A Web-based Framework of Project Performance and Control System

Jui-Sheng Chou*
National Taiwan University of Science and Technology,
Department of Construction Engineering
Taipei, Taiwan
jschou@mail.ntust.edu.tw
* *Corresponding author*

Wai Kiong Chong
University of Kansas, Department of Civil, Environmental and Architectural Engineering
Laurence, Kansas, USA
oswald@ku.edu

***Abstract*—Making sure projects are completed on time, within budget and according to specified quality are the ultimate goals for all projects. The powers of modern computing system and World Wide Web (WWW) have made it easier for project managers to monitor information in the comfort of their office and home. Internet allows project managers access to information from any location of their choice and thus they could manage their projects without being present on location. Converting and delivering project-based information are necessary in order to make full use of the internet. Earned Value Management (EVM) is one of the many tools that project managers used to track cost growth and project delay. It provides an objective measure of the amount of work that has been accomplished. EVM is often utilized by project managers to track project progress and determine their achievements. Project information could be converted into manageable and easily understood pieces that would form information clusters. The purpose of this paper is to layout a visualized architecture of project performance measurement that integrates earned value analysis and control within a web-based system which would allow construction personnel to track, modify and update cost and time-based data of project status online.**

***Keywords*—project management, project control, EVM, Web technology**

I. Introduction

Construction projects continue to face problems from schedule and cost overruns. Modern technology has improved tracking capability, accuracy of project schedules and cost estimates. Companies can now develop their own automated systems to track project progress. Information technology has relieved project managers the cumbersome jobs of documenting, analyzing, and presenting project information. Companies can now improve their business processes and profits by tracking key project performance indicators daily, and detect/correct any cost and schedule overruns instantly.

Project Performance Measurement (PPM) has been applied successfully in many industries and projects. The speed and storage capacities of computers have allowed complex programs to be written so that massive amount of data could be analyzed efficiently. Information technology is critical to PPM. Earned Value Management (EVM) is a project or program management technique that objectively tracks physical accomplishment of work. EVM integrates measurements of schedule and cost performances with project scope. It has become an important project control tool for construction projects. Managers can use earned value analysis to measure project performances and detect problems before they occur so that they could take corrective actions in subsequent activities [11].

Converting and presenting data as visual information has becoming a critical business process [1-3, 7-8]. Visual information is clearer and easier to understand than qualitative and numeric information. It also relieves companies from training their staffs to interpret qualitative and numerical information. It is, thus, important to convert qualitative information into visual information. Automating the visualization process is also very important as it eliminates the job of manually analyzing and presenting information.

II. EARNED VALUE MANAGEMENT SYSTEM AND PPMB

EVM has improved the ability of project managers to control project progress through the improvement of information prediction accuracy [6]. It also sets the platform for project controls as information are consolidated accordingly and thus risks are also appropriated. As a result, project risk controls become more unified and accurate [10]. EVM is a tool that allows projects to be better controlled and managed by consolidating vital project data and expresses them in useful information, where such information highlights the risks and measures project performances. As such, EVM could be used as a project performance measurement baseline (PPMB) to determine and control the outcomes of projects and appropriate actions could be taken [5]. Ref. [6] concluded that the acceptance and utility of EVM could increase significantly if EVM application concentrates on the users, and improves its methodology, project environment and implementation process. Furthermore, a successful implementation of EVM must be associated with an overall organizational approach, continuing top-level management support, organizational integration, and effective training.

III. WEB-BASED PROJECT LIFE CYCLE FRAMEWORK

The ability to access data and information almost anywhere is the global trend why web-based technology has become extremely popular. The ability to detract from software applications is the biggest advantage of web-based technology. Also the system does not require complicated functions and lower cost of application has further popularized its use [2]. A proposed framework for evaluating project performance using project data life cycle visualization is depicted in Fig.1. EVMS plays an important role in the project execution phase where project information needs to be detailed since the capability to change cost and schedule reduces as project progresses [9]. Project has to be initiated and planned using Work Breakdown Structure (WBS) and other resources. These data could then be saved to an operational database for subsequent tracking and documentation. Project managers could then update and modify project schedule and cost estimates as and when necessary. Stakeholders could also establish consensus baseline with their project manager using the system. Project data are then fed into the earned value management process and EVMS. Project information could then be acquired during construction and used to update in the EVMS. At the closeout stage, the EVMS structured data could then be normalized using data warehouse relational modeling for knowledge management. Using web-based technology, the data warehouse could be published on line so that project managers could access both the project information and lessons-learned database at any location and time. The data warehouse could also be mined and used to develop other artificial intelligence (AI) tools, such as case-based reasoning system, neural networks, and parametric estimating models, to aid project initiation and planning, since many of information such as project functions, features, and characteristics are also stored in the data warehouse.

IV. EARNED VALUE MANAGEMENT METRICS AND CONSTRUCTION PROCESS

The purpose of this paper is to describe the framework for visualizing earned value (EV) process and a layout design of automating the system in order to apply it as a project performance measurement baseline (PPMB) tool. Construction project is an integration of various activities that result in the delivery of a construction product. Each activity has its own schedule and cost and is closely linked to another (normally identified as a lead-lag relationship). Cost, time, scope and quality are the most important components in the construction process. Cost represents the amount of money needed to complete the work scope, time represents the period needed to complete it while quality is the acceptance of work done by owner or his/her representative. EVMS integrates these components to measure the outcomes of project. The x-axis of the EVM diagram (Fig.2) represents time, the y-axis represents cost, and the graph of Actual Cost of Work Performed (ACWP) represents work items that have been inspected and are paid for (or earned).

There are three curves on the EVM diagram: planned value (PV) curve, actual cost, and earned value. The planned value curve, also known as the budgeted cost of work scheduled (BCWS) curve, represents planned work. The actual cost curve represents total incurred construction cost while the earned value curve represents actual payment received for completed work. The actual cost and earned value curves are dynamic during construction. Project performances could be measured by project Cost Variance (CV, BCWP minus ACWP), Schedule Variance (SV, BCWP minus BCWS), Cost Performance Index (CPI, BCWP/CWP), Schedule Performance Index (SPI, BCWP/BCWS), and Combined cost-

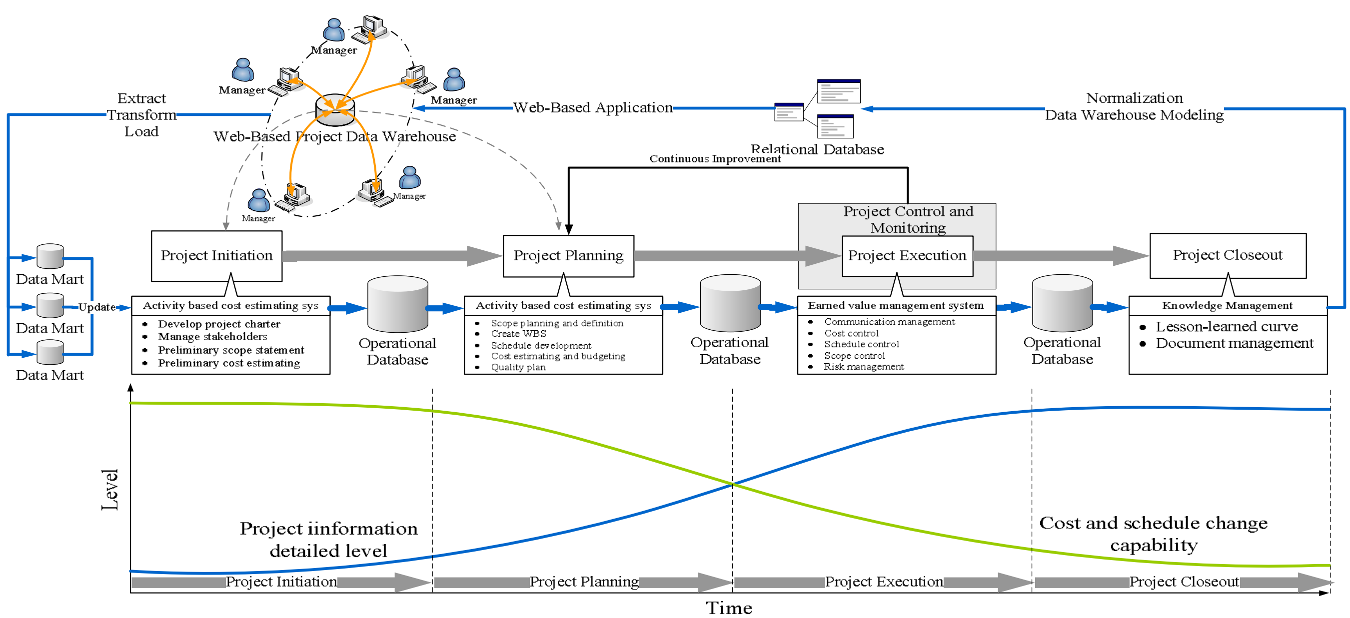

Figure 1. Project data life cycle

schedule index (CPI x SPI). BCWS or PV is the initial submitted and accepted contractor's bid. To work out the EVMS curves, contractor's bid should be divided into monthly values and with the dates for the monthly payment acting as points on the time-axis. The schedule will be used to work out the actual work values to be completed in various months. The earned value is equivalent to the amount of money that the client will pay the contractor. There is a difficulty of associating value with the work on construction site [4]. The key to make EVM effective lies in the honest appraisal of the status of ongoing activity [11].

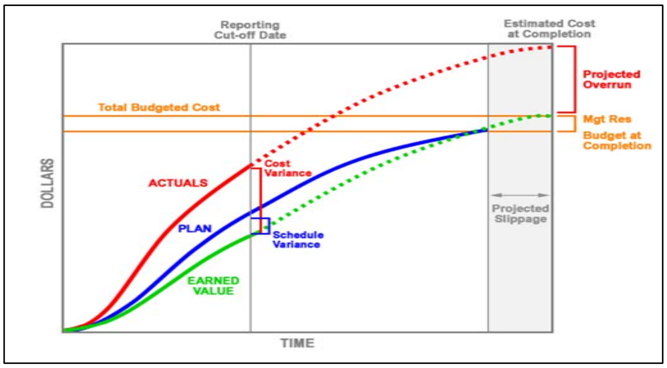

Figure 2. Earned value management graphical representation

V. SIMPLIFIED PROCESS COMPONENTS FOR EVMS

Earned value management methodology can be implemented successfully using a work breakdown structure that is associated with project time, cost, and scope data [5]. Earned value analysis works better if data input are accurately arranged in a timely manner. Traditionally, site data are recorded on paper forms and then the information on the forms are keyed into computers manually. However, many efficient IT platforms are available to facilitate automatic data acquisition and inputs to support project control and cost management [1-3, 7-8], such platforms include bar-code technology, pen-based computer, RFID (Radio Frequency IDentification), multimedia, and LADAR [8]. However, the cost and schedule of IT applications are the major concern in construction process.

Fig.3 demonstrates the data components and processes in constituting the visualized graph. With the verified work scope and organization resources, activity-based scheduling can be developed with detailed work packages including description of task, task start and finish dates, budget and resource to execute the task, and the person in charge of the activity. As the stakeholders consolidate the baseline, the project is ready to execute in a comparative manner. The EVMS provides the following functions and benefits: (1) An interface of data collection and input semi-automatically or manually depending on the resources available; (2) variance analysis as project proceeds; (3) work efficiency index; (4) trend analysis; (5) display of project status; (6) early and accurate identification of problems; and (7) basis for corrective actions. The system could detect trends of cost and schedule overruns, and would suggest increase productivity rate or improved work rate as corrective actions based on the lessons-learned knowledge.

VI. DATA CONVERSION INTO VISUAL INFORMATION

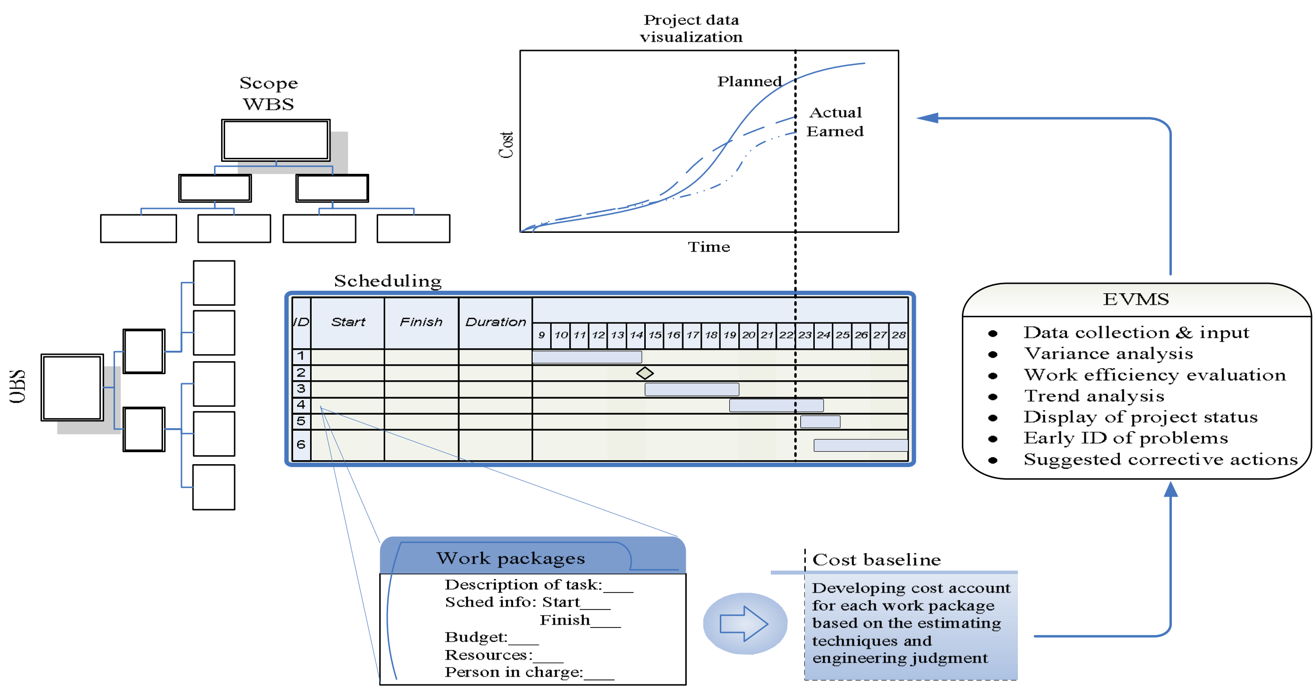

Figure 3. Simplified process components for the EVMS

Once project data are saved as baseline, the data should be collected and updated frequently and automatically as and when needed by the project managers. A simplified data flow chart to facilitate EVMS implementation is depicted in Fig.4. To measure project performance in real-time, the following data need to be further analyzed:

(1) Work scope data:

- Detailed activities in the work breakdown structure.

(2) Project time data, including:

- Actual start and finish dates of the task.
- Expected start and finish dates of the task.
- Completion ratio of the task based on personal judgment.

(3) Project cost data, including:

- Actual cost incurred to complete the task.
- Expected cost to complete the task.

VII. PROJECT EXECUTION AND CONTROL WITH EVMS

Continuous improvement should be part of EVMS that could be used to improve of project control and monitoring. EVMS's database management system is expected to toggle project information within IT architecture in order to continuously evaluate project performance during construction. Furthermore, the system provides a document trail for project stakeholders from project initiation stage to closeout stage. As such, a lessons-learned database could be developed from the EVMS. Such lessons-learned can become an asset of explicit knowledge management in a corporation. Fig.5 shows the operation flow of such system framework. As the user enters into the EVMS main menu, the system will provide a web-based interface for the user to input actual information, baseline comparison, and proceed with earned value analysis. The baseline information is loaded from preliminary planning or previous project. Information is also divided into conceptual, initial, planning, bidding, construction, and close-out phases. As user proceeds with the analysis, the system will provide three primary functions to evaluate project performance, i.e. variance analysis, work efficiency evaluation, and trend analysis. For variance analysis, the schedule and cost variances would be automatically calculated and presented in graphical figures. It is saved to a database for further tracking and documentation. For work efficiency evaluation and trend analysis, project forecasting report could be viewed as cost and time outputs. It is the managers' responsibility to take right actions upon reviewing the outputs from EVMS.

VIII. ISSUES FACING THE AUTOMATION OF THE SYSTEM AND CONCLUSION

The above figures highlight the preliminary setup of an EVMS. There are many implementation issues that need attention. First, measuring and coordinating information flow process could be a challenge. Completed work will only be paid after owners are satisfied with them and could pose a challenge if the data inputs become automatic with remote sensing technology. Second, services that are intangible "works" and are embedded in another work items should be grouped separately. If not, the proposed EVMS may not be able to pick up the differences and thus may create an artificial performance. Third, frequent changes to project scope and designs will pose a problem on the automation of the system. Other IT tools may be needed to help differentiate approved and unapproved changes. Communicating the approved and unapproved information within the system could pose a challenge to the system controller. Fourth, construction project bid is often itemized, most commonly by the CSI Master format (or other formats depending on the clients). The structuring of information in the system could pose a challenge since not all contractors and clients use similar grouping system.

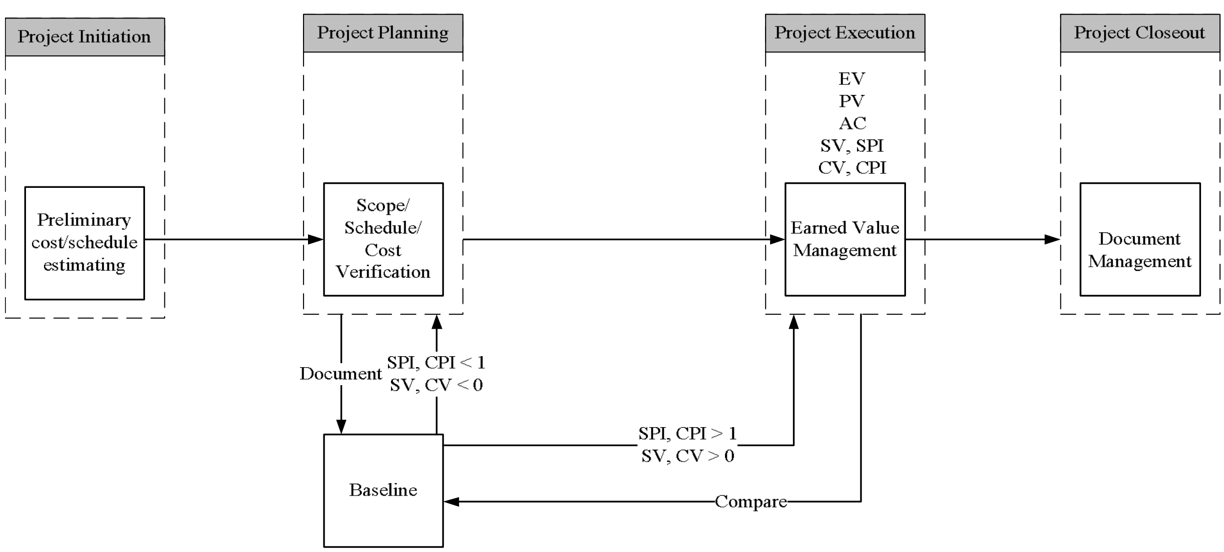

Figure 4. Data Flow for EVMS

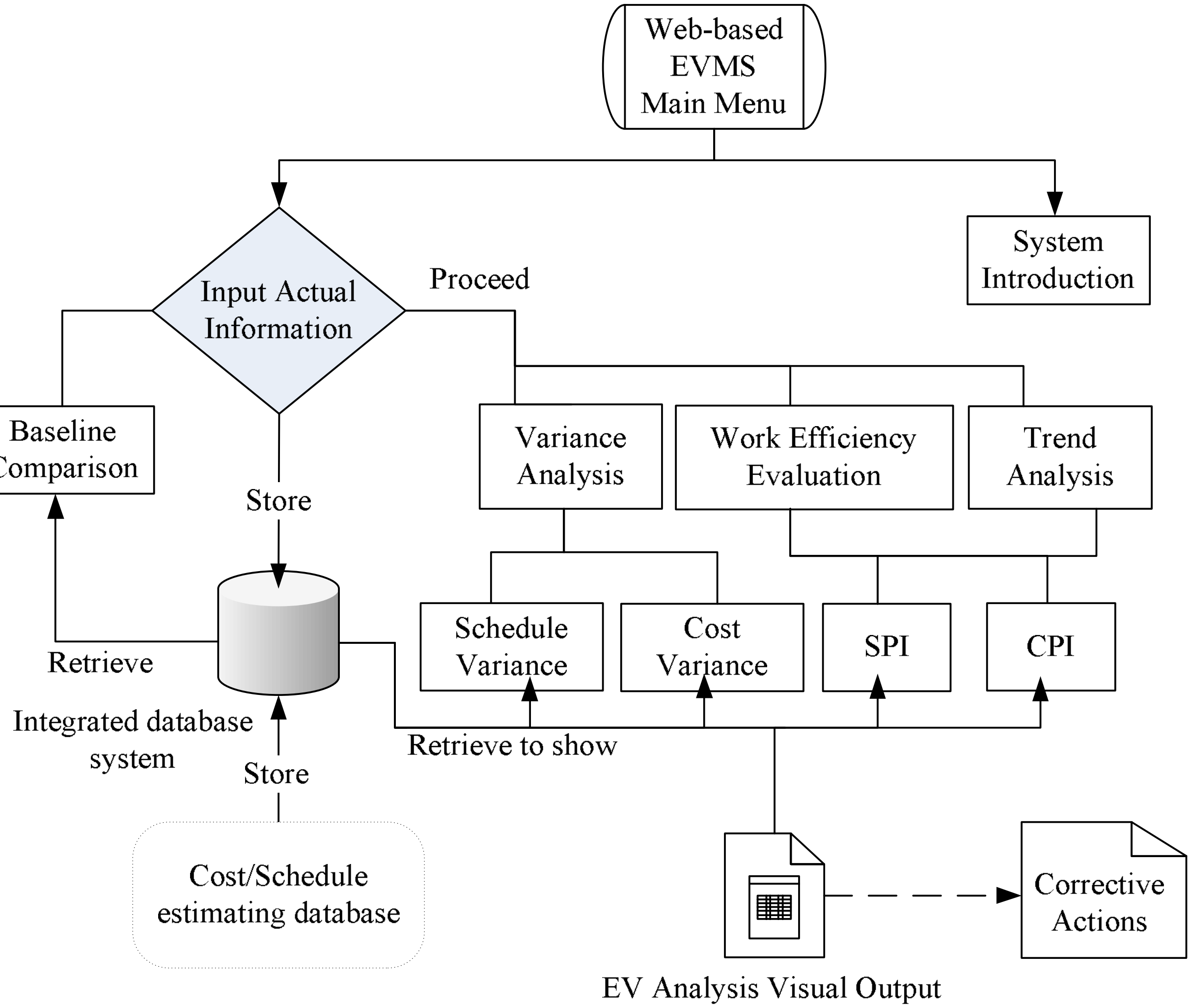

Figure 5. Operations flow of the framework

The implementation of EVMS may hint the need to change current project estimation and control techniques. The controllers and the users of the system need to standardize their definitions and working methods as non-standard definitions and work methods could result in conflicts during data entry if computers cannot recognize the definitions. The future research direction of this paper is to develop a prototype system to examine ways to overcome these limitations.

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