Application of Earned Value in the Korean Construction Industry
— A Case Study

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Abstract

Earned Value (EV) is a project control technique used in many countries which provides a quantitative measure for integrating on schedule and cost information. It also evaluates work progress in order to identify potential delay and cost overruns. South Korea had not used this concept until 2000, when the Korean government legislated that EV should be used in construction projects of more than 50 million dollars. In order to effectively implement EV in the Korean context, several reforms must be made regarding its unique conditions, such as the cost accounting system. This paper seeks to integrate cost as related to bill of quantity and schedule in a manner that is suitable for application in Korea. An example application of the proposed EV model to two actual separate projects is provided.

Keywords: earned value; work breakdown structure; cost breakdown structure; integration model

1. Introduction

Earned Value, a simple but very practical concept, is founded on the Cost/Schedule Control System Criteria (C/SCSC) that the U.S. Department of Defense has applied to major business with a high risk of cost increase since 1967 in order to measure the outcomes of projects (Singh 1991, Niemann 1991). The simplified concept for fitting the diverse baselines of C/SCSC to civil enterprises is the Earned Value Management System (EVMS) (Fleming and Koppelman 1997). The concept of EVMS becomes important because the primary objective during the construction process lies in completing the project on time and within the budget, while meeting established quality requirements and other specifications (Rasdorf and Abudayyeh 1991). Therefore, many developed countries have been using the EVMS for an array of public and private practices since the early 1990s, resulting in dramatic improvement in companies' construction practices.

Because of these positive aspects, the Korean Congress passed "The Effective Plan of the Public Construction Industry Bill" in July 2000, which mandated companies to use EVMS when total project cost exceeds 50 million dollars. However, there have been significant problems regarding implementation of EVMS in the Korean construction industry due to confusion concerning its concept.

The biggest problem in applying the EVMS is that it is hard to find project control systems that integrate cost and schedule control functions (Hendrickson and Au 1989). Rather, cost and schedule control function separately under two different control structures: the Work Breakdown Structure (WBS) and the Cost Breakdown Structure (CBS). The cost control function, represented by CBS, is performed at a less detailed level than that of the schedule control function, represented by the WBS.

There are two objectives in this paper. The first is to develop a hybrid EVMS model that is suitable for the Korean construction industry, of which spending is expected to account for $130 billion in 2007. The second objective is to develop an enhanced EVMS through a pilot test, which tests and analyzes an actual construction project in order to verify its system.

2. Literature Review

Many attempts have been made to integrate two structures in a single structure (Lee and Kyoo 1999). The integration of time and cost constitutes an attractive issue in project scheduling. A traditional approach to solving the time and cost problems on schedule is to assign a time and cost curve to each activity of a project (Harris 1978). Teicholz (1978) proposed a mapping mechanism between the Cost Breakdown Structure (CBS) and the Work Breakdown Structure (WBS) that has been used as the basis for many of the current approaches to integrating cost and schedule control functions.
Structure (WBS) to integrate the differences in the level of details. The key concept of this model is to allot a cost account of specific percentages to a given task. Rasdorf and Abudayyeh (1991) suggested that the work-packaging model is the best model, however it requires collecting excessive amounts of detailed data.

Thus, to achieve the desired integration, cost and schedule data must be acquired and maintained at an established common denominator control account. It was concluded that using the WBS as the basis for both the cost and schedule planning and control is the best and natural approach to truly achieving integration (Abudayyeh and Rasdorf 1990). This means that WBS provides a unified view of project costs and schedule data for defining and maintaining control accounts, and therefore is accepted as a basic concept.

However, when the WBS based EV model was applied to the construction industry, it did not always fit the real construction project. According to Little's empirical research (1983, 1984), while there was general agreement with C/SCSC principles, serious problems occurred concerning implementation. Furthermore, considering Coopers & Lybrand's empirical research (1989), the costs of implementing C/SCSC are relatively high, and a joint government and industry study named Total Quality Management Study (1989) identified that the majority of the cost-driver procedures are not required by C/SCSC. Another empirical government industry joint study, DoD/NSIA (1991), surveyed 250 managers and confirmed that most of them consider C/SCSC an important and necessary tool for project management.

In Korea, Kim et al. (2001) proposed a construction management process for cost-schedule integration management by analyzing the problems of the existing construction management system, while Kim et al. (2002) suggested a model for cost-schedule integration management in which the problems of construction performance measurement, earned value estimation and paying method were considered based on the work package model. Also, Song et al. (2003) clarified the base of the necessary resource plan and proposed a resource management system according to the necessary resource plan by using the actual data of the cost-schedule integration management abstracted from the frame of a construction management system.

In summary, while C/SCSC or EV are essential tools for controlling a construction project, the common denominator is not a cost account but a schedule account, and using the schedule account as a common denominator could create a problem. So, when the EV model is eventually applied to the construction industry it will need a special approach and EV model.

2.1 The Condition of the Korean Construction Industry

This chapter analyzes the present situation and problems in Korea's construction companies concerning WBS, production process and construction cost. In the past the EV model was applied to several projects such as the Yeongkwang nuclear power plants 3 and 4. However, these projects were very special, so the owner and contractors compromised in applying the EV concept by making a unique WBS. As a result, most construction companies use a WBS that is fit for their own situation. Because each company's WBS is different from that of others there is no national level of coordination. Ultimately, contractors have built an EVMS based on each construction company's WBS. Therefore, the companies are inconvenienced by various EVMS's.

Generally, Korea's construction companies have different systems for schedule and cost management. Most construction companies do not have a specialized department for schedule management, so on each construction site, the schedule TF (Task Force) will form a Project Management Baseline (PMB) based on a thousand activities. Based on the PMB, a monthly, 2-weekly, weekly and daily schedule will be made. Even though these schedules imply the major schedule information, there is no labor, material and equipment information. That is to say, most schedules are used only as an "exhibition" or as a report to the owner. As one can easily see, there is almost no actual schedule management, although cost information is the main item regarding construction management.

From the cost aspect, most construction projects in Korea are generally contracted by fixed price; once the contract is awarded the owner is no longer concerned with the cost. As a consequence, the contractor must take responsibility for the cost. Additionally, construction cost is directly connected to the accounting department and there is much discrepancy between the construction cost and accounting.

A Budget Breakdown Structure (BBS) that is similar to CBS is organized by work item such as material costs, labor costs, equipment costs, and outsourcing costs, and is used to express the breakdown structure concretely, including quantity and unit price. BBS's are classified as work item, construction sequence, and workspace (i.e. building, floor, room) and are not directly linked to cost. In order to link schedule management with cost management, information from the schedule concerning workspace and construction sequence should be unified as a work item, and then linked with cost information.

2.2 The EVMS Concept

Fleming and Koppleman (2000) defined EVMS as "a control method for estimating the final cost and schedule of a project and to perform continuous estimation of actual work in a detailed construction work plan." EV makes it possible to anticipate the actual construction cost against the planned construction schedule, and furthermore suggests a method to predict the potential success of the project. The basic concept of EVMS first classifies all works including a business, then sets up a WBS and connects
it to the CBS. After connecting two structures, a Budgeted Cost of Work Scheduled (BCWS, PV) is set up, and a Budgeted Cost of Work Performed (BCWP, EV) and Actual Cost of Work Performed (ACWP, AC) are calculated. The present progress status, anticipated construction cost, etc. are predicted by calculating the Schedule Variance (SV), Cost Variance (CV), Estimated to Completion (ETC), Estimated at Completion (EAC), Variance at Completion (VAC), Schedule Performance Index (SPI), Cost Performance Index (CPI), and the estimate index of business results, by estimated PV, EV, AC. For further details refer to the book, "Earned Value Project Management" by Fleming and Koppleman (2000).

2.3 Integration Model of the Construction Schedule and Cost

As shown above, EVMS is based on the WBS. However, at present the WBS is difficult to use in direct connection with the BBS because of the level of details between WBS and BBS. This paper proposes an EV model that is integrated with regard to schedule and cost. BBS is different from WBS, so BBS needs to be divided into lower level. To integrate the cost and schedule information, integrated activity and a representative item are used in the Sub-task level. Fig.2 shows the total model flowchart for the unified management of schedule and costs. First of all, to connect the cost items with the schedule, they must be re-arranged. The representative item, which is a standard of EV performance in one of the Sub-task levels, possesses the assistant item. Next, the type of workspace will be defined by the Overall Construction Plan. After the matrix of the workspace and the Sub-task level have been divided, the representative item will be assigned to them. Then, the materials and costs will be calculated and prepared as a representative item. To raise the efficiency of construction management, activities that occur at the same time and place will be integrated as an integrated activity. Using this integrated activity, a schedule will be planned on the basis of the CPM.

The initial schedule was established by Early Start (ES) and Early Finish (EF) via the initial construction plan. The monthly progress report, which measures completeness of the construction on a monthly basis, will be the AC performance. Using the EVMS plan, the project's progress, EAC, and expected completion time can be predicted. The details of each step will be reviewed in the following chapters.

2.4 Work Breakdown Structure (WBS)

The WBS is commonly used in schedule management and cost management, which constitutes Technology/Area/Major Task and Sub-task. The subordinates of schedule and cost management are detailed activity and cost item, respectively. This means that the superior parts of both schedule and cost management are integrated.

Therefore, Sub-task is the minimum unit that makes it possible to analyze the actual performance, and can be used as a linkage to the schedule and cost.
2.5 BBS reorganization

The BBS is used to classify, sum up and control cost items (or cost breakdown) in the bill of quantity. In this model, the system can be reorganized into the following organization: Unit (Area)/Work Item (that consists of Classification/Major Task/Sub-task (a link ring of BBS and WBS) and cost items. The BBS efficiently manages the schedule and the cost through a standardization of item division and is defined as the core technique that integrates each division's mutual relationship regarding comprehensive management.

2.6 Assign representative/assistant item

There are two things constituted in one of the Sub-tasks; one is the representative item that is used to calculate the EV and another is the assistant item. The assistant item's EV is calculated by the belonged representative item. The representative item becomes a standard of calculating the progress rate of the activity and EV's quantity. The representative item decides the activity's ratio through quantity journalizing, and the quantity of the assistant item will automatically be divided from the belonged representative item's quantity.

2.7 Space Breakdown Structure

The Space Breakdown Structure sorts workspace and element by a two-step hierarchical structure. It becomes not only the standard for schedule activity, but also the minimum control unit for project control. Therefore, the type of workspace (e.g. area, floors, section, rooms, etc) can be defined by the Overall Construction Plan, which is classified into two steps; the workspace and the element, both of which can be defined by each Sub-task before being assigned. Therefore, the Space Breakdown Structure of the whole system consists of Technology/Area/Major Task/Sub-task/Workspace and Element.

2.8 Quantity division

Materials of the representative item are divided by each Sub-task level, which was defined previously. Therefore, the materials of the assistant item are automatically calculated as the representative item's ratio. In terms of quantity division, it is a crucial part of the beginning process in the whole construction project that should last long enough to take precise and accurate measurements.

2.9 Appointment of integrated activity and preparation of schedule

Activities performed at the same time and the same place can be bound to one activity. For the sake of efficiency, various activities can be integrated into major work. The integrated activity imports the ID and description properties to the scheduling S/W program and connects duration with precedence- and successor activity, thus establishing the PMB.

2.10 Establishing the schedule

A schedule must be established by CPM in order to understand the present situation and to work out a countermeasure according to the Overall Construction Plan. This requires calculating the time required for work completion of each activity, with consideration given to construction sequence by the construction method and workspace, thus establishing the relation of the working unit. The schedule is then completed by connecting the duration and relationship of the precedence-and-successor activity after importing the activity ID and activity description created in the scheduling S/W program.

2.11 Preparing PV (Planned Value)

A monthly PV is set up to measure the progress of the project by calculating the entire cost items performed. However, if the established PV is different from the field condition, it must be modified. There are rare cases in which the PV is decided from the beginning, and must be established through tests and the correction of the schedule regarding the current field conditions.

2.12 Monthly cost adjustment

The rate of construction progress, which is updated on a monthly basis, is input in the schedule. These updated values then automatically generate AC. If the AC shows a deviation from the estimate, the rate of construction progress should be adjusted, and the AC re-generated. The quantity of representative items is divided by the Space Breakdown Structure, registered by each Sub-task, and allocated to activity. Moreover EVMS is executed after calculating the AC and the
outsourcing AC by the progress rate data through schedule control.

3. Resource management and analysis of EVMS results

Each cost item investment plan is calculated using updated values of ES and EF. When the schedule is adjusted monthly, the monthly performance plan should be regenerated to a new condition. Using the new value, a current year's materials requirement plan and total sales can be estimated based on the current work progress. Also, by using SPI and CPI the EAC and estimated completion date can be predicted.

A calculation formality of the Estimated at Completion (EAC) is calculated as follows:

\[ EAC = AC + \frac{(BAC - EV)}{CPI} \]

\( CPI \) (Cost Performance index) is replaced by \( CPI' \). CPI is originally calculated by

\[ CPI = \frac{EV}{AC} \]

However, the \( CPI' \) reflects general ideas in the Korean construction industry (estimating the cost rate by operation), so the \( CPI' \) is reversed as follows:

\[ CPI' = \frac{AC}{EV} \]

Also, the Schedule Performance Index (SPI) is calculated from the PV. A calculation of the SPI is as follows:

\[ SPI = \frac{EV}{PV} \]
4. Case Study

This case study has been selected to demonstrate the model established above and to verify its efficiency. The general outline of the applied demonstration field is as follows:

- Structure: RC and Steel
- Number of Stories: 2 stories (Logistics Center/Research Bldg.), 1 story (Security Guard Bldg.)
- Gross Area: Total 5,009.04 m², Logistics Center (4,200.822 m²), Research Bldg. (806.436 m²)
- Bldg. Area: Total 5,009.04 m², Logistics Center (3,146.688 m²), Research Bldg. (635.79 m²)
- Construction Periods: Apr. 20, 00 – Nov. 15, 00

The monthly work was carried out by means of the proposed integration model, and the schedule control checked the progress rate by activity, all the while updating the construction schedule table. Direct AC based on the progress rate by activity was automatically calculated. Indirect AC was accounted for by monthly direct input. The EV was calculated on the basis of the quantity of AC. The outsourcing EV was finally confirmed by making adjustments while considering the field conditions. Based on the progress rate, the AC was automatically calculated.

The accuracy of the analysis was examined through a comparison between the value in the system and actual value from the construction site.

This chart (Table 1.) shows analysis results of the work activities that compare between cost item and the integrated activity. For the architectural work, the number of activities was reduced to 27% against the cost item. For the facility work, it was about 5%, which indicates there was improvement in the activity management as the amount of activity management decreased. For the electrical work, its activity was reduced to 18% in this chart. For the temporary work and the overhead cost at the construction site, due to difficulty of managing and combining these two costs, the total cost items managed was 2,085 items, and 504 activities, which represented about 25% of the total activity. These results indicate that the amount of work has declined from the activity management.

This chart (Table 2.) shows the total number of activities of a specific part in the construction and average cost per activity. For the architectural work, it shows 196 total activities, and in terms of finance, about $7,832. For facility work it shows a total of 27 activities and $7,832. The total of all activities was 504 and $4,193. The amount of money shown in each activity can be managed and confirmed at a construction site.

This chart (Table 3.) shows the analysis of AC marginal error by month, which represents a comparison between amounts derived from using the model and actual amounts that were derived from the construction site. The difference of the total between the accumulated AC and the accumulated AC by integration model indicated 3.91% in June in the case of architectural work, showing a decreasing monthly trend. In September it was 0.21%, showing no significant difference. For electrical work, there was a slight difference, but a greater error took place when the activities were divided significantly in August.

The error was gradually decreased from 2.87% in June to 0.32% in September for the entire construction, and results showed that the margin of error was under control. Due to lack of manpower, the datum for the facility work's AC could not be processed and analyzed at the construction site. The important point is that if activity is divided for control on a large scale, a significant difference can be found from the AC. In the case that division is on a small scale, the error between AC and AC in this system will be decreased, but it is possible that work loads will become too much to handle and therefore uncontrollable. As a result, the integration control of schedule and cost focuses less on labor in the AC and more on productivity. Thus, control adjustment should be made for each construction. The model built for this paper was tested with actual construction projects to verify its system and results.

Table 1. Comparison of Cost Item and Activity Number

| Logistics Center | Research Institute | Total |
|------------------|--------------------|-------|
| Architectural Work | 425 | 110 | 535 | 110 | 295 | 86 | 71 | 196 |
| Facility Work | 417 | 18 | 135 | 9 | 556 | 27 |
| Electrical Work | 415 | 67 | 234 | 51 | 649 | 118 |
| Temporary Work | 39 | 39 | 19 | 19 | 58 | 58 |
| Field Mgmt. Cost | 105 | 105 | 0 | 0 | 105 | 105 |
| Total | 1,401 | 339 | 684 | 165 | 2,085 | 504 |

Table 2. Integrated Activity Number and Average Price by an Activity (unit: number, $)

| Logistics Center | Research Institute | Total |
|------------------|--------------------|-------|
| Architectural Work | 110 | 11,472 | 80 | 3,244 | 190 | 7,832 |
| Facility Work | 18 | 11,076 | 9 | 1,345 | 27 | 7,832 |
| Electrical Work | 67 | 1,978 | 51 | 475 | 118 | 1,345 |
| Temporary Work | 39 | 3,000 | 19 | 791 | 58 | 2,294 |
| Field Mgmt. Cost | 105 | 949 | 4 | 0 | 105 | 949 |
| Total | 339 | 5,301 | 165 | 2,057 | 504 | 4,193 |
In this study, the EV model was provided to assist the Korean construction industry in applying the EV concept of integrating schedule and cost. The goal of construction is to complete a project with adequate quality, and minimum cost, and within a minimum time period. To accomplish this, the control for many management areas such as schedule, cost, quality, safety and resources are required. The schedule and cost control are the most important factors for the success or failure of any construction project. Also, the related technique of schedule and cost is required because they have a correlated relationship. EVMS was made based on this concept, and has been applied to most large-scale construction (projects over 50 million dollars) in Korea. In the past, however, the schedule and cost control have been activated with separate construction systems, which has caused many problems in applying EVMS properly.

A new integration model must be implemented to reflect actual Korean conditions through analysis of the given study and its construction situation. After rearranging the current BBS, and combining with WBS at the Sub-task level, the overall construction schedule could be based on the single view of the WBS. The effectiveness of this proposed model was verified through the two case studies. The result was that the average error rate showed 0.90% for four months, indicating that its application to the actual field would work successfully.

Also, this model showed additional benefit as follows:

1. The Sub-task classified by space becomes the schedule activity. Therefore, the entire schedule plan is made out at the Sub-task level, helping to see the field engineer or worker at a glance.

2. The schedule progress rate becomes the standard for calculating the AC according to the work control in connection with the scheduled activity and cost item, which help to eliminate unnecessary work.

In cases where cost management is the main focus of construction, the construction cost should be reclassified in the BBS and then connected to an appropriate level of the schedule management. Considering a given Korean construction condition, that appropriate level is set as a Sub-task level. There was an attempt to link the Sub-task level to the schedule management in this paper. A country that has similar conditions to Korea could follow the flow in Fig.2., and should be able to achieve the EVMS linked to the Sub-task level. Furthermore, it should be able to achieve similar results shown in this paper. This study concludes that if a construction environment is similar, regardless of the schedule management and cost management, EVMS can be established in other nations when locally modified.

For future reference, an AC evaluation method and standard procedure (Fig.2.) that can be easily applied to actual projects needs to be developed and unified within the industry. Also, the EAC and schedule control should be calibrated and adjusted to a construction environment similar to those of Korea.

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| Items               | Jun.  | Jul.  | Aug.  | Sept.  |
|---------------------|-------|-------|-------|--------|
| Architectural Work  | 379,962 | 365,652 | 571,930 | 908,746 |
| Electrical Work     | 12,088 | 11,907 | 20,589 | 31,869 |
| Temporary Work      | 61,668 | 61,668 | 98,317 | 125,955 |
| Facility Work       | 8,169  | 8,169  | 12,359 | 19,566  |
| Insurance Fee       | 43,943 | 43,943 | 60,138 | 80,389 |
| Field Mgmt. Cost    | 13,491 | 13,491 | 21,428 | 30,145 |
| Security Mgmt. Cost | 43,943 | 43,943 | 60,138 | 80,389 |
| Total               | 656,421 | 638,134 | 991,939 | 1,512,103 |
References

1) Abudayyeh, O. Y. and Rasdorf, William J. (1990). "An Assessment of Cost and Schedule Control Integration Models." Tech. Rep. No. CE-90-10, Civ. Engrg. Dept., North Carolina State University, Raleigh, N.C.

2) Abudayyeh, O. Y., and Rasdorf, W. J. (1991). "Design of Construction Industry Information Management System." Journal of Construction and Management, ASCE, 117(4), pp.698-715.

3) "Act: The Effective Plan of the Public Construction Industry." (2000). Ministry of Construction and Transportation, Korea.

4) Chris Hendrickson and Tung AU. Project Management for Construction, Chapter 12. Cost Control, Monitoring and Accounting, 1989.

5) Coopers & Lybrand/TASC. "The DoD Regulatory Cost Premium: A Quantitative Assessment" (1989).

6) Department of Defense and National Security Industrial Association. Joint DoD/Industry Total Quality Management Team Report for Program Management on the Cost/Schedule Control Systems Criteria. (May 17, 1991).

7) Fleming, Q. W. and Koppleman, J. M. (1997). Earned Value Project Management, PMI.

8) Fleming, Q. W. and Koppleman, J. M. (2000). Earned Value Project Management, PMI.

9) Harris, R. B. (1978). Precedence and Arrow Networking Techniques for Construction. Wiley, New York.

10) Hribar, John P. and Ashby, Gregory E. (1985). "Elements of Cost and Schedule Management". Journal of Management in Engineering, ASCE, 1(3), pp.138-148.

11) Kim, Jun-woo, Lee, Keun-Hyoung, and Kim, Jae-Jun (2001) "Earned Value Management System Using Project Model", Journal of AKI, Vol. 17, No. 12.

12) Kim, Woo-Young, Kim, Ok-Kyu, Choi, Yoon-Ki, and Lee, Hyun-Soo (2002) "Development of Cost and Schedule Integration Model for Construction Project Based on Common Denominator and Common Category", Journal of AKI, Vol. 18, No. 8.

13) Lee, Hyun-soo and Kyoo Jin Yi (1999) "Application of Mathematical Matrix to Integrate Project Schedule and Cost" Journal of Construction Engineering and Management, ASCE, pp.339-346.

14) Little, Arthur D. Inc., Survey Relating to the Implementation of Cost/Schedule Control System Criteria within the Department of Defense and Industry, Phase I and II: A Report for the Assistant Secretary of Defense (1983 and 1984).

15) Little, (1983) For more detailed information on costs and benefits of EVM, see D. S. Christensen, "The Costs and Benefits of the Earned Value Management Process," Acquisition Review Quarterly, (Fall, 1998): pp.373-386.

16) N. M. Nguyen, "Effective Subcontractor Management in High-Tech Projects," AACE Transactions (1991): D. 1.1-7.

17) PMI Standards Committee (1996) A Guide of Project Management Body of Knowledge. PMI.

18) Rasdorf, William J. and Abudayyeh, Osama Y. (1991). "Cost and Schedule Control Integration: Issues and Needs". Journal of Construction Engineering and Management, ASCE, 117(3), pp.486-502.

19) Singh, A., "Knowledge Bases of C/SCSC". Cost Engineering, AACE, Vol. 33, No. 6, 1991, pp.39-49.

20) Song, Young-Woong and Choi, Yoon-Ki (2003) "A Study on Material Requirement Planning by Integrating Schedule and Cost", Journal of KICEM, Vol. 4, No. 1.

21) Teicholz, Paul and Fischer, Martin (1994). "Strategy for Computer Integrated Construction Technology". Journal of Construction Engineering and Management, ASCE, 120(1), pp.117-131.

22) U.S. Department of Energy (1979). Cost and Schedule Control System Criteria For Contract Performance Measurement.