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The Implementation of Earned Value Management in Construction Cost Management and Audit

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Abstract
Earned Value Management (EVM) is recognised as one of the best practice to track and report project performance, trend and forecast costs to completion, as well as project audit. The methodology can be extended to undertake project appraisal and evaluation, rank and select project for best financial performance. EVM is applicable to all types and sizes of projects including construction of facilities. This paper reviewed the principles of EVM and used case study to demonstrate the implementation of EVM in construction cost management and audit.

Keywords
Earned Value Management, Construction, Cost Management, Project Quality, Audit

1. Introduction

Earned Value Management (EVM) is a project management technique that measures forward progress objectively and bring cost and schedule variance analysis together to provide managers with a more accurate status of a project (Kim et al., 2003). It takes into account the work complete, the time taken and the costs incurred to complete the project and it helps to evaluate and control project risk by measuring project progress in monetary terms. Essential features of any EVM implementation include a *project plan* that identifies work to be accomplished, a valuation of planned work, called *planned value* (*PV*), and pre-defined "earning rules" (also called metrics) to quantify the accomplishment of work, called *Earned Value* (*EV*). EVM implementations for large or complex projects include many more features, such as indicators and forecasts of cost performance and schedule performance. The most basic requirement of an EVM system, however, is that it quantifies progress using PV and EV.

The concept of EVM came forth in 1960s primarily in the defense contracting industry in the USA and Australia (Gowan et al., 2006). EVM was developed by the US Department of Defense (DoD) and originally called PERT/COST and further evolved into Cost/Schedule Control Systems Criteria (C/SCSC) which was considered overly burdensome (not very adaptable) by contractors who were mandated to use it, and many variations of it began to proliferate among various procurement programs. In 1970s and early

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1980s, a subculture of C/SCSC analysis grew, but the technique was often ignored or even actively resisted by project managers in both government and industry. C/SCSC was often considered a financial control tool that could be delegated to analytical specialists. The terminology was revised by the DoD in 1996 and accepted as American National Standards Institute/Electronic Industry Association Standard #748 in 1998, titled EVMS. The standard was accepted by the DoD in 1999.

EVM was not limited to the DoD for long. It was quickly adopted by the National Aeronautics and Space Administration, United States Department of Energy and other technology-related agencies. Many industrialized nations also began to utilize EVM in their own procurement programs. The construction industry was an early commercial adopter of EVM. Closer integration of EVM with project management profession accelerated in the 1990s. The primary professional association for EVM, called the Performance Management Association merged with the Project Management Institute (**PMI**) in 1999 to become PMI's first college, the College of Performance Management. Efforts to simplify and generalize EVM gained momentum in the early 2000s. The United States Office of Management and Budget began to mandate the use of EVM across all government agencies, and for the first time, for certain internally-managed projects (not just for contractors). EVM also received greater attention by publicly traded companies in response to the Sarbanes-Oxley Act of 2002.

EVM is widely used by Government Agencies in Australia, Canada and the United Kingdom and more recently used by business and industry in general. The methodology provides project management guidelines and standards as detailed in:

- PMI PMBOK 2003 – Earned Value Guidelines
- Australia Standard AS 4817 - Project Performance Measurement Using Earned Value
- US DODI 5000.2R United States And ANSI EIA 748 - Industry Guidelines for Earned Value
- Canadian Standard CGSB 187.2 99 Guidelines for Earned Value

As can be seen, main purpose of carrying out Earned Value analysis is to ascertain that the project is proceeding as planned and is within allocated budget. No matter how small, complex or large the project is, the client would appreciate that the project will finish in time, with appropriate quality and within budget specified.

2. EVM Based Software

One can carry out the process of EVM using an Excel spreadsheet, or manually through the accounting system used on the project. However, the Authors believe that it would be a very time-consuming and onerous task. One may be able to simplify the process by use of one of the available software developed by various groups globally. There are over 40 types of such software available in the market place. Following are some examples of such software:

- NHH Enterprise EVMS providing resources for government projects in USA.
- Earned Value Maturity Model containing profiles of EV maturity as a working white paper on maturity.
- Earned Value Management for Self Directed Software Teams, Steve Lett, Software Engineering Process Group, Lockheed Martin.
- Using CMMI to improve Earned Value Management, CMU/SEI-2002-TN-016.
- Earned Value Engine, Supertech Pty. Ltd.

3. Using Earned Value Management for Construction Cost Management

Construction projects are one-off endeavours with many unique features such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures (Flanagan and Norman, 1993; Smith, 1999) and such organizational and technological complexity generates enormous risks. The diverse interests of project stakeholders on a construction project further exacerbate the

changeability and complexity of the risks (Zou et al., 2006). As a result of poor management of risks, construction time will be delayed and construction cost will be tremendously increased. Hence, identifying major causes of project delays and construction cost blowouts and using potentially effective tools such as Earned Value Management to manage the potential occurrence of these risks are of significant importance.

3.1 Major Causes of Program Delays, Cost Blowouts and Contractual Disputes

Extensive research has been carried out to explore the causes of program delays (Shen, 1997; Mulholland and Christian, 1999), cost blowouts (Kaming et al., 1997; Chen et al., 2004) and cause of contractual disputes (Jannadia et al., 2000; Mitropoulos and Howell, 2001). As a summary, the factors resulting in project delays, cost blowouts and cause of contractual disputes are listed in Table 1.

Table 1: Major Causes of Program Delays, Cost Blowouts and Contractual Disputes

Project Phases	Major Causes
Documentation	• Poorly defined scope of works and documentation, architectural and engineering detail and coordination resulting in extended sub-contractor shop detailing or clarification to design through request for information. • Late review of documentation, shop drawings and vendor data submitted by builder. • Poor and untimely responses to RFI's – Request for Information. • Unmanaged client initiated design changes during construction. • Poor definition of Operational And Access Constraints
Procurement and Subcontract Management	• Poor project planning and underestimating time and cost of work to completion. • Late commitment to vendors and sub-contract packages. • Selection of vendors and sub-contractors with insufficient offsite and on site resources to undertake and sustain the project. • Late payment of Vendors and Subcontractors.
Implementation	• Poor work quality and performance resulting in rework and extended defects repair period prior to project handover. • Poor supply chain management of material supply and vertical transportation to the work face. • Poor HR - Human Resources and IR - Industrial Relations management resulting in lost time due to accidents and industrial issues. • Unexpected site conditions resulting in Contractor and or sub-contractor increased cost and work. • Poor site protection works resulting in more than average lost time effects due to inclement weather.

3.2 Why Use Earned Value Methodology for Construction Cost Management

EVM is applicable to all types and size of construction projects. It requires focused and structured planning for successful implementation and subsequent report generation useful for trend analysis and decision making. It uses key industry performance indicators and variance mathematics to trend and established final costs. EVM can be used to determine the cash position of the project, how much profit was planned, how much profit is forecast to be made, cost of interest. It can be extended to resource and materials management, financial analysis and contract management. EVM can form the basis of a company's cost management framework to integrate traditional accounting practices with focused project based cost management. Generally, EVM gives project managers the ability to know and answer to the following questions at any level of the project structure:

- How much work was actually performed and how much did it cost?
- How much work remains to be done and how much will it cost?
- For the work performed, how does the cost stack up against the budget?
- Will the remaining budget be enough to cover the cost of the remaining work?
- Was the work performed on time?
- Will the remaining work be completed on time?

3.3 Key Steps in Using EVM for a Construction Project Audit

A successful construction project audit using EVM consist of the following key steps:

- Ensure the WBS - Work Breakdown and OBS - Organizational Breakdown Structure of the project program and cost control system is at a sufficient level of detail that identifies all the phased development of the project contract. For construction projects this includes architectural, structural and engineering design services, procurement and subcontract, pre-construction and construction activities by area and trade package breakdown.
- Sufficient visibility is given to activities to allow the simulation of change and consequential delay effects to the structure, architectural finishes and specialist services.
- Key statutory approval periods and hold points related to the finance, payment conditions and penalties as provided for by the contract are clearly identified.
- The program reflects fully the model for administering the contact and facilitating the tracking of as constructed program data and can be used for evaluating and controlling extension of time claims.
- The budget, committed and contract price are distributed against the program activities to facilitate: the identification of problem areas, undertake performance trending related to program and cost, and to identify the appropriate action to take under the contact.

Being able to provide a clear track of project cost distribution, EVM can support the prosecuting or rebutting of a claim

- EVM establishes the cash position of the project including the risk profile with respect to the cost distribution and estimated work to completion.
- EVM allows the structured calculation of variations in the cost of project finance and can be used to substantiate or rebut extension of time and cost claims.
- EVM provides a proven and consistent framework and governance for the prosecution and evaluation of project performance which can be extended to the evaluation of business disruption claims, additional cost of finance, lost opportunity cost, insurance claims and other related issues.

The paper demonstrates the application of EVM by use of a case study. This case study has been based on Earned Value Engine (EVE) software developed by Supertech Project Management Pty Ltd in Australia. EVE software is a Microsoft Excel™ add-in utility that covers all computational requirements for performance measurement, trending and reporting to international accepted standards and guidelines. Other features include cash position, payment administration, and productivity key performance indexes and investment analysis (More EVE information is available website www.evengine.biz).

4. Term Used in EVM

A series of technical terms are defined below to support the application of EVM in construction cost management and project audit.

4.1 Defining EVM Standard Terms and Formulae Defined

A cluster of terms used in EVM are defined and demonstrated in the Figure 1.

Budget at Completion (BAC) is the funds allocated to activities to ensure the project is completed on time and budget.
Estimate at Completion (EAC) is the sum of the Actual Cost (AC) incurred to the end of the project report period and the Estimate to Complete (ETC), the cost for any remaining work scheduled.
Sell Price (SP) is the Budget at Completion (BAC) plus Margin that allows the measurement of Planned Profit (PP) and Profit (P).
Earned Value (EV) is the time phased cumulative value for work actually completed to the end of each report period as calculated from the project actual or scheduled start and finish dates.
Planned Value (PV) is the time phased cumulative value of work that should be completed at the end of each report period as calculated from the project baseline start and finish dates. PV is also described as the time phased baseline cash flow.

Earned Sell Price (ESP) is the time phased cumulative sell price for work actually completed to the end of each report period as calculated from the project actual or scheduled start and finish dates.
Actual Cost (AC) is the time phased cumulative cost for work completed to the end of the report period as calculated from the project actual or scheduled start and finish dates.

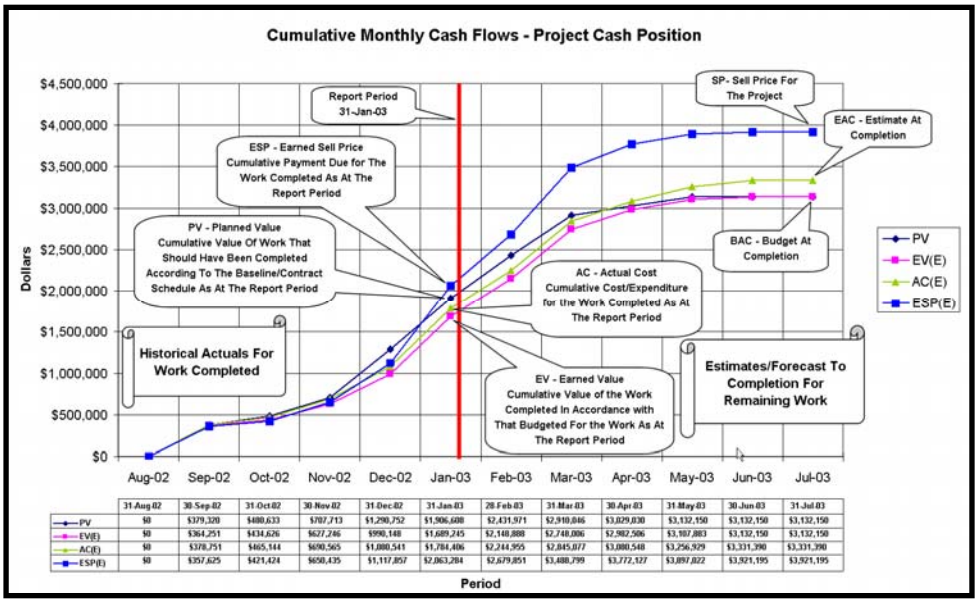

Figure 1: A Cluster of Terms Used in EVM

4.2 EVM Performance Base Formulas & Report Interpretation

The EVM performance evaluation process is visualized around a triangle in Figure 2.

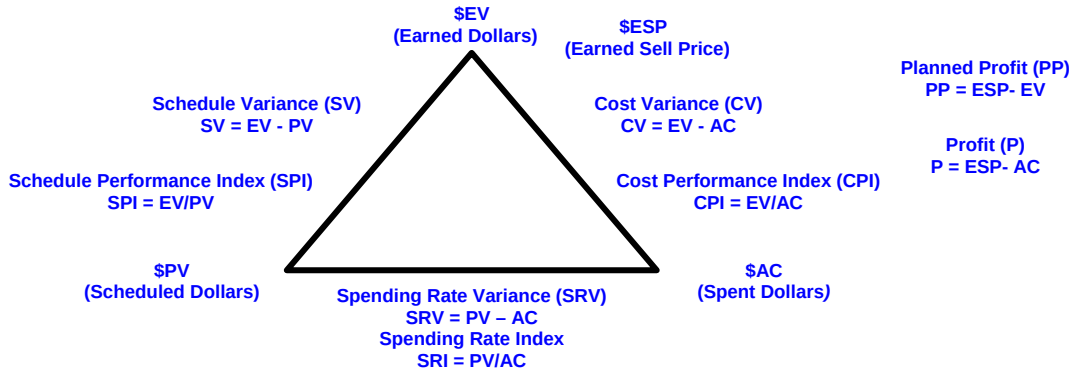

Figure 2: EVM Performance Evaluation Process

Cost Variance (CV) measures the variance between the Earned Value (EV) and the Actual Cost (AC). The CV determines by cost amount how much each task and project overspends or under-spends its allocated budget. CV = EV – AC. If CV ≥$0.00, this is interpreted as either breaking even or making a cost saving. If CV <$0.00, this is interpreted as overspending.
Schedule Variance (SV) measures the variance between the EV – Earned Value and the PV – Planed Value. The SV determines by cost amount how much each task and project is behind or ahead of the baseline (Contract) plan. SV = EV – PV. If SV ≥$0.00, this is interpreted as either on schedule or ahead of schedule. If SV <$0.00, this is interpreted as behind schedule.
Planned Profit (PP) is the profit planned for the project where PP = ESP-EV. *Profit (P)* is the actual profit for the project where P = ESP – AC.

Cost Performance Index (CPI) measures the cost performance at the project task outline level. The index is calculated as follows: CPI = EV/AC If CPI is < 1, spending for the work completed is greater than the allocated budget indicating overspending. If CPI is > 1, spending is less than the allocated budget indicating a cost saving.
Schedule Performance Index (SPI) measures the schedule performance at the project task outline level. The index is calculated as follows: SPI = EV/PV If SPI is < 1, project is behind the scheduled baseline completion and will be delivered late. If SPI is > 1, project is ahead of the scheduled baseline and will be delivered early. At completion of the project the SPI is always = 1.0 as the EV = PV = BAC.

The Schedule and Cost Performance Indices can be used to assess performance at WBS and CBS outline line levels for the project report period. The Terminology & Formulas are defined in PMBOK 2000, Modified ANSI 748, US DODI 5000.2R and AS 4817-2003 Standards.

5. Case Study - Using EVM to Successfully Administer a Construction Project

A case study is used to illustrate the process of using EVM for the construction cost management and followed by a successful project audit. The project is an apartment block comprising two basement levels, one street retail and eight high rise residential levels, as shown in Figure 3.

Figure 3: Architectural Drawing of the Project

Some basic information about this construction project is described in Table 2.

Table 2: Construction Project Information

Cost/Time	Project Information
Builders Cost	Estimated Builder's Construction Cost $15,677,648. Committed Trades & Preliminary Costs $15,072,043 at 90% of Trade Package Commitment.
Developers Cost	Cost to the Developer $18,813,178. Land Cost $2,000,000. Legal & Finance Charges $2,000,000 Design Charges and Permitting $500,000 Project Management $200,000 GST $760,800
Benefits	Sale Value $30,000,000. Before Tax Profit $5,726,022.
Time	Development Period 22 Months Construction Period 14 Months.

It was decided by the project's builder that a project audit should take place to substantiate his claim for extension of time plus variation costs. An initial audit of the builder's project management systems suggested that a significant upgrade in project management skills was necessary to bring the project under

control. As part of the auditing process an EVM project management control system was established to fairly protect the interest of all parties and avoid disputes that could lead to expensive litigation. The Supertech's Earned Value Engine (EVE) project Control Software" was chosen for cost performance analysis and reporting.

Project management control charter was established with the following characteristics:

- One single point for project program maintenance, financial control and performance reporting avoiding reporting duplication.
- One single combined project program structured to fulfill the requirements for tracking design, procurement and construction activities.
- A fully resourced program to give visibility to all labour requirements by trade package.
- A stakeholder agreed control baseline for both program and cost control.
- An agreed and documented mechanism for resolving disputes between the project stakeholders.
- A site agreement with the relevant labour unions with a No Strike disputes resolution process.
- Computer based project management, performance measurement and reporting system.

5.1 WBS Work Breakdown and OBS Cost Breakdown Structures

To facilitate the project audit, the project program and cost control system was restructured to identify the key construction elements by area and trade level, as shown in Figure 4.

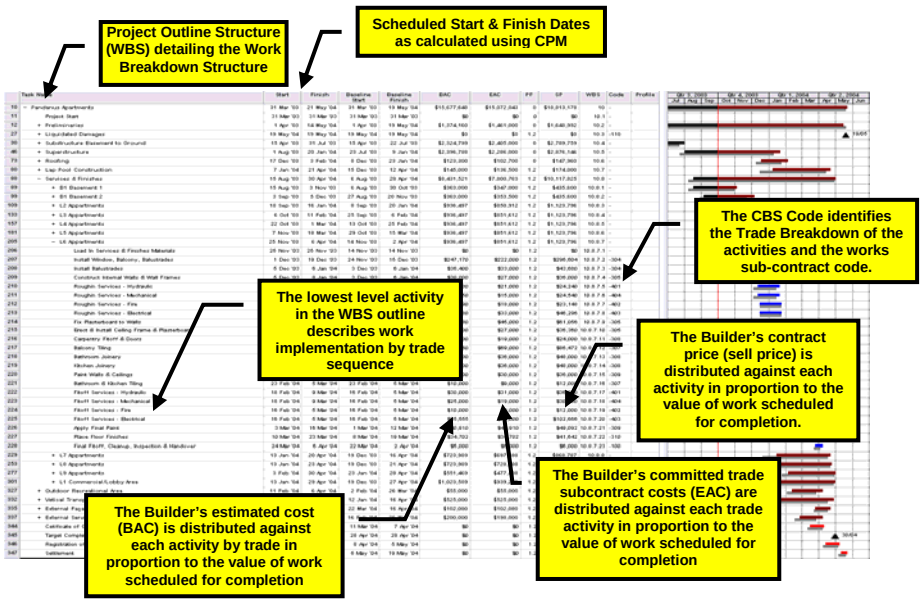

Figure 4: WBS and OBS of a Typical Project Used in EVE

5.2 A Formal Progress Measurement Cycle

A formal progress measurement cycle was introduced below:

- Daily program updating with respect to:
  - √ Recording as constructed history for activities started or completed.
  - √ Revising and Adding New cost and program data with respect to material, equipment and finishes supply and subcontract package commitments.
- The objective to maintain a real time project model to facilitate:
  - √ Daily schedule variance reporting.
  - √ Daily resource/manpower requirements.
  - √ Materials supply chain management and coordination.
  - √ Project cash management.

- Weekly construction program performance reporting for trade and supplier coordination and for project stakeholder progress briefing.
- Monthly Progress Certification for builder and subcontractor payment using EVM - Earned Value Cost Performance measurement and reporting to AS 4817-2003 standards with additional reports covering the profit and loss status for the project builder.

The Measurement Overhead includes:

- Additional time for setup of project program with cost codes and cost assignments, 50% more program planning time.
- Daily program maintenance, one hour per day.
- Weekly construction performance reports and analysis, using Microsoft Project with EVE.NET Project Control software, half day.
- Monthly performance measurement, profit and loss statements, claim and payment certification, including project inspection by the bank's engineer and sign-off, one day. This included processing 12 of 29 subcontracts active at any time.
- Using EVE.NET software all performance data captured was archived away for later retrieval, if required, to resolve any program or financial claims.

5.3 Results of the EVM Audit

The following slides illustrate the some typical performance graphs & reports used to audit the project, measure performance and administer the contract to completion.

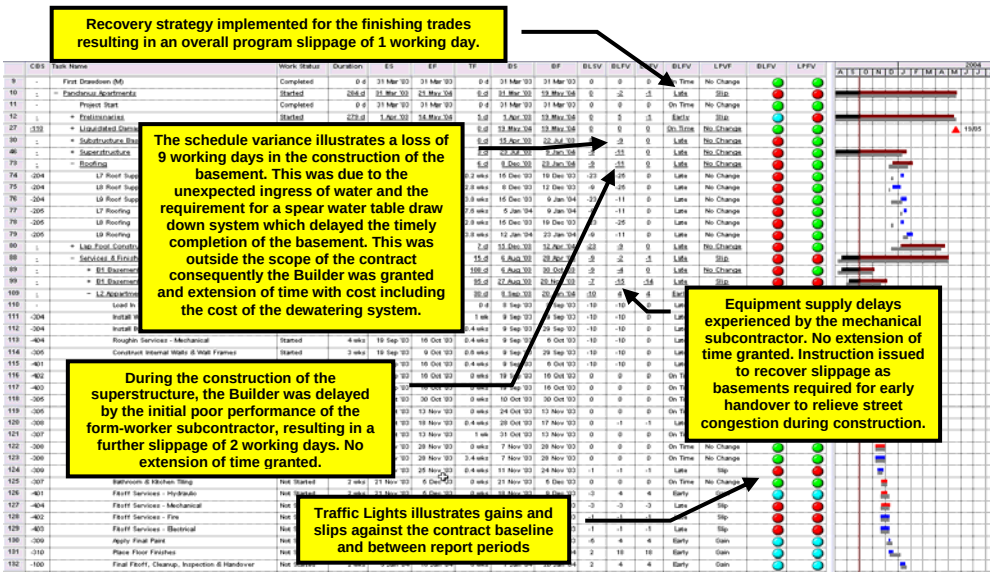

Figure 5: Report No.1 EVE - Microsoft Project Schedule Performance Measurement Using Baseline and Report Period Variance

Having restructured the builder's program the following schedule performance analysis was possible to substantiate the builder's extension of time claims. Figure 5 illustrates schedule variance between the contract baseline and the last period target. Using this methodology identifies slips and gains from the contract and between report periods. Microsoft Project Tables and Gantt Charts were customized to facilitate schedule variance reporting. The traffic light system highlights program slips and gains. Figure 6 indicates that Earned Value is lower than Planned Value however the Earned Sell Price has sufficient margin and is above actual cost. Figure 7 illustrates the project cash position with respect to Schedule, Cost and Profit. This report was used extensively to by the Building Contractor's senior management to evaluate profit, risk and trends. Figure 8 gives a continuation sheet to the certificate of builder's claim detailing the basis of the claim between the two report periods.

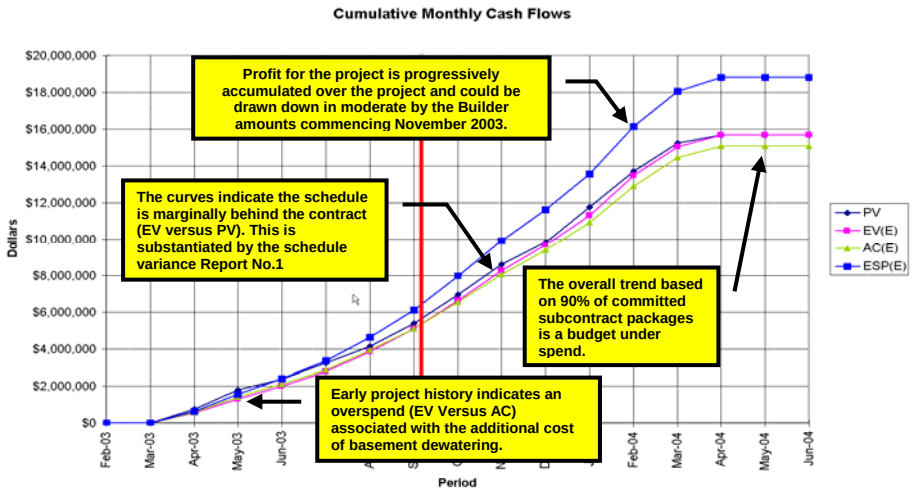

Figure 6: Report No.2 EVE - Cost Performance Analysis by S-Curve

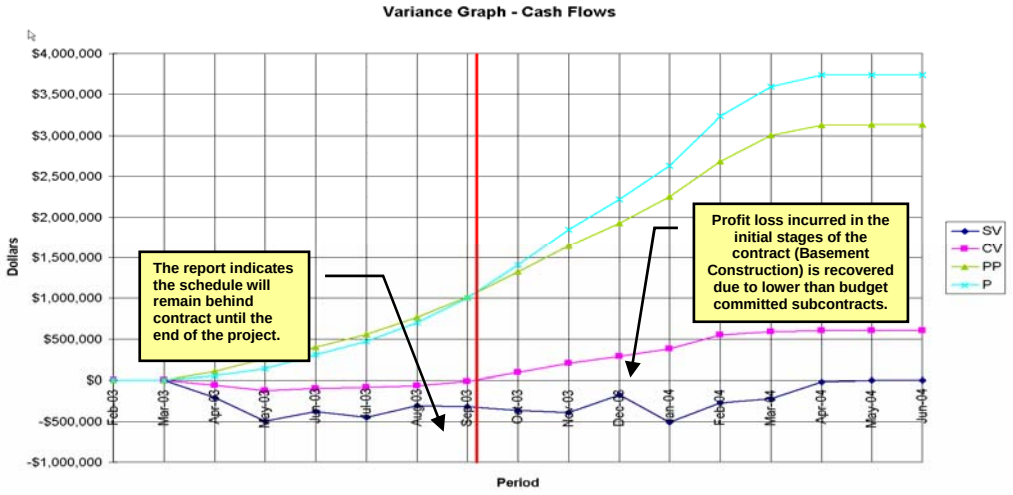

Figure 7: Report No.3 EVE - Cost Analysis by Variance Graph

Activities	WBS Code	Selection Code	This Report Period Continuation Sheet ESP	SP	SPTC	%C(SP)	Last Report Period Continuation Sheet ESP	SP	SPTC	%C(SP)
Project Management	10.2.1		$261,969	$564,000	$302,041	46.45%	$219,015	$564,000	$344,985	38.83%
Site Establishment	10.2.2	100-Prelims	$100,000	$100,000	$0	100.00%	$100,000	$100,000	$0	100.00%
Demolition	10.2.3	102-Demolition	$76,160	$76,160	$0	100.00%	$76,160	$76,160	$0	100.00%
Site Hoardings/Fencing	10.2.4	100-Prelims	$20,000	$20,000	$0	100.00%	$20,000	$20,000	$0	100.00%
Erect Crane	10.2.5	100-Prelims	$50,000	$50,000	$0	100.00%	$50,000	$50,000	$0	100.00%
Crane Usage	10.2.6	100-Prelims	$138,571	$300,000	$161,429	46.19%	$95,714	$300,000	$204,286	31.90%
Dismantle Crane	10.2.7	100-Prelims	$0	$30,000	$30,000	0.00%	$0	$30,000	$30,000	0.00%
Hoist Usage	10.2.9	100-Prelims	$46,857	$224,000	$177,143	20.92%	$12,571	$224,000	$211,429	5.61%
Dismantle Hoist	10.2.10	100-Prelims	$0	$10,000	$10,000	0.00%	$0	$10,000	$10,000	0.00%
Perimeter Piling	10.4.1	200-Piling	$873,600	$873,600	$0	100.00%	$873,600	$873,600	$0	100.00%
Excavation & Disposal of Spoil	10.4.2	201-Earthworks	$604,800	$604,800	$0	100.00%	$604,800	$604,800	$0	100.00%
Strip Footings	10.4.3	202-Concrete	$42,965	$42,965	$0	100.00%	$42,965	$42,965	$0	100.00%
Crane Footing	10.4.4	202-Concrete	$0	$0	$0	0.00%	$0	$0	$0	0.00%
Lift/Stair Footings	10.4.5	202-Concrete	$125,496	$125,496	$0	100.00%	$125,496	$125,496	$0	100.00%
Basement to Ground Walls	10.4.6	203-Precast	$246,989	$246,989	$0	100.00%	$246,989	$246,989	$0	100.00%
Column Pad Footings	10.4.7	202-Concrete	$6,720	$6,720	$0	100.00%	$6,720	$6,720	$0	100.00%
B2 to B1 Columns	10.4.8	202-Concrete	$17,280	$17,280	$0	100.00%	$17,280	$17,280	$0	100.00%
B2 to B1 Staircase/Lift Core	10.4.9	202-Concrete	$16,128	$16,128	$0	100.00%	$16,128	$16,128	$0	100.00%
Surface Treatments	10.4.10	103-Surface Treatments	$26,112	$26,112	$0	100.00%	$26,112	$26,112	$0	100.00%
Basement 2 Ground Slab	10.4.11	202-Concrete	$150,450	$150,450					$0	100.00%
Basement 1 Slab	10.4.12	202-Concrete	$330,970	$330,970					$0	100.00%
B1 to L1 Stair/Lift Walls	10.4.13	202-Concrete	$0	$0					$0	0.00%
B1 to L1 Columns	10.4.14	202-Concrete	$17,280	$17,280					$0	100.00%
L1 Slab	10.4.15	202-Concrete	$330,970	$330,970					$0	100.00%
L1 to L2 Staircase/Lift Core	10.5.1	202-Concrete	$25,020	$25,020	$0	100.00%	$25,020	$25,020	$0	100.00%
L1 to L2 - Walls - Structural Precast	10.5.2	203-Precast	$305,280	$305,280	$0	100.00%	$305,280	$305,280	$0	100.00%
L2 Floor Slab	10.5.3	202-Concrete	$297,024	$297,024	$0	100.00%	$297,024	$297,024	$0	100.00%
L2 to L3 Staircase/Lift Core	10.5.4	202-Concrete	$16,001	$16,001	$0	100.00%	$16,001	$16,001	$0	100.00%
L2 to L3 - Walls - Structural Precast	10.5.5	203-Precast	$139,200	$139,200	$0	100.00%	$139,200	$139,200	$0	100.00%
L3 Floor Slab	10.5.6	202-Concrete	$157,560	$157,560	$0	100.00%	$115,544	$157,560	$42,016	73.33%
L3 to L4 Staircase/Lift Core	10.5.7	202-Concrete	$16,001	$16,001	$0	100.00%	$0	$16,001	$16,001	0.00%
L3 to L4 - Walls - Structural Precast	10.5.8	203-Precast	$139,200	$139,200	$0	100.00%	$0	$139,200	$139,200	0.00%
L4 Floor Slab	10.5.9	202-Concrete	$16,001	$16,001	$0	100.00%	$0	$16,001	$16,001	0.00%
L4 to L5 Staircase/Lift Core	10.5.10	202-Concrete	$123,733	$139,200	$15,467	88.89%	$0	$139,200	$139,200	0.00%
L4 to L5 - Walls - Structural Precast	10.5.11	203-Precast	$157,560	$157,560	$0	100.00%	$0	$157,560	$157,560	0.00%
L5 Floor Slab	10.5.12	202-Concrete	$6,857	$16,001	$9,143	42.86%	$0	$16,001	$16,001	0.00%
L5 to L6 Staircase/Lift Core	10.5.13	202-Concrete	$0	$139,200	$139,200	0.00%	$0	$139,200	$139,200	0.00%
L5 to L6 - Walls - Structural Precast	10.5.14	203-Precast	$0	$157,560	$157,560	0.00%	$0	$157,560	$157,560	0.00%
L6 Floor Slab	10.5.15	202-Concrete	$0	$157,560	$157,560	0.00%	$0	$157,560	$157,560	0.00%
L6 to L7 Staircase/Lift Core	10.5.16	202-Concrete	$0	$139,200	$139,200	0.00%	$0	$139,200	$139,200	0.00%
L6 to L7 - Walls - Structural Precast	10.5.17	203-Precast	$0	$157,560	$157,560	0.00%	$0	$157,560	$157,560	0.00%
L7 Floor Slab	10.5.18	202-Concrete	$0	$157,560	$157,560	0.00%	$0	$157,560	$157,560	0.00%

The advantage of using this system is a complete reconciliation between schedule completion and

Figure 8: Report No.4 EVE - Continuation Sheet to Certificates of Claim and Payment

6. Conclusions

Earned Value Management with the aid of proper software allows project stakeholders to undertake the forensic analysis as demonstrated.

- PM can take full control of the project program and cost performance reporting by using a consistent reporting framework conforming to Australian Standard AS 4817;
- Produce professional performance reports and graphs to assist in trending and identifying problem with respect to schedule and budget.
- Undertake formula based cash management of the project by removing uncertainty with respect to the project cash position. Cash management saved the project some 2% of the project finance costs in the case study example.
- Realize significant cost savings (calculated at 20% of the project management budget) in administrative cost by automating the Earned Value reporting and payment certification process. Calculate and issue payment certificates on the same day as the end of month schedule status.
- Minimized disputes with the Builder, Subcontractors and Suppliers over the value of progress claims and payments.
- Integrate and synchronize accounts payable data with the certification process.
- EVM can also be extended to evaluation of performance based on Man-hours and on Quantities.
- Using a combination of Cost, Work and Quantities performance can be measured against average industry performance indices.
- Applying discounted cash flow to the project cash position life cycle the return period and investment potential of a project can be evaluated.

7. References

Chen, H., Hao, G., Poon, S.W. and Ng, F.F. (2004). "Cost risk management in West Rail Project of Hong Kong". *2004 AACE Int. Transact*.

Flanagan, R. and Norman, G. (1993). *Risk Management and Construction*, Victoria: Blackwell Science Pty Ltd, Australia.

Gowan, J.A., Mathieu, R.G. and Hey, M.B. (2006). "Earned value management in a data warehouse project". *Information Management & Computer Security*, Vol. 14, No. 1, pp37-50.

Jannadia, M.O., Assaf, S., Bubshait, A.A. and Naji, A. (2000). "Contractual methods for dispute avoidance and resolution (DAR)'. *International Journal of Project Management*, Vol. 18, pp41-49.

Kaming, P.F., Olomolaiye, P.O., Holt, G.D. and Harris, F.C. (1997). "Factors influencing construction time and cost overruns on high rise projects in Indonesia". *Constr. Manage. and Econom.,* Vol. 15, pp83-94.

Kim, E., Wells, W.G. and Duffey, M.R. (2003). "A model for effective implementation of Earned Value Management methodology". *International Journal of Project Management*, Vol. 21, pp375-382.

Mitropoulos, P. and Howell, G. (2001). "Model for understanding, preventing and resolving project disputes'. Journal of Construction Engineering and Management, Vol. 127, No. 3, pp223-231.

Mulholland, B. and Christian, J. (1999). "Risk assessment in construction scheduling". *J. Constr. Eng. and Manage.*, Vol. 125, No. 1, pp8-15.

Shen, L.Y. (1997). "Project risk management in Hong Kong". *Int. J. Proj. Manage.,* Vol. 15, No. 2, pp101-105.

Smith, N.J. (1999). *Managing Risk in Construction Projects*, Oxford: Blackwell.

Zou, P.X.W., Zhang, G. and Wang, J.Y. (2006). "Identifying key risks in construction projects: life cycle and stakeholder perspectives". *Proc. 12th Pacific Rim Real Estate Society Conference*, Auckland, New Zealand, 22-25 Jan.