling can be considered as a combination optimization problem. Because of the complexity of engineering projects, the genetic algorithm can quickly find the optimal solution in the whole space, and the genetic algorithm can quickly find the optimal solution in the space.

Chromosome structure: each chromosome has a n gene, each gene position represents a process, each gene value indicates the operating time of the corresponding process.

Genetic manipulation:(1) Selection operation roulette wheel selection method;(2) Binary mutation operation is used in mutation operation;(3)Two-point crossover crossover selection method; adaptive parameters using the following formula:

Crossover probability:

$$pos_{CIS} = \begin{cases} \beta_1 - \beta_2 \times (f - f_{avg}) / (f_{\max} - f_{avg}) & f \geqslant f_{avg} \\ \beta_1 & f < f_{avg} \end{cases}$$

Variation probability:

$$pos_{mut} = \begin{cases} \beta_{3.} - \beta_4 \times (f - f_{avg}) / (f_{\max} - f_{avg}) & f \geqslant f_{avg} \\ \beta_3 & f < f_{avg} \end{cases}$$

Among them , $\beta_1, \beta_2, \beta_{3.}, \beta_4 \in [0,1]$;f stands for the genetic manipulation of two individuals to adapt to a larger value; f_{avg} stands for average fitness value; $f_{\max}$ stands for the maximum fitness value.

(4) The adaptive value takes the comprehensive evaluation index R, the evolution along the adaptation value in the direction of large.

$$R(A) = \frac{d(S(A),\ S(A^-))}{d(S(A),\ S(A^+)) + d(S(A),\ S(A^-))}$$

$$d(S(A),\ S(A^+)) = \sum_x w_x d(S(x),\ S(x_{\min})) \qquad d(S(A),\ S(A^-)) = \sum_x w_x d(S(x),\ S(x_{\max}))$$

A^+ stands for positive ideal solution $(C_{\min}, -Q_{\max}, 1-P_{\max})$, A^- stands for negative ideal solution $(C_{\max}, -Q_{\min}, 1-P_{\min})$;The weight of a is w_x, which is assigned by the decision maker.

(5)The calculation is terminated when the best individual for 30 generations did not change.

5. Case Study

BIM 4D construction simulation technology in the person A comprehensive hospital for a practical application. The total construction area of 29507 square meters, of which the ground area: 27931 square meters, underground area of 1576 square meters. Building storey height: 13 on the ground floor, 13 storey height of parapets 54.75 meters, 58.38 meters the highest point, 5 m three storey underground; the first floor layer is 4.8 meters tall, two to five storey is 4.5 meters, six to 13 layers of 3.6 meters high. The key of BIM technology application is to use structure Revit to build 3D model, based on BIM model for component oriented, using structured query language to extract the amount of engineering materials and the amount of statistics from the model. The establishment of the project schedule with the Project Microsoft after the establishment of 3D visualization model.

Select one of the sub items of the work duration, quality parameters and the direct cost is shown in Table 1:

Table 1 sub-project duration, quality parameters and direct costs Reference Table

Sub-project	Normal time			Shortest time			Longest time		
	T_{in}	C_{in}	Q_{in}	T_{io}	C_{io}	Q_{io}	T_{ip}	C_{ip}	Q_{ip}
1-2	5	1500	1	4	2000	0.7	7	1200	0.8
1-3	18	5000	1	15	6000	0.8	20	4000	0.83
2-3	32	10000	1	30	12000	0.9	35	8500	0.92
2-4	28	8000	1	25	10000	0.8	30	6500	0.78
3-4	32	12000	1	30	14000	0.9	35	11000	0.91
4-5	30	9000	1	17	10000	0.95	38	9100	0.97

Order ΔC^i =300, i_0=8%, π=5%，

The scale of population is 300. β_1 =0.9, β_2 =0.3, β_3 =0.15, β_4 =0.2. Obtain: $T_{\min}$ =58, $T_{\max}$ =123, $Q_{\min}$ =0.835, $Q_{\max}$ =1, $C_{\min}$ =71500, $C_{\max}$ =8500, Solving the 140 generation termination, the satisfactory solution is C=82400, Q=0.873, T=73, Schedule as shown in Figure 4:

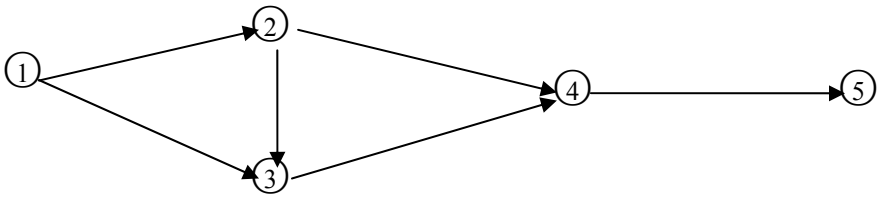

Fig.4 schedule network diagram

6. Conclusion

In this paper, the realization mechanism of BIM in engineering multi dimension management is cut in point, and the three aspects of quality objectives, time targets and cost objectives are considered. Through the integration of BIM management system, it makes up for the defects of the existing engineering project management system, which greatly improves the construction management decision-making, and provides a new way for the application of BIM technology in engineering project management and decision making. However, the practical application of the model has to be used to test, and the factors affecting the quality of the project construction period are different from the actual characteristics, which will be further deepened in the follow-up study.

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