Study on the Optimization of Aim-Oriented Construction Project's Control System

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Abstract

This paper analyzes the Time-Cost, Quality-Cost, Time-Quality aim optimization models of construction project, by studying on the aim system of construction project, and puts up an optimization model of Time-Quality-Cost.

Keywords: Construction project, Aim-oriented, Control system, Optimization

1. Introduction

The aim system of construction project is the description of the final state that will be accomplished in the construction project in essence. Because the project management adopts the aim management methods, construction project has a clear aim system that is the masterstroke during the project process. Project control is a process that includes a series of activities. During the process of accomplishing the project aim, the subjects of project management will examine and collect the information that reflects the project state, based on the prediction for the future and the original action plan, rules, and measures, by the organizational system and any possible way, and compare the information with the original plan. They will find errors and analyze relevant reasons, adopt measures to correct these errors and guarantee the normal execution of project plan, which can help to realize the original aim (Hu Cheng, 2004).

2. A brief introduction for the aim system of construction project

According to the structure of aim, the aim system of construction project is composed of three levels, namely the system aim, the child aim, and the operable aim. According to aim's levels and thinking ways, the aim system of the construction project, especially the large and complex one that has great effects on national economy has three aspects, namely the real thinking aspect (includes quality, cost, time, source, and other basic aims), the logical thinking aspect (refers to the satisfying aims in every aspects), and the philosophical thinking aspect (includes aims of coordinating with environment and sustainable development) (Liping Lan, 2004).

(1) Quality aim. The quality aim during the lifelong period of construction project is the unity of the work quality, the project quality, and the final quality of project functions, products, or services. It emphasizes more on project technology system's integrated functions, technological standards, and safety. Thereof, the design quality includes quality of design work, technological standards, and feasibilities. The construction quality includes quality of materials and equipments, construction quality system, quality of each construction part, and quality of whole construction. The operation quality includes quality of project's employing functions, products, or services, reliability of operations and services, safety of operations, and maintenance.

(2) Cost aim. The cost aim of whole construction project process should take relevant costs and returns during the lifelong period of construction project into consideration, such as total investments, costs of operations (services), and costs of maintenance.

(3) Time aim. For the total process management of modern construction project, the time aim has more contents, including not only construction time, investment-return time, and period of maintenance, update, and reconstruction, but also design life and service life of project.

(4) Satisfaction from every aspect. The success of a project is based on the common efforts of all participators in the project supply chain. Without satisfaction from every aspect, it is impossible for the project winning success. Therefore, the aim system of project should include aims of each participator, reflecting the interest balance of every aspect, and satisfying each participator, which can benefit the cooperation and coordination, and help to cultivate a fair, trust, and cooperative atmosphere. For example, aims of contractors and suppliers usually include expectations for project price, time, corporate image, and relation (credit).

(5) Coordinate with environment and achieve sustainable development. Because of the uniqueness of the whole process of construction projection, the abilities of coordinating with environment and achieving sustainable development include: the project products and service functions are stable and sustainable, what can not only satisfy the present requirements but also meet the future requirements, satisfying the requirements for coordinating with environment; the construction project should update the functions and structure expediently at lower costs; the

construction project can provide with sustainable support for local or national economic development; the construction project should have the capabilities of escaping from disasters, including the capability of supervision and prediction, the capability of defending calamities, and the capability of timely response.

3. The cooperation of aim system of construction project

Construction project's multiple aim system is composed of time child-system, cost child-system, quality child-system, and resource-control child-system. These child systems have relative independence and have special functions and operational aims.

The aim system of construction project should be a stable, balance, and complete aim system. Too- much emphasis on certain aim (child aim) usually kills or hurts other aims. Therefore, the improvement of harmony of project's aim system can be achieved by the cooperation and optimization of multiple aims. The core of construction project's multiple-aim cooperation is to emphasize on the conformity of completeness and integration, aiming at improving the general efficiency and effect of construction project management. In specific:

(1) Consistency. In an aim system, according to the structure of aims, aims at lower levels should obey aims at higher levels. Aims at higher levels have superiorities over aims at lower levels. In other words, the system aim has precedence over child aim, and child aim operable aim.

(2) Completeness. The sum of project's aim factors should wholly reflect the requirements of higher system. Especially, it should ensure the compulsory aim factor. Therefore, the project is usually a complete system composed of many aims. The shortcomings of aim system may cause bugs in project technological system, errors in implementing plans, and difficulties in control. Just as what has been mentioned above, modern complex construction project should adopt the process-oriented procedure management. Therefore, the aim system should reflect the requirements of being process-oriented, including not only aims in construction period, but also aims in construction operation (Xiaolin Cao. & Bing Han, 2002).

(3) Equilibrium. The process-oriented aim of construction project should reach the equilibrium of all participators. Every participator accepts the aim and reaches an agreement. Especially, the aim should notice the equilibrium among time, expenses (costs, investments), and quality (function). During the project's multiple aim coordinative management process, we should notice that the project aims may have different precedence during the lifelong process of the project. For example, the quality aim is the core at the decision stage, the cost at the implement stage, and the time at the later stage. In addition, different kinds of projects have different emphasis on the three basic aims. Under the special condition, it is possible to give up strict requirements for one aim in order to realize certain aim.

(4) Dynamics. Aim system has a dynamic development process. It is a complete aim-guaranteed system formed gradually during the process of aim design, feasibility research, technological design and plan. Because of the changeable environment, higher system may change its requirements for the project. Therefore, the aim system will change more or less during the whole process, such as the increase or decrease of aim factors, and the adjustment of indicator levels. As a result, the design scheme, the contract changes, and the implementation scheme will change.

4. The optimization of aim-oriented construction project's control system

This paper is chiefly to coordinate and optimize the main project aims, such as time, quality, and cost. In implementing the project management, we should take the project scope, costs, time, quality, labors, risks, information communication, biding management, and other project factors into consideration from a view of general optimization.

4.1 The construction of the optimized quality-cost control model

Project quality is determined by the quality of working procedures in the construction process. The quality of each procedure will directly or indirectly affect the project quality at last. Therefore, the procedure quality is the most fundamental part for the project quality. In general, if the project time is shortened, the project quality will become poor. But many spot managers do not think so. In their opinion, even if the time is shortened, the procedure quality does not necessarily become poor.

Any procedure needs time. The procedure quality is formed during the time. Different time contributes to different procedure quality. Here, we make an assumption that if the construction factors do not change, there is a linear function relationship between the procedure quality and its time. In other words, there is positive correlation between them. See to the figure 1 as follow. Use the continuous numbers from 0 to 1 to reflect the strictness of requirements for procedure quality. The shorter the time is, the nearer to 0 the number is, the lower the strictness of requirements for procedure quality is, and the poorer the procedure quality is. Conversely, the nearer to 1 the number is, the higher the strictness of requirements for quality, and the higher the procedure quality is.

With the assumption above, the slope of the curve, namely the Time-Quality function, is:

$$\alpha_i = \frac{nq_i - sq_i}{nt_i - st_i}$$

Then, the real quality of the procedure i is: $Qi = sq_i + \alpha_i (t_i - st_i)$

If the whole project includes m procedures, the whole project quality is equal to the average of weighted quality of every procedure.

$$Q = \sum_{i=1}^{m} \omega_i Q_i, \qquad \left(\sum_{i=1}^{m} \omega_i = 1 \right)$$

The control model of Quality-Time is:

$$\max Q = \max \sum_{i}^{m} \omega_i Q_i = \max \sum_{i}^{m} \omega_i \left[sq_i + \alpha_i (t_i - st_i) \right]$$

$$s.t.: \qquad nt_i \geq t_i \geq st_i > 0;$$

$$\omega_k > 0, \sum_{k}^{m} \omega_k = 1$$

Here, nt_i refers to the time consumed by the procedure under the normal condition. st_i refers to the time consumed by the procedure in order to catch up with the plan. t_i refers to the time consumed by the procedure in fact. ω_i refers to the weighed quality of procedure i to the whole project quality.

4.2 The construction of the optimized cost-time control model

The relationship between procedure time and cost is changeable under different conditions. In general, as the procedure time is shortened, the cost will rise. The shorter the time, the fast the cost increases (Xiaolin Cao. & Bing Han, 2002). Of course, some procedures may adjust the operation time by increasing or re-allocating resources. Under this condition, the procedure cost does not change. But for common procedure, the relationship between its time and cost can be reflected by figure 2 as follow.

According to the figure 2 above, the reasonable procedure time should be confined to [Ds, D_L]. Without increasing procedure cost, the shorter the procedure time, the better. Because the project time is determined by the key procedure time, the key procedure time should be confined to [Ds, D_N] in cost optimization. For non-key procedures, the procedure time can be adjusted between [Ds, DL] based on the requirements for resource balance as the cost optimization is over. Besides, because the Time-Cost relationship is a curve, it is complicate to establish all the relationship between every procedure cost and time. In practice, we usually replace the curve with the line from S to N. By this way, the calculated procedure cost is slightly higher than real procedure cost, what is allowable in practice. In addition, considering all uncertain information in construction, such as labors, materials, technologies, and management levels, the conservative calculation is necessary. The slope of this line is the rate of direct cost, namely the average increasing procedure cost as the procedure time is shortened by one unit. It is β_i in the following equation.

$$\beta_i = \frac{nc_i - sc_i}{nt_i - st_i}$$

In this equation, nt_i refers to the time of procedure i under the normal condition. st_i refers to the time of procedure i under the rush-up condition. nc_i refers to the cost of procedure i under the normal condition. sc_i refers to the cost of procedure i under the rush-up condition.

The relationship between the procedure cost and the procedure time is: $c_i = sc_i + \beta i(t_i - st_i)$.

Here, t_i refers to the time of procedure i. c_i refers to the cost of procedure i as it consumes the time t_i.

The figure 2 can not reflect the indirect cost. In optimization, we can use the rate of indirect cost to deal with the indirect cost. The so-called rate of indirect cost means the decreasing (or increasing) indirect cost as the procedure time is shortened (or prolonged) by one unit. Use γ to represent it. The rate of indirect cost is usually based on real facts.

4.3 The construction of optimized Time-Cost control model

The Time-Cost optimization aims at establishing the time of every procedure in order to realize the lowest reasonable cost with the precondition of meeting the contract time (or planed time). The time aim is one of three main aims in construction project management, which is an important factor for construction enterprises winning credit. Properly dealing with the relationship between time and cost is an important part in construction project's cost management. However, shorter project time does not necessarily mean excellence. The right way is to seek for the most reasonable cost by adjusting the time properly. In general, the project cost is reflected in two aspects. In the first aspect, it is the cost generated by the construction sector in order to guarantee the project time, such as the increasing cost originated from increasing resources, and updating technologies. In the second aspect, the prolonged project time may cause new cost. If the prolonged project time is caused by construction environment or natural environment, we can gain compensation from owners. But if the loss is caused by internal factors, we have to shoulder it by ourselves. Therefore, it is necessary for us to find out the right time for lowest cost.

To summarize the Time-Cost relationship, we can get the Time-Cost control model as follow:

$$\max C = \max \sum_{i}^{m} \left[sc_i + \beta_i (t_i - st_i) - (p_a + \gamma) d_a + (p_p + \gamma) d_p \right]$$

$$s.t.: \qquad st_i \le t_i \le nt_i;$$

$$d_a = \begin{cases} T_p - T_c; T_p > T_c \\ 0, T_p > T_c \end{cases}, d_p = \begin{cases} T_c - T_p; T_c \ge T_p \\ 0, T_c < T_p \end{cases}$$

In the equation above, C refers to the total project cost. t_i refers to the time of procedure i. nt_i refers to the time of procedure i under the normal condition. st_i refers to the time of procedure a under the rush- up condition. nc_i refers to the cost of procedure a under the normal condition. sc_i refers to the cost of procedure i under the rush-up condition. β_i refers to the rate of direct cost of procedure i. Y is the rate of indirect cost. Pa is the prize for shortened one-unit time. Pp is the compensation for owners due to prolonged one-unit time. da is the number of days for shortened one-unit time. dp is the number of days for prolonged one-unit time. Tp is the planed time. Tc is the calculated time. m is the number of procedures.

4.4 The construction of optimized Time-Cost-Quality integrated control model

By integrating every aim control model, we can get a Time-Cost-Quality multiple-aim integrated model.

$$\begin{cases} \min T = TE(m) - TE(0) \\ \min C = \min \sum_{i=1}^{m} \left[sc_i + \beta (t_i - st_i) - (p_a + \gamma) d_a + (p_p + \gamma) d_p \right] \\ \min Q = \min \sum_{i=1}^{m} \omega_i Q_i = \max \sum_{i=1}^{m} \omega_i \left[sq_i + \alpha_i (t_i - st_i) \right] \end{cases}$$

$$s.t.: \qquad st_i \le t_i \le nt_i$$

$$TE(j) - TE(i) - t_i \ge 0$$

In this equation, TE(i) and TE(j) respectively refer to the earliest time of i and j in the net.

This model is to realize the multiple-aim optimization of construction project. It pursues the optimization of three aims, namely time, cost, and quality, instead of the optimization of one aim. It respects a systematic idea and requirement.

5. Conclusion

The whole construction project control process is a dynamic optimized management process. The essence of coordination and optimization is to look for the right point that satisfies all restrictions, reaching the integrated optimization of system (or the highest coordination state of system). As thepractical control aim (quality, time, and cost) fails to the planed aim, we should take measures to correct parameters and adjust the original plan. At this moment, the control system should make new decisions. Therefore, during the construction process, we should make proper adjustment according to the changeable relationship of time, cost, and quality in the aim system.

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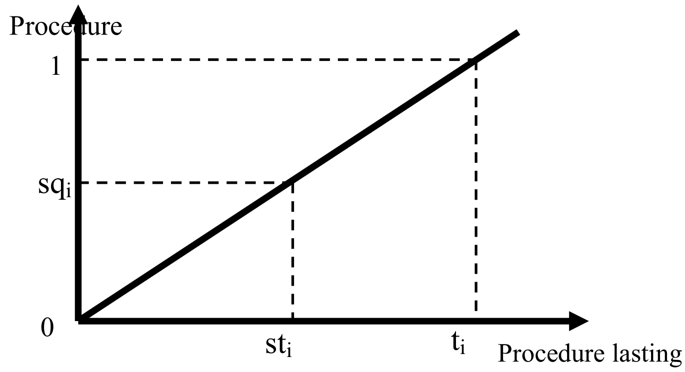

Figure 1. The Relationship between Procedure Time and Procedure Quality.

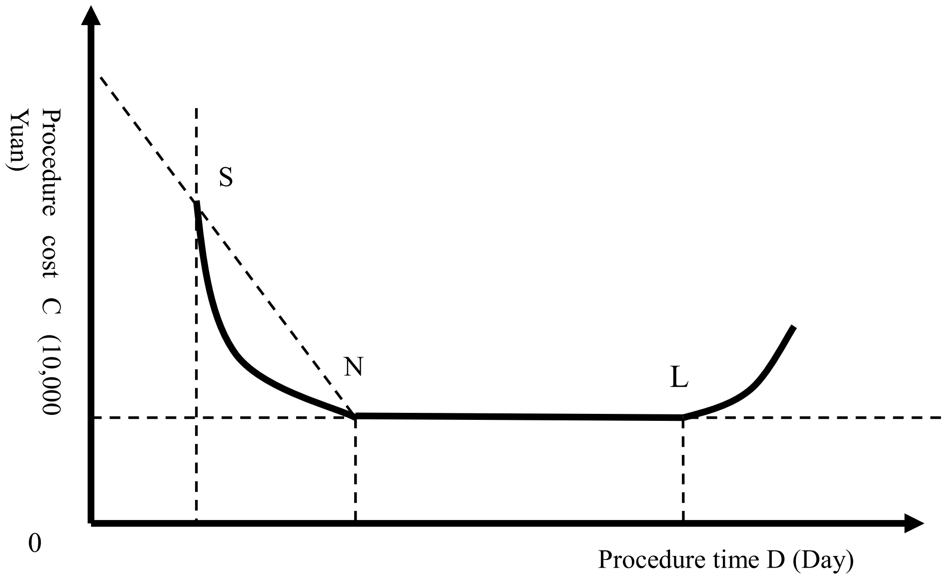

Figure 2. The Time-Cost Curve.