Project Integrated Management Based on Quality Earned Value

Jiyao Xu
Management Science and Engineering, Business School
Hohai University, HHU
Nanjing, P.R.China
joytsui@126.com

Hengquan Zhang
Management Science and Engineering, Business School
Hohai University, HHU
Nanjing, P.R.China
hqzhang630@163.com

Feixiang Li
Management Science and Engineering, Business School
Hohai University, HHU
Nanjing, P.R.China
flyingaround1985@163.com

***Abstract*—Aiming at the problems of the traditional earned value method widely used currently, this article established a quality earned value model, and built up the project quality evaluation system, considering the quality factor. This model can improve and perfect the existing Earned Value, and coordinate the three project control objectives, quality, cost and schedule, based on fuzzy membership. It can comprehensively measure and reflect the actual situation of the overall project progress, thus ensuring integrated management of the project objectives of quality, cost and schedule.**

Keywords-project management; quality earned value; integrated management; fuzzy membership

I. INTRODUCTION

In the modern project management systems, project earned value management is one of the leading content of the project integrated management, which is a kind of comprehensive and overall management of concern. The EV (Earned Value, EV) method is a kind of method to analysis the differences between implementation and expectation objectives of the project. "Project Management Body of Knowledge (PMBOK 2000)" newly issued by Project Management Bureau (PMB) of US defined EV method as "a technology used to measure and report project performance from initiation to closeout".

The concept of EV management is firstly used in the U.S. Navy's Polaris Program in 60's of the 20th century, and further developed by the Air Force. In 1967, U.S. Department of Defense formulated a cost/schedule control system criteria (C/SCSC), and applied the EV to industrial and governmental projects as an effective integrated management tool for cost, schedule and technical performance. Subsequently, many other countries such as Australia, Canada, Sweden and Britain, prescribe their own governmental and industrial project management standard, combing the guidelines of U.S. Department of Defense [1].

In China, research on the EV method started in 90's of the 20th century, HU De-yin [2] introduced the theory and process of EV method, and expatiated the basis work and steps of project comprehensive control of costs and schedule in international models systematically. Then, the EV method began to capture the attention of the management community. However, as the current EV management theory and methods involve only two factors, cost and schedule, and have not considered the quality impact on the cost and schedule, there are deficiencies in quality control.

This article established a project management model of QEV (Quality Earned Value, QEV) based on the latest research on improving the EV method. This article took the fuzzy membership method to evaluate the project quality, so as to quantify the quality evaluation results, and reflect in the basic variable of the EV, making the QEV method more accurate to reflect the interactional relationship among quality, cost and schedule. The QEV method can achieve integrated control of the project quality, cost and schedule, providing the correct decision of the project control measures.

II. BASIC PRINCIPLE OF EARNED VALUE

The QEV method can overall measure project schedule and cost, its basic element is to measure the project schedule with the money supply instead of the engineering quantity.

The QEV method includes three basic parameters:

978-1-4244- 7618-3 /10/$26.00 ©2010 IEEE

① PV (Planed Value), or called $BCWS$ (Budgeted Cost for Work Scheduled), the calculation formula is: $PV=Q_0P_0$.

② AC (Actual Cost), or called $ACWP$ (Actual Cost for Work Performed), the calculation formula is: $AC=Q_1P_1$.

③ EV (Earned Value), or called $BCWP$ (Budgeted Cost for Work Performed), the calculation formula is: $EV=Q_1P_0$.

Where, Q_1 is workload finished; Q_0 is workload in plan; P_1 is real consumption; P_0 is budget quota.

Four variance parameters can be derived from the three parameters above:

① CV (Cost Variance), the calculation formula is: $CV=EV–AC=Q_0(P_0–P_1)$

② SV (Schedule Variance),the calculation formula is: $SV=EV–PV=P_0(Q_1–Q_0)$

③ CPI (Cost Performed Index),the calculation formula is: $VI=EV/AC=P_0/P_1$

④ SPI (Schedule Performed Index), the calculation formula is: $SPI=EV/PV=Q_1/Q_0$

Taking the project schedule and cost as monitoring objectives, the QEV method can analyze and judge the executive condition of schedule and cost at the monitoring point preliminarily.

III. QUALITY EARNED VALUE MODEL

A. Shortage of traditional EV

The traditional EV method is a effective integrated control method of cost and schedule. But it doesn't considering the quality factors, so although when CV <0, it means cost overrun, but it is unknown that whether the cost overrun is due to the increased resources investment for speeding up the progress or increased cost for improving the project quality. Similarly, when SV> 0, it is indistinguishable whether the progress advance is due to labor efficiency, or jerry-build. Therefore, the quality factors must be taken into account, in order to define the impact of the quality factors on the cost and schedule. Thus, this article established the concept and model of the Quality Earned Value based on the previous research.

B. Determination of EV_Q

As an intermediate variable in QEV model, parameter EV_Q (quality of the earned value) represents the quality situation, and is the key to the QEV method. Its value is determined according to the evaluation results of the finished project at the checking time.

1) Establishment of the project quality assessment system

Since the project decomposition, schedule, cost and quality plan generally will be done before the implementation of the project, we can take the project quality inspection procedures (inspection lot - subentry project - part project - unit project) as the project quality assessment system, that is, the quality score of the inspection lot is basic of the score of subentry project, the score of subentry project is the basic of the score of the part project, and so on.

2) Project Quality Fuzzy Evaluation Model

Project quality Evaluation is fuzzy, so the fuzzy membership evaluation method can be used to quantify the project quality assessment. The full score of the project quality evaluation results is 10. According to the project quality evaluation system above, the quality evaluation grades and scores of each part of the project are set as follows in Table 1.

TAB.1 PROJECT QUALITY EVALUATION LEVEL

Grade classification	Grade			
	Excellent	***Good***	***Qualified***	***Unqualified***
Subentry project	A1	A2	A3	A4
Quality score	9~10	8~9	6~8	0~6
Score values	9.5	8.5	7	3

The total number N of the test items of a certain subentry project can be determined according to the project quality test standard, suppose the test items number passing the standard acceptance criteria is Nt, then the percentage of this subentry project passing the standard acceptance criteria is:

$$P_j = \frac{N_t}{N} \times 100\%$$

P_j is the basic to calculate the subentry project scores, the important coefficient or the weight of parts of the project can be determined by AHP or Delphi.

(1) Scores of subentry projects. The membership functions of subentry projects on the level of Ai (1<i<4) are:

$$\mu_{A1} = \begin{cases} 1 & 95\% < P_j \le 1 \\ \dfrac{P_j - 85\%}{10\%} & 85\% < P_j \le 95\% \\ 0 & P_j \le 85\% \end{cases} \quad \mu_{A1} = \begin{cases} \dfrac{95\% - P_j}{10\%} & 85\% < P_j \le 95\% \\ \dfrac{P_j - 70\%}{15\%} & 70\% < P_j \le 85\% \\ 0 & P_j \le 70\% or P_j > 95\% \end{cases}$$

$$\mu_{A1} = \begin{cases} \dfrac{85\% - P_j}{15\%} & 70\% < P_j \le 85\% \\ \dfrac{P_j - 50\%}{20\%} & 50\% < P_j \le 70\% \\ 0 & P_j \le 50\% or P_j > 85\% \end{cases} \quad \mu_{A1} = \begin{cases} \dfrac{70\% - P_j}{20\%} & 50\% < P_j \le 70\% \\ \dfrac{P_j}{50\%} & P_j \le 50\% \\ 0 & P_j > 70\% \end{cases}$$

So the scores of subentry projects are:

$$S_A=9.5\mu_{A1}+8.5\mu_{A2}+7\mu_{A3}+3\mu_{A4}$$

(2) Score of part project. The quality score of the part project are:

$$S_B = \sum_{j=1}^{m} \omega_{Aj} S_A$$

Where: m represents that there are m subentry projects in the subentry project; ω_{Aj} represents the important coefficient of the subentry projects to the part project.

(3) Score of unit project. The quality score of the unit project are:

$$S_C = \sum_{j=1}^{n} \omega_{Bj} S_B$$

Where: n represents that there are n subentry projects in the unit project; ω_{Bj} represents the important coefficient of the part project to the unit project.

(4) Quality score of the finished projects *AQ* (Actual Quality). According to the scores and weights of unit projects and the score values of each Quality score, the *AQ* formula is as follows::

AQ=∑Actual Quality score of the finished projects ×Corresponding weights

3) Project quality fuzzy evaluation

(1) Calculation of the finished projects BQ (Budget Quality). The evaluation score of the budget quality of the finished project can be got similarly according to the basic steps of the calculation of the finished projects AQ. So the BQ formula is as follows:

BQ=∑Budget Quality score of the finished projects ×Corresponding weights

(2) Calculation of Qe (Quality Index).

$$Q_e = \frac{AQ}{BQ}$$

(3) Determination of CVI (Cost Variance Index)：

$$CVI=f(Q_e)$$

The $f(Q_e)$ is an experience function, fitted based on the relation diagram of the cost and quality according to the historical data. Its parameters can be got through the statistical treatment of the historical data, or the comprehensive evaluation of the experienced engineers. Then the traditional earned value can be modified according to the CVI, so that the more realistic quality earned value can be got to reflect the deviation of cost and schedule more accurately.

(4) Calculation of EV_Q.

$$EV_Q = EV \times CVI$$

C. Index system of QEV model

Five key indicators and their meanings of QEV model are shown in Table 2.

TAB.2 INDEX SYSTEM OF QEV

Index	***Index value***	***Meaning***	***Calculation formula***
QV	$QV>0$	Increased cost due to quality level improvement	$QV=EV_Q-EV$
	$QV=0$	Actual quality level is the same as that of plan	
	$QV<0$	Reduced cost due to quality level decrease	
CV_Q	$QV>0$	Cost saving in the case of considering quality	$CV_Q= EV_Q-AC =(EV_Q-EV) +(EV-AC) = QV+CV$
	$QV=0$	Quality level does not affect the cost	
	$QV<0$	Cost overrun in the case of considering quality	
SV_Q	$SV_Q>0$	Cost equivalent of progress advance affected by quality level	$SV_Q= EV_Q-PV = (EV_Q-EV) +(EV-PC) = QV+SV$
	$SV_Q=0$	Quality level does not affect the schedule	
	$SV_Q<0$	Cost equivalent of progress lag affected by quality level	
CVP_Q	$CVP_Q>1$	Deviation rate that actual quality cost is lower than that of budget	$CVP_Q= CV_Q / EV_Q$
	$CVP_Q=1$	Quality level does not affect the cost	
	$CVP_Q<1$	Deviation rate that actual quality cost is higher than that of budget	
SVP_Q	$SVP_Q>1$	Deviation rate of progress advance affected by quality level	$SVP_Q= SV_Q /PV$
	$SVP_Q=1$	Quality level does not affect the schedule	
	$SVP_Q<1$	Deviation rate of progress lag affected by quality level	

The QEV method can be described with graph as follows, shown in Figure 2.

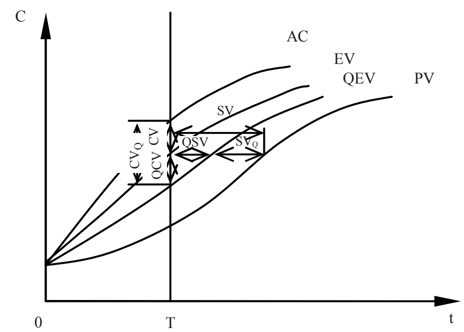

Fig.1 Schematic of quality earned value method

D. Discrimination of the QEV model

The basic principle of the QEV model is introducing the intermediate variable EV_Q, then determining the project quality level according to the positive or negative of *QV* and CV_Q, and evaluating the cost and duration of the project.

(1) In the case that the quality level meets the requirements, that is $QV=0$, traditional EV method can be used and corresponding cost and schedule control measures should be adopted.

(2) In the case that the quality level exceeds the requirements, that is, $QV>0$, when $CV_Q\geq0$, if $SV_Q<0$, the cost meets the requirements, but the schedule lags, so the construction speed should be accelerated; if $SV_Q\geq0$, the cost and the schedule requirements are both met, so the quality control should be strengthened. When $CV_Q<0$, if $SV_Q\geq0$, the schedule meets the requirements, but cost overspends, so the cost control should be strengthened, if $SV_Q<0$, the cost overspends, the schedule lags, so the cost and schedule control both should be strengthened.

(3) When $QV<0$, the quality doesn't meet the requirements. The quality must be emphasized firstly, and the cost and schedule performance should be considered subsequently.

IV. EXAMPLE

A. Project general situation

The total contract price of an engineering project is ＄5 million, and on a checking time, the *PV* of the foundation and foundation engineering (earthworks, foundation treatment, waterproof engineering, concrete foundation, masonry foundation) and the main structure (concrete structure, masonry structure, brick structure) which have been finished is ＄3 million, while the *AC* and the *EV* are ＄3.4 million and ＄2.7 million. Otherwise, the project quality standard is qualified.

B. Project quality evaluation

The quality evaluation system of the finished work is established, shown in Figure 2.

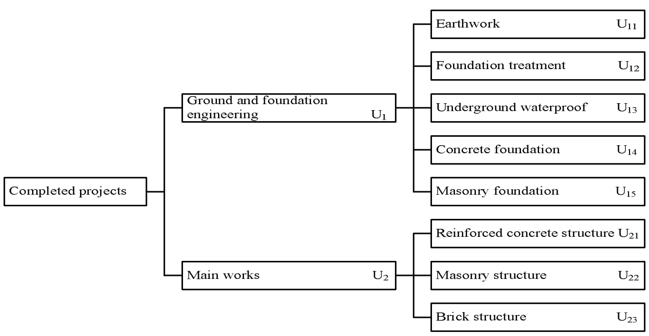

Fig.2 Quality evaluation system of completed projects

The results of the indicators of this project are shown in Table 3. The *CVI* is identified as 1.201 according to the engineering experience. According to results in Table 3, we can see: The project completed has reach the required quality level, the total progress has lag 300 thousand, but deducting the factor in quality improvement, the real progress is ahead of ＄192.2 thousand; the total cost has overspent ＄700 thousand, but deducting the increased cost due to the increased quality level, the real cost has overspent ＄20.78 million, thus, the current cost control is almost satisfactory. The quality level should be reduced appropriately on the premise of the regulatory requirements, so as to save cost and accelerate the construction schedule.

V. CONCLUSION

This paper built the QEV model to judge the architectural engineering construction quality using fuzzy membership. This model considers mutual restrictive and interactional relationship among quality, cost and schedule; and it can reflect the deviations of cost and schedule more realistically. The QEV model is a more practical deviation analysis method for developers and contractors in integrated management on quality, cost and schedule, and it is certainly helpful to improve the project management level and raise the economic benefit of the construction enterprises.

There are still some deficiencies in this paper, for instance, the *CVI* function corresponding to Q_e is not established well. Instead, this paper only gave guiding directions that the function can be fitting processed according to the engineering practice statistics. Therefore, it requires further research and exploration to define the specific function expression.

REFERENCES

[1] GUO Jian, WEI Fa-jie. “Foreign Project Earned Value Management and the Enlightenment,” Productivity Research. 2006,pp,102–104.

[2] HU De-yin. “Apply the Earned Value Assessment Principles to the Project Costs / Schedule Control,” Chemical Engineering Design, Feb,1994,pp,46–51.

[3] Project Management Institute: “A Guide to the Project Management Body of Knowledge (PMBOK 2000),” 2001.

[4] Harold Kerzner. “Project Management Systematic Method in Plan, Schedule and Control,” Beijing: Publishing House of Electronic Industry,2002.

[5] Samuel J. Mantel, J r, Jack R. Meredith, Scott M, Shafer & Margaret Ml Sutton: “Project Management in Practice,” John Wiley & Sons: Inc,2002.

[6] WANG Zhuo-fu, TAN Fei. “Project management——Theories, Methods and Applications,” Beijing: China Water Power Press.

[7] QI An-bang. “Research on Multi-element project integrated management,” Nankai Business Review, Jun,2002,pp,70–75.

[8] LI Chang-wei. “Multi-level Fuzzy Comprehensive Evaluation Method of the Construction Quality,” Construction technology development, 2003(6),pp,85–86.

[9] ZHONG Dong-mei. “Research on Project Integrated Management Method Earned Value Management,” Sichuan: Southwest Petroleum University.

[10] James P. Lewis: “Project Planning, Scheduling and Control (3rd ed),” McGraw Hill Companies, Inc, 2002.

TAB.3 PROJECTS CALCULATION TABLE

Projects		**U_1(0.65)**					**U_2(0.35)**			**Index calculation**
		U_{11}	***U_{12}***	***U_{13}***	***U_{14}***	***U_{15}***	***U_{21}***	***U_{22}***	***U_{23}***	
		0.045	***0.077***	***0.146***	***0.422***	***0.310***	***0.437***	***0.335***	***0.238***	CV=−70
Membership	C1	0.000	0.000	0.100	0.700	0.000	0.300	0.467	0.000	SV=−30
	C2	0.067	0.400	0.900	0.300	0.133	0.700	0.533	0.000	Qe=1.182
	C3	0.933	0.600	0.000	0.000	0.867	0.000	0.000	0.750	EV_Q=319.22
	C4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	QV=49.22
	B	8.275					8.278			CV_Q=−20.78
Construction quality score	*AQ*	8.276								SV_Q=19.22
	BQ	7.000								CVP_Q=−0.065
										SVP_Q=−0.064