Construction Cost Control Based on PDCA Cycle

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Abstract — Construction cost control plays a key role in the process of construction cost control during the construction phase, which determines the economic benefits of construction enterprise. This thesis tries to analyze the price deviation during the construction phase based on the cost control principles in the construction phase. At the same time, it will combine with the PDCA circulation theory so as to establish its model by combining with the Earned Value Management. For the deviation of the price, we can control it through the organization, technology, economy and contract measures. Through the empirical analysis, this cycle can analyze the cost deviation accurately during the construction phase of engineering project, and then provide the correspondent control measures to correct deviation. Therefore we can eventually realize the cost control target of construction enterprise. The research shows that it is practical to introduce the PDCA cycle to the construction cost control, and the cost is controlled progressively.

Keywords - Construction cost; Control; Construction Phase; PDCA Cycle; Earned Value Management

I. INTRODUCTION

In terms of the construction project, construction stage is the largest phase of capital investment, and it is also the essential one which turns monetary funds into the construction entity. Therefore, the cost control of construction stage plays a key role in the project of cost control, which goes through the whole construction process by starting from the cost prediction of construction project to the preparation stage, from the project cost control during the construction period to the final completion of cost control. Along with the fast development of the market economy, the rising prices of the goods and the escalating competition among construction enterprises, studying how to control the cost of the construction phase becomes increasingly more and more important.

II. RESEARCH QUESTIONS

Because of one-pieced, long-termed, and complex characteristics during the construction projects, there are lots of factors during the construction cost control so it becomes more difficult in the cost control. In the practical projects, it is just a mere formality in some construction companies because they didn’t pay attention to the cost control. Even it is irrevocable to rescue the overruns for they didn’t pay any attentions to the beforehand control until they check the price, and any rescues will be impossible at that time. For some companies who are aware of the cost control but still use the wrong methods, which makes the cost control ineffectively. Considering all these circumstances, the biggest problem is the absence of a step-by-step, progressive control process to guide the construction business from the beginning to the completion during all the construction. PDCA (Plan-Do -Check-Action) cycle was first proposed by a famous quality management expert W. Edwards Deming. As a kind of effective project management tool, it has been widely applied in quality management and also has achieved significant effect [1]. Advancement and circulatory of PDCA cycle can be applied to the cost control construction.

III. RESEARCH STATUS

The research of construction cost control has caused attentions of scholars both at home and abroad. In China, Wu Mingli tried to forecast and control the cost in the construction phase by establishing a grey model GM (1,1) [2]. Fu Qingchao analyzed kinds of elements during the
construction process and the key part of cost control [3]; Chen Xiangyun along with Dong Na, Xiong Feng and Xiao Zixi tried to take BIM technology into cost control [4]; Zheng Xiaoming has taken the M company case for study, and proposed improvement measures by analyzing the M's presence in solving the cost control problems during construction project [5]; Chen Jie tried to control the cost by building the system dynamics model with the assistance of method of dynamics [6]; Wan Yuanlin and Zhang Sai tried to control the construction project cost based on the PDCA cycle from the view of owner [7]. In abroad, Jarousse Lee Ann proposed that control construction costs before its starting and the control contains the whole process rather the part of the construction phase [8]; Kim Byung-Cheol and Reinschmidt Kenneth F indicated that the construction cost control is the most important goal of the project, and Earned Value Management (EVM) is the most effective method of the cost control [9]. Among lots of scholars’ researches on controlling the construction cost, there are certain practical significance and feasibility. However, it can’t be a directly step-by-step guide to the costs loop control, and it also can’t reflect directly the cost overruns or savings, ahead of schedule or still lags behind. What’s more, it lacks the correspondent corrective measures for deviation.

IV. PRINCIPLES AND METHODS

A. The Theory of Cost Control During the Construction Stage

During the construction stage, the construction enterprise try to achieve the cost control target according to the construction organization plan and designed drawings for construction in preparation stage, then check, compare, analyze and correct the actual datum with the predicted one in the construction process [10]. The effective control of construction price is based on the core of reasonable decision and effective control. When deviation occurs in the construction cost, the construction enterprise should timely find the reason and then take measures to correct it so as to ensure the implementation of cost control target, which means making the enterprise gain better economic benefits by making use of personal, material resources and financial resources in this construction project.

B. PDCA Cycle

PDCA circulation method is such a cycle process according to the Plan, Do, Check, and Action, that continually go through to the next cycle for some unresolved issues in the previous cycle. PDCA cycle includes four parts, that is plan, do, check, and action. The specific contents are: plan, that is to design some specific implementation programs based on the certain objectives and guidelines; Do, that’s the implementation of designed programs; Check, that’s the results of the implementation plan, where we can find out the question and know the results which is right or not; Action is the one to deal with the results and then standardized it according to the checks carried out and by affirming the successful experience and summing up the lessons of failure, and then submitting the unsolved problem to the next PDCA cycle process.

According to theories of cost control during the construction stage, combined with engineering construction program, it is theoretically possible to use the PDCA cycle to control the construction cost. During the cost control, first is to make a plan, and then inspect the program implementation according to the plan by introducing the earned value management analysis deviations. Finally, correcting the deviation of the process. This is a single PDCA cycle construction cost control, shown in Figure 1.

However, the cost of control is not a one-time behavior, neither as the PDCA cycle. After the accomplishment of one cycle, we did correct deviations and control the costs. For the unresolved issues and new emerged deviations will go into the next cycle. With the stepped rising, it can form a
continuous PDCA cycle which shows in Figure 2.

![Continuous PDCA Cycle](image-url)

Figure 2. Continuous PDCA Cycle.

C. Earned Value Management (EVM)

Earned Value Management (EVM) is a holistic approach to measure progress of the project fully and the cost situation, whose essential element is the amount of money instead of quantities to measure the progress of the project. However, it was measured by translated money to outcomes rather how much money invested to reflect progress of the project. It is a complete and effective indicator and methods in monitoring the project [11].

1) Basic Parameters
   a) Budgeted Cost for Work Performed (BCWP)

BCWP means the budget, a sum total funds, for the completion of the work, and the work (or part of the work) finished in a certain time, with the permission of standards of the budget.

\[
BCWP = \text{Completed workload} \times \text{Budget price} \quad (1)
\]

b) Budgeted Cost for Work Scheduled (BCWS)

According to schedule, Budgeted Cost for Work Scheduled is the total funds needed for the budget as a standard sometime the work should be completed. In general, the BCWS should remain unchanged in the project implementation process, unless the contract has changed.

\[
BCWS = \text{Planned workload} \times \text{Budget price} \quad (2)
\]

c) Actual Cost for Work Performed (ACWP)

ACWP, that is the total actual funds for the work finished at a certain time.

\[
ACWP = \text{Completed workload} \times \text{Actual Price} \quad (3)
\]

2) Evaluation Index

   a) Cost Variance (CV)

\[
CV = BCWP - ACWP \quad (4)
\]

When the cost of variance is negative, it means that the project runs over budget expenses; otherwise, it represents that the actual cost does not exceed the estimated cost.

   b) Schedule Variance (SV)

\[
SV = BCWP - BCWS \quad (5)
\]

When the schedule variance is negative, it means the project delay in progress, that is to say the actual progress behind the schedule; however, when the schedule variance is positive, it indicates the progress is in advance, and the actual progress is faster than schedule.

   c) Cost Performance Index

\[
CPI = \frac{BCWP}{ACWP} \quad (6)
\]

When CPI < 1, it indicates that actual costs are higher than budgeted costs;

When CPI > 1, it indicates that actual costs are lower than budgeted costs.

   d) Schedule performance index

\[
SPI = \frac{BCWP}{BCWS} \quad (7)
\]

When SPI < 1, it indicates that the actual progress is slower than schedule;

When SPI > 1, it indicates that the actual progress is faster than schedule.

Among the four evaluation indexes, they can reflect the deviation of progress and costs directly, especially the bias of the cost, which reflects the absolute deviation, and the result is intuitive. Besides, the result helps managers understand the cost of the absolute terms deviation, and some certain measures was taken to adjust expenditure plans and financing plans. Therefore, we can use the EVM in the check phase of the PDCA cycle so as to analyze the cost and the deviations.

V. APPLICATION OF PDCA CYCLE

Combined with the construction process of the construction project, we can take the established PDCA cycle to control the cost in the construction phase.

A. P—Plan

Plan is the most important aspect of cost control, and it is
the prerequisite for control. Only if the plan was possess, the cost can be controlled. Therefore, a good plan is the half of the control work. The plan of construction enterprises can be divided into the following two steps:

1) Cost Forecast

Cost forecast is to analyze the various changeable factors influencing the cost of construction projects in the predicted period. That’s to say to compare the price recently completed or nearing complete in construction project by analyzing the extent of influence of these factors in the project so as to predict the project cost. Through cost forecast, the construction enterprise can choose a low-cost, good economic optimum cost plan which meets the requirement of the project owner. And it can strengthen the control of the cost in the weak aspects and avoid blindness so as to improve the predictability in the construction of the project cost formation process.

2) Cost Plan

Cost plan is the written one which formulates the construction cost, cost level, the reduction of rate and the main methods & programs to reduce the cost within the scheduled time of the construction project in the form of monetary. Cost plan is the foundation of developing the responsibility system of construction project cost management and the core of carrying out cost control and cost check. It is also the instructive documents of the cost control of construction projects and the basis of setting up the cost goal.

According to the cost forecast and the project cost control target, construction enterprises can make a detailed construction organization design, a material consumption plan, a capital consumption plan and a construction schedule etc. Plan is a prerequisite for control, and only with the good plan of control of the cost in advance, can we control the costs better in construction phase. A good cost control plan is equivalent to half of the controlling work in advance, so we can see its importance. In controlling the cost of the construction, construction enterprises should take the pre-control plan as the first choice, and make the cost prediction well carefully, seriously and specifically before the starting of construction, which is doomed to yield twice the result with half the effort.

B. D—Do

After the construction of the project started, the construction enterprises take it into action according to the predict plan, it is a complex and important phase and forming process which turns the construction project concept into reality. Long periodic is one of the characteristics, so as the implementation of the plan. The rising of material prices, the adjustments of national policy and changes of designs during the implementation are all affect the plan, so as to affect the project cost control goals. Therefore, the construction enterprises should regularly check the implementation of the plan during the program of the implementation process.

C. C-Check

Check is to find out the deviations and problems in time according to the situation and effect about the construction during the implementation of the plan. Check generally includes two aspects: first is to check whether the plan was taken into the action, whether the actual conditions was changed or not, then summarizing the successful implementation experience and identifying the reasons for failure to the plan; second is to check whether the results of inspection of program has met the requirements of construction organization design or not, etc., and whether there has been any progress over the project cost plan or behind schedule or not. Check is a critical step, which is directly related to whether the construction enterprise have control the occurred situation and measures to correct the deviation.

When check the implementation of construction projects, Earned Value Management can directly and objectively reflect the cost overruns or savings and the progress lead or lag.

D. A-Action

After deviation analysis, construction enterprises should find out the reasons of the deviation promptly, then control the cost by taking the organization, technology, economy and contract measures in the process of the deviation correcting.

1) Organizational Measures
Construction phase cost control requires full participation. In the organizational structure, we can take the implementation of the project manager responsibility system with the implementation of specific cost management organization and personnel, and at the same time a clear mission of the manager in all levels of construction cost, a division of rights and responsibilities are all needed in the process. During the correction process, firstly, construction enterprises should strengthen the management organizational structure to maximize people's subjective initiative.

On the other hand, organizational measure is the preparation of construction cost control plan which determines the detailed workflow. Cost management should do well in the construction procurement plans by optimizing the allocation of factors of production, rational use, dynamic management, effective control of the actual cost. In order to control the cost, cost manager can strengthen the construction management and construction tasks single quota management by controlling the living labor and consumption of materialized labor; Besides, they can strengthen the construction schedule to avoid poor design and construction slowdown which caused by the increased cost phenomenon such as loss of blind schedule, machine utilization rate, the backlog of material.

2) Technical Measures
   During the construction phase, in order to control the project cost, technical measures can be taken as follows.
   - Through technical and economic analysis to determine the best construction plan.
   - Combining the construction methods and comparing the using materials, we can lower the consumption of the cost by substituting, changing the mix, and using additive on the premise to meet the functional requirements.
   - Selecting the most appropriate construction machinery and equipment usage scenarios.
   - Reducing the inventory costs and transportation costs of materials by considering the project construction organization design and natural geographical conditions.

   - Using the advanced construction technology, the new materials and the newly developed machinery and equipment etc. according to the characteristics of the construction project.

When construction enterprise take these measures, they should avoid selecting construction scheme merely from the technical point, while neglecting the evaluation of its economic effect.

3) Economic Measures
   Of all these measures, economic measures are the easiest one to be accepted and adopted by people. Project managers should improve the fund use plan prepared by the previous and correct the deviation and decompose the cost management objectives. At the same time, the preventive policies to avoid risk analysis of construction cost management objectives should be taken; on expenditures, they should do a good job of funds use plan, and take a strictly control during the construction; timely and accurately recording, collecting, sorting, accounting actually counts the cost. For the variety of changes, which in account of a timely manner, and timely implementation of good owners visas, timely settlement project price.

4) Contract Measures
   Adopt contract measures to control the construction cost, which should go through the all period of the contract, including contract negotiations from the beginning to the end of the contract process. First of all, the construction enterprises should analysis and compare the various contractual structure model and try to find the suitable one according to the scope, quality and characteristics during the contract negotiations. Secondly, contract construction companies should carefully consider all the factors that will affect the costs and benefits, especially the potential risk factors. From it, we should identify and analysis these risk factors which caused by changes of the cost and take the necessary risk responsible measures, like making a reasonable way to increase the number of individuals to take risks, reducing the proportion and the probability of loss, and making these policies are reflected in the contract specific terms ultimately. During the construction phase, contract managers not only should monitor the situation of the other party according to the contract so as to seek opportunities for
contract claims; they should also pay close attention to the situation of their performance of the contract to prevent the other party counterclaim.

In the process of construction, according to the above established PDCA cycle, the construction enterprise make plans based on the actual situation; implement according to the plan; then check program implementation; ultimately, correct the deviation in the implementation of the plan. Thus, the PDCA cycle is completed. Due to the untreated problems, we can sum up lessons and take it into the next PDCA cycle for processing. By using the PDCA cycle model, and during each cycle, the project cost can be effectively controlled, so it will get close to the actual cost of the project. Therefore, mutual connection, mutual promotion and spiral are the characteristics of PDCA cycle model.

V. EMPIRICAL ANALYSIS

A construction project construction contract was signed in December 2011, agreed that the contract duration is 20 months which begins formally in January 2012. Time scale network plan was compiled according to the contract schedule requirements (as shown in Fig. (3)), which had get the professional supervision engineers’ permission [12].

<table>
<thead>
<tr>
<th>The Work</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
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<tbody>
<tr>
<td>Planned engineering (100 m³)</td>
<td>86</td>
<td>90</td>
<td>54</td>
<td>100</td>
<td>52</td>
<td>62</td>
<td>10</td>
<td>36</td>
</tr>
<tr>
<td>Actual engineering (100m³)</td>
<td>86</td>
<td>90</td>
<td>54</td>
<td>92</td>
<td>50</td>
<td>58</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1. THE AMOUNT OF PLANNED AND ACTUAL ENGINEERING WORKS

![Figure 3. Time Scale Network Plan.](image)

All parts of the work of the project were arranged according to the earliest start time schedule, and the monthly amount equals to the completion of the project. Plan quantities and actual quantities of each work were shown in Table 1. The duration of the actual work of work D, E, F was the same as the duration of the work plan.

According to the contract, the concrete structure was priced at 1000 yuan/m³, and monthly billing. Adjusting settled price according to the concrete structural engineering projects, concrete structures of each month during project implementation price index as shown in Table II and Table III.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Price Index  (%)</td>
<td>100</td>
<td>115</td>
<td>105</td>
<td>110</td>
<td>115</td>
</tr>
</tbody>
</table>

Table II. CONSTRUCTION PRICE INDEX TABLE

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Index  (%)</td>
<td>110</td>
<td>110</td>
<td>120</td>
<td>110</td>
<td>110</td>
</tr>
</tbody>
</table>

Table III. CONSTRUCTION PRICE INDEX TABLE

During the construction period, due to the project developer, the start time of work H was delayed a month than the scheduled start time and the duration of work H was added one month because of the extra quantities.

E. P—Plan

In this construction project, the construction enterprises compiled the construction management plan and time scale network plan according to the contract schedule requirements. From the time scale network plan, we could clearly known the concrete structural engineering duration was eight months. And this plan had been reviewed and approved by professional supervision engineer, which was an effective plan conformed to the contract period.

F. D—Do

During construction, the duration of actual work D, E, F were the same as the planned work. However, the time of work H was delayed a month longer than the scheduled start time and the work duration was extended a month more. When the work duration was extended, it would definitely affect the progress of the program, even affecting the all project and its cost. At this time, construction enterprise should check the work H by analyzing the causes, predicting
its results and trying to take measures to control the expected project cost within the target.

G. C—Check

At the end of August, the concrete structural could not be completed on time because the work H had been extended one month. In this way we could use Earned Value Management to analysis the causes and effects of this generated bias, and the way how to deal with it. Based on datum, we could use the calculation table to compare the three basic parameters in Earned Value Management which was shown in TABLE IV and TABLE V.

<table>
<thead>
<tr>
<th>TABLE IV. THE RESULTS TABEL</th>
<th>Investment Data (10 thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>subheadings</td>
<td>1</td>
</tr>
<tr>
<td>Investment completed</td>
<td>880</td>
</tr>
<tr>
<td>Accumulated investment</td>
<td>880</td>
</tr>
<tr>
<td>Investment had completed</td>
<td>880</td>
</tr>
<tr>
<td>Accumulated investment had completed</td>
<td>880</td>
</tr>
<tr>
<td>Actual investment had completed</td>
<td>1012</td>
</tr>
<tr>
<td>Cumulative actual investment had completed</td>
<td>1012</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE V. THE RESULTS TABEL</th>
<th>Investment Data (10 thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subheadings</td>
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<tr>
<td>Investment completed</td>
<td>370</td>
</tr>
<tr>
<td>Accumulated investment</td>
<td>4060</td>
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<tr>
<td>Investment had completed</td>
<td>355</td>
</tr>
<tr>
<td>Accumulated investment had completed</td>
<td>3845</td>
</tr>
<tr>
<td>Actual investment had completed</td>
<td>391</td>
</tr>
<tr>
<td>Cumulative actual investment had completed</td>
<td>4262</td>
</tr>
</tbody>
</table>

According to the results table, we could calculate the cost evaluation index in the end of August.

\[
CV = BCWP - ACWP = 4775 - 5337 = -562 \text{ (10 thousand)}
\]

\[
SV = BCWP - BCWS = 4775 - 4900 = -125 \text{ (10 thousand)}
\]

\[
CPI = \frac{BCWP}{ACWP} = \frac{4775}{5337} = 0.89
\]

\[
SPI = \frac{BCWP}{BCWS} = \frac{4775}{4900} = 0.97
\]

When the CV was negative, the cost overspent 5.62 million RMB, for CPI was below 1. By analyzing the schedule variance, the progress had been delayed 1.25 million RMB, for SPI is below 1, the progress lagged. At this point, construction enterprises should analyze the reason progress lagged. From these cases, it showed that the work H’s earliest start time was delayed a month when compared with the scheduled start time, but work H had a month free float which just offset the impact of deadline. The biggest reason for cost deviation was the larger works of H’s, and changed in the price of concrete structures, which increased the project cost and the extension of one month.

H. A—Action

The cost increased and the time extended due to the quantity of the project, and the best corrective measures to deal with the situation for construction enterprise was economic measures and contract measures, which is to claim the compensation from the construction according to the contract about compensation. As the added quantity was not the case for construction enterprises, and this part of the responsibility should be borne by the construction side. During the construction work H, datum compilation should be prepared and the visa should be timely handled, at the same time we should prepared the claim report in accordance with the provisions of the program within the prescribed time to charge cost claim for 5.62 million RMB and for extension of one more month. In the process, construction enterprise should also supervise other processing cases to control the cost within the predicted range.

VI. RESULTS

During the operation of PDCA cycle, we can predict that the work H will be postponed one month more and the increased amount of engineering might affect the cost and schedule. Therefore, when operating to the check stage by using earned value management to analysis, the results of the cost would increase 5.62 million and the schedule would lag one month behind. After analyzing the reason, we can
know that it is the construction company that increases amounts of work H. While in the stage of action, we should take economic measures and contractual measures to claim for the added construction costs and duration. Through this PDCA cycle, construction companies received the fee due to the increased amount of H engineering work so as to realize the cost control in advance. It also proved that it is feasible and effective to establish the PDCA cycle to control construction costs in practice. When finish this PDCA cycle, construction enterprises need to deal with the deviation by using the PDCA cycle again and again in the late stage of construction. By recycling process again and again, constantly correcting the deviation, the cost could be well controlled and the construction will achieve the target of cost control eventually.

VII. CONCLUSIONS

Summarized above researches, the establishing of PDCA cycle in preparation phase can guide construction enterprises to draw up the cost control plan. During the construction processing, it can oversee the implementation of its plan. We can predict in advance because of some factors that could affect construction costs and analysis cost deviations and its reasons by using the method of earned value management. Finally, we can correct the deviation by four ways of organization, technical, economy and contract. Such a clear process were used to control the cost step by step for construction enterprises. Besides, PDCA cycle is not run just one time, but still continues throughout the cycle companied with the error was found and the deviation was correct until the end of the project. After the cycle of PDCA runs over and over again, construction costs can be controlled progressively, at the same time construction enterprises are able to achieve the economic benefits. Therefore, for projects, especially large projects, establishing the PDCA cycle control process is a good control method to control the construction costs for more benefits.

REFERENCE