EARNED VALUE MANAGEMENT SYSTEM AS A PROJECT MANAGEMENT TOOL FOR MAJOR MULTI-DISCIPLINARY PROJECTS

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Abstract: The Earned Value Management System (EVMS) is a useful management tool available for project managers to monitor and control major multi-disciplinary projects. EVMS measures project performance by comparing the amount of work planned against the amount of work actually carried out and the actual costs incurred. EVMS combines the work scope, schedule and the cost elements of a project and facilitates the integrated reporting of a project's progress and the cost status. The earned value concept was first introduced by industrial engineers working in American factories over a century ago and this concept was used to manage the production cost of commercial industrial products. The basic concepts of earned value were adopted by the United States Air force in the early 1960s and later endorsed by the United States Department of Defence in all major system acquisitions. Earned Value Management is a technique that can be applied to the management of all infrastructure projects, in any industry, while employing any contracting approach.

This paper summarizes the basic concepts and the theory of EVMS, briefly explains how EVMS can be implemented for a multi-disciplinary project, the challenges encountered during implementation and its benefits to a project as a project management tool.

1 Introduction

The management of multi-disciplinary infrastructure projects requires monitoring and control tools for effective project control. The Earned Value Management System (EVMS) is one of the tools for measuring project performance by comparing the amount of work planned against the amount of work actually done and the actual cost incurred. EVMS integrates the scope, cost (or resource) and schedule to help the project team assess project performance (PMBOK Guide, 2002). The concept of earned value management system was first introduced by industrial engineers working in American factories over a century ago (Fleming & Koppelman, 1999). This concept was used to manage the production cost of commercial industrial products. The basic concepts of earned value were originally adopted by the United States Air force in the early 1960s and by 1967, the United States Department of Defence formally endorsed the use of earned value management in all major system acquisitions (Fleming & Koppelman, 1999). The basic concepts of earned value management have not changed since 1967 (Christensen, 1999). Earned Value Management is a technique that can be applied to the management of all capital projects, in any industry, while employing any contracting approach (Fleming & Koppelman, 2002). The Earned Value Management System has been successfully implemented for the project management and control of a major mult-disciplinary infrastructure development project in Hong Kong (Dissanayake, 2007).

To understand the concept of EVMS, it is important to compare EVMS with the traditional method of project cost management. In the traditional approach there are two data sources, the budget (planned) expenditures and the actual expenditures. The comparison between the budget versus the actual only indicates what was planned to be spent and the actual amount spent at a given time. But this does not give any idea about how much work has been done. Therefore, in the traditional approach there is no measure of the physical amount of work performed. It does not indicate anything about what has been achieved for the money spent. In EVMS, unlike in the traditional approach, there are three data sources, the budget (planned), actual expenditure and the "earned value" which is the physical work done at a given time. Therefore, in EVMS the planned value of the work could be compared with the earned value and actual cost. The three basic definitions used in EVMS are as follows:

Budgeted Cost of Work Scheduled (BCWS) = Planned Value
Budgeted Cost of Work Performed (BCWP) = Earned Value
Actual Cost of Work Performed (ACWP) = Actual Cost

During the planning stage of a project, a time phased budget is developed based on the estimated cost of various elements of the project and the works programme. This time phased budget serves as a performance measurement baseline against which the project progress is monitored. At a given point in time on the date of analysis, the value of the performance measurement baseline becomes the BCWS. The BCWS is compared with the BCWP and ACWP, all expressed in terms of monetary values. The following variances are used to measure project performance.

Cost Variance (CV) = BCWP – ACWP

CV is an indicator of expenditure measured against the completion of the corresponding work scopes. If CV = 0, the performance is on target, if CV > 1.0, it indicates a favourable performance and if CV < 1.0, it indicates a cost overrun.

Schedule Variance (SV) = BCWP – BCWS

SV is an indicator of the schedule status as compared to the plan in terms of a monetary value. If SV = 0, then the project is progressing as planned, if SV > 0, it indicates the project is ahead of schedule and if SV < 0, it indicates the project is behind schedule.

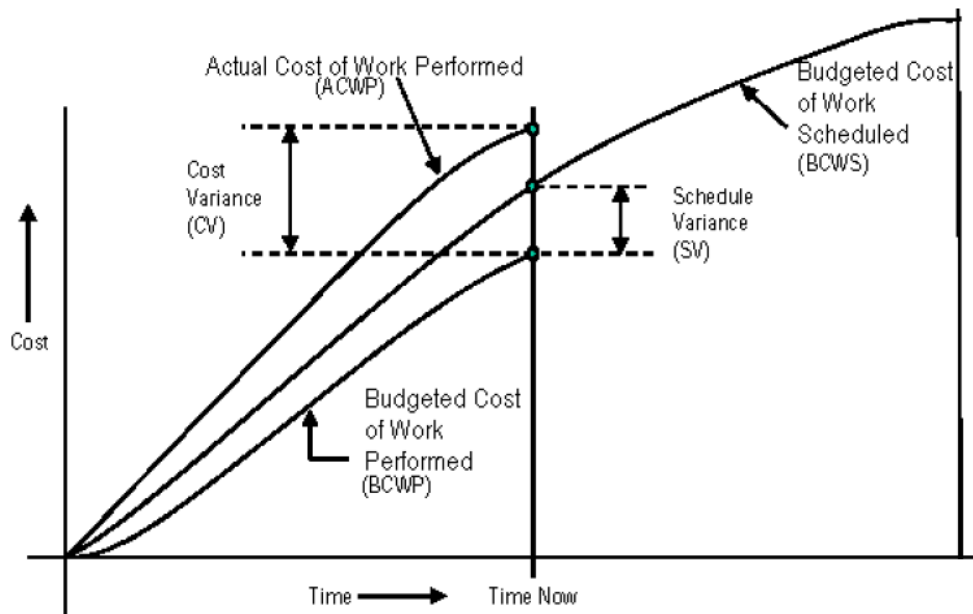Fig. 1 illustrates the graphical representation of the above earned value parameters.

Fig. 1 – *Graphical Representation of Earned Value Parameters*

The following indices are used to measure project performance.

Cost Performance Index (CPI) = $\dfrac{BCWP}{ACWP}$

If CPI = 1.0, then the performance is on target, CPI > 1.0, then the performance is exceptional and if CPI<1.0, then the performance is substandard.

Schedule Performance Index (SPI) = $\dfrac{BCWP}{BCWS}$

If SPI = 1.0, then the performance is on target, SPI>1.0, then the performance is exceptional and if SPI<1.0, then the performance is substandard. The two indices CPI and SPI may give results that may seem contradictory if CPI >1 and SPI < 1. In this situation, the project is within budget which is good but it is behind schedule. This indicates that money was saved because not enough work was done. Therefore, the Cost-Schedule Index (CSI) is introduced (Barr, 1996).

Cost Schedule Index (CSI) = CPI x SPI = $\dfrac{BCWP^2}{ACWP \times BCWS}$

It is said that if the CSI value in general is greater or around 1.0, a project is not having any serious problems (Barr, 1996).

2 Implementation of EVMS

In order to implement EVMS for an infrastructure project, it is important that the following steps are followed.

2.1 Detailed Work Breakdown Structure (WBS)

The development of the WBS is considered as the cornerstone of effective project planning, execution, controlling and reporting (US DOE, 2003). Therefore, it is important that a detailed WBS is developed for the whole project that will include all the major elements and their sub-elements with further detailed breakdown of the sub-elements as required. Any major infrastructure project would essentially be a multi-disciplinary project and hence a large number of consultants and contractors would be involved in the project at various stages. Therefore, it is important that all these parties who would be participating in the project be included in the WBS. The WBS should include all work that is carried out under the project that will incur a cost to the project. Therefore, all consultants and contactors having separate contractual arrangements with the client need to be included in the WBS.

2.2 Integrated Programme (Schedule)

Developing an Integrated Programme (IP) is an essential step in the implementation of EVMS. It should include all the elements, sub-elements etc. included in the WBS. A comprehensive IP should be developed by the project manager. It is also possible to get the help of the individual consultants and contractors to prepare the programmes for their own portion of works (project programmes) that will form the IP.

2.3 Formal guideline for the preparation of Project Programmes (PP)

Any major multi-disciplinary infrastructure project will include a large number of consultancies and works contracts and the development of IP will be a collective exercise. It is therefore essential that a formal guideline is prepared for the development of PP (that will form the IP). This will ensure that once PPs are prepared, they could be integrated to form the IP. The guideline should cover the activity identification numbering scheme, activity coding structure (in-line with WBS), activity identification codes, calendar codes and resource identifications. This formal guideline will form the backbone of the EVMS and hence should be prepared with great care. The formal guideline should include a copy of the WBS, guidelines for the preparation of individual PPs, the incorporation of project cost information, the procedure for the integration of PPs and the updating of project progress and cost data.

2.4 Activities for Earned Value (EV) Measurement

It is important to note that it is not practical to use all activities in the IP to monitor EV at the end of each reporting period. Therefore, the project manager needs to select a reasonable number of activities that will be assigned with cost data and will be used to measure the EV parameters. The Earned Value Elements are to be selected in such a way that when the progress and cost status are reported against these Earned Value Elements, it should reflect the overall progress and cost status of each contract package.

2.5 EV Measuring Techniques

It is important that EV measuring techniques are established for each type of activity before carrying out project monitoring work. The determination of earned value depends on the type of effort, whether it is discrete, apportioned or on the level of effort.

2.5.1 Discrete effort

There are three basic earned value methodologies applicable to the discrete effort. They are based on valued milestones, standard hours and management assessment. A typical example would be a contract with a milestone payment arrangement where a pre-determined monitory value will be earned once a particular milestone is achieved.

2.5.2 Apportioned effort

Apportioned effort is work for which planning and progress is tied to other efforts. The budget for apportioned account will be time-phased in relation with the resource plans for the base account. A typical example would be in a software design project where the task manager would apportion computer costs to the design and coding effort.

2.5.3 Level of Effort

Level of effort is work scope of a general or supportive nature for which performance cannot be measured or impracticable to measure. Resource requirements are represented by a time-phased budget schedule in accordance with the time the support will likely be needed. A typical example would be the head office staff work-hours spent on administration work for a particular project.

3 Application of EVMS

EVMS was used as a management tool for the project monitoring and control of a major multi-disciplinary infrastructure development project in Hong, the Hong Kong Science Park Phase 2 Development. The author, a former employee of Maunsell AECOM (a Project Manager of Hong Kong Science Park Phase 2 Development) was responsible for the implementation of the EVMS for the above project. Hong Kong Science Park Phase 2 was the second phase of a 3 phased development project funded by the government of Hong Kong at a total cost of more than US$ 1.5 billion. Upon completion of the Science Park, a total Gross Floor Area of 330,000 m2 will be provided for office and laboratory facilities for applied research and development of the four strategic industries, namely Information Technology and Telecommunications, Electronics, Precision Engineering and Biotechnology.

A formal guideline, the Protocol for Integration of Programmes, was developed to include the detailed WBS covering all consultancies and works contracts, the essential steps in the preparation of PPs, the setting-up of the IP and the subsequent updating the IP with progress and cost information. A formal mechanism was set-up and implemented in the preparation of initial PPs and the subsequent updating of progress and cost data at the end of each month by the respective consultant / contractor under the close supervision of the Project Manager and the Resident Site Staff.

Primavera Project Planner (P3) was used in the preparation of all PPs, as it had the capability of integrating PPs to form an IP and also its ability to handle time and cost data. The necessary clauses were written into the respective agreements of consultancies and works contracts to comply with the Protocol for Integration of Programmes in preparing their programmes.

The WBS developed for Hong Kong Science Park Phase 2 Development included 3 no. consultancy agreements, 2 no. foundation works contracts, 4 no. main works contacts, 6 no. specialist works contracts and 5 no. nominated supply contracts.

Since EVMS was used to report the progress and cost status of the project to the client (Hong Kong Science and Technology Parks Corporation), it was important that ACWP should reflect the cost to the client rather than the cost incurred by the consultants or the contractors. Therefore, ACWP was defined as the total cost of payments that have been certified at any given time. In the case of the works contracts, it is the total amount of work that the Quantity Surveyor has certified at any given time. In the case of the consultancies, it was the total amount certified by the Project Manager. For other payments that were directly handled by the client, the ACWP was defined as the total amount issued for payment by the client.

To facilitate the measurement of BCWP, it was necessary to develop a systematic method of breaking down the total cost and to assign the cost to the specific activities within each PP. In the case of consultancies, the schedule of fees was the basis for distributing the consultant's fees among the activities. In the case of works contracts, the contractors were required to propose the breakdown of the cost of works based on the bill of quantities and to assign cost figures to a reasonable number of activities within each PP. The requirement was to have a manageable number of activities to measure and report the earned value at the end of each month.

4 Results

Fig. 2 shows earned value data (BCWS, BCWP and ACWP) from the commencement of the project (June 2001) up to June 2007 when most of the site work were substantially completed. As illustrated in Fig. 2, the original baseline for the BCWS was used from the commencement of the project up to April 2003 which included the BCWS of the Client and the Project Manager. In May 2003, the original baseline was revised (1st revision) to take account of the award of the consultancy agreements which changed the baseline of the BCWS.
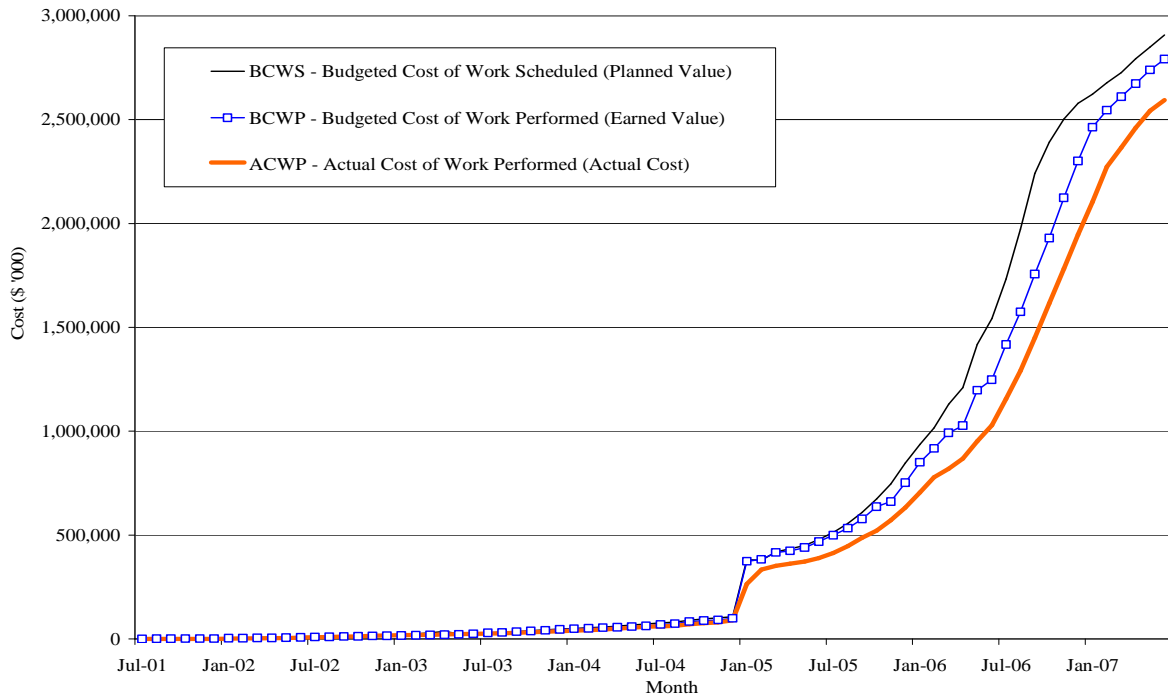

Fig. 2 – *Earned Value Graph (Up to June 2007)*

Fig. 3 shows the Cost Variance (CV) and the Schedule Variance (SV) from the commencement of the project up to June 2007. The value of CV is positive and it indicates that less money has been spent. This is mainly due to the payment arrangement where completed work is considered paid only after the Quantity Surveyor has certified the work and hence there is a lag of one month. The SV is negative and it indicates that the works are behind schedule. This is mainly due to the slow progress of works under several main works contracts and specialist contracts. Since September 2006 onwards, the negative SV has sharply reduced with the improved progress status of the works contracts.
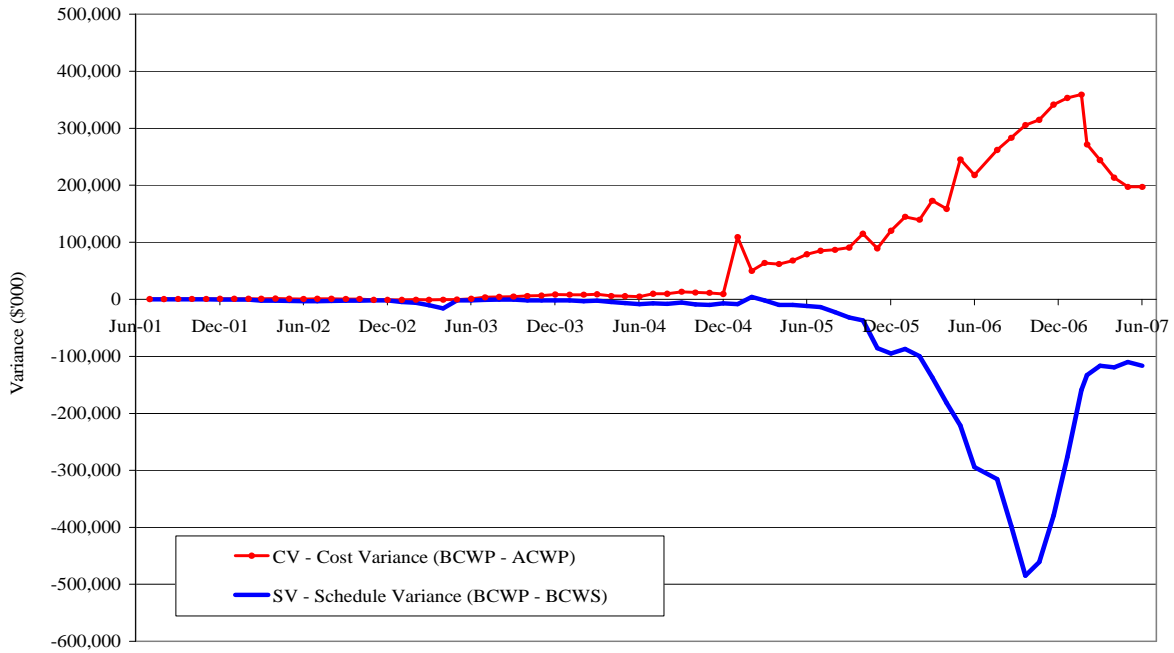
Fig. 3 – *Cost Variance (CV) and Schedule Variance (SV)*

Fig. 4 shows the Cost Performance Index (CPI) and the Schedule Performance Index (SPI) from the commencement of the project up to June 2007. It is noted that the CPI has stabilized around 1.2. This is largely due to the works already carried but yet to be certified. A value of CPI > 1 is considered as a favourable situation. The SPI is around 0.96 in June 2007 and had been in the range between 1.0 and 0.8 during the preceding four years. A value of SPI < 1 indicates that the project is behind schedule. The SPI has been gradually slipping since June 2005 following the commencement of the major main works contracts. The SPI has been increasing since September 2006 with the improvement in the progress of works contracts.
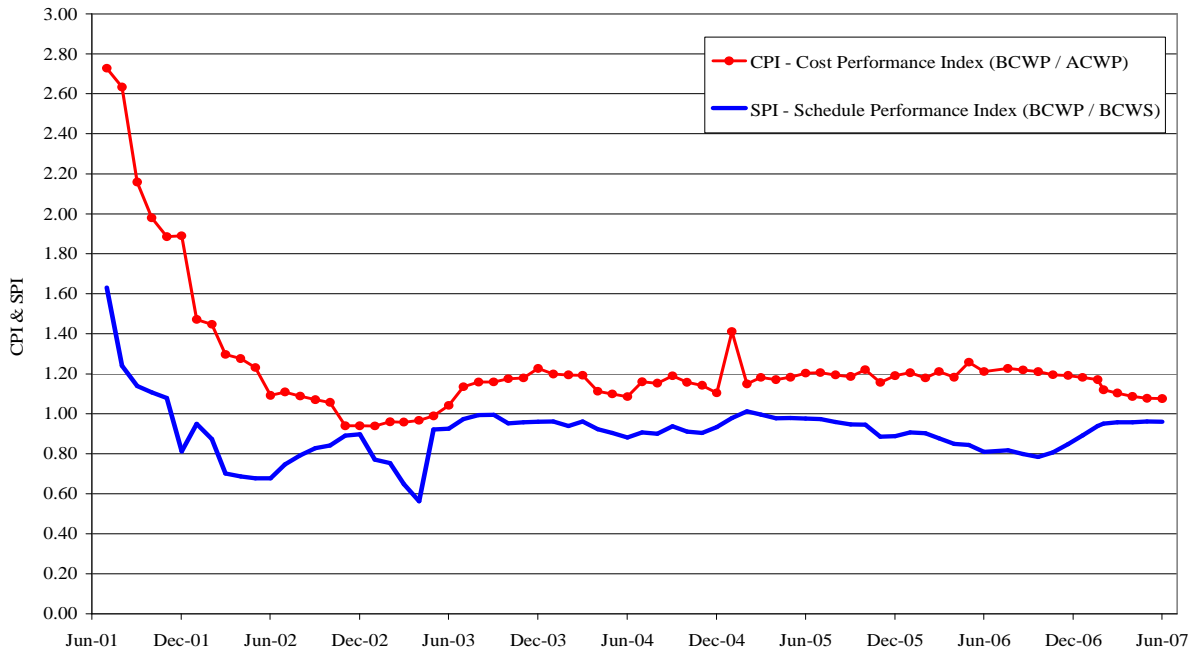

Fig. 4 – *Cost Performance Index (CPI) and Schedule Performance Index (SPI)*

Fig. 5 shows the Cost-Schedule Index (CSI) from the commencement of the project up to June 2007. The value of CSI has been above or around 1.0 with the exception from March 2002 to June 2003. During this period the approval of the Master Layout Plan for the Science Park was deferred by the government of Hong Kong and hence the postponement of the award of the design consultancies. If the CSI value is greater or around 1.0, it indicates that the project is not having any serious problems (Barr, 1996).
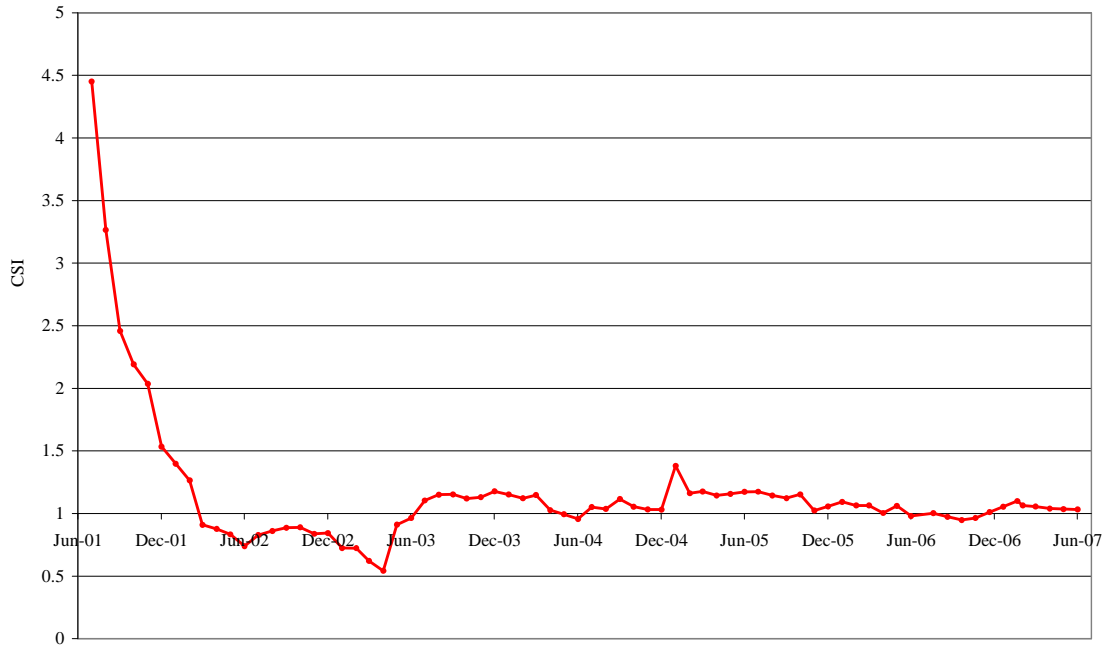

Fig. 5 – *Cost Schedule Index (CSI)*

Fig. 6 shows a plot of the Cost Performance Index (CPI) versus the Schedule Performance Index (SPI). Most of the points are located in the quadrant where the project is behind schedule and under spent. However, a few points are within the least desirable quadrant where the project is behind schedule and overspent. This situation prevailed prior to the award of the design consultancies in the first half of 2003.
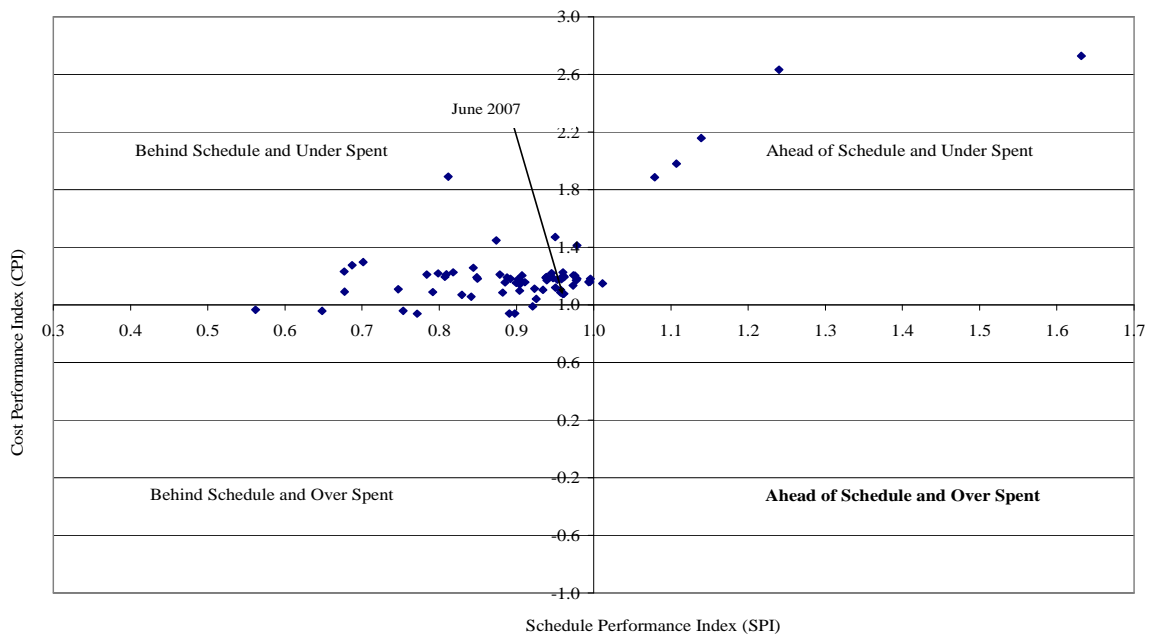

Fig. 6 – *Cost Performance Index (CPI) Vs. Schedule Performance Index (SPI)*

5 Conclusion

SV and the SPI shown in Fig. 3 and Fig. 4 indicate that the overall project progress was slightly behind schedule. But based on the value of CSI shown in Fig. 5, it could be concluded that the project was not having any serious problems with regard to project progress and cost status as the value of CSI is above or around 1.0. The earned value results point out that the management should focus mainly on the SV and the SPI.

Since EVMS was relatively new to Hong Kong, considerable effort by the Project Manager was required to educate the consultants, the resident site staff and the contractors on the application of EVMS and the requirements outlined in the Protocol for Integration of Programmes in preparing the PPs. The main difficulty encountered during the implementation of EVMS was the slow progress achieved by the contractors in getting their PPs approved early on to ensure a smooth and timely integration into the IP. Until such time, the consultant's construction programme was used to generate the earned value parameters for these works contracts. It was noted that this arrangement contributed some degree of error to the earned value parameters at the early stage of the project. It was also observed that some activities in the works programmes especially within the specialist contracts had large floats where the early finish and late finish dates were far apart. This too contributed to the negative SV as the earned value data have been generated based on the early finish dates rather than the late finish dates. Therefore, it is important to ensure that contractor's works programmes are not overly optimistic. However, it was possible to overcome the above challenges and successfully implement the EVMS as a project management tool for Hong Kong Science Park Phase 2 Development. It can be concluded that EVMS could be used as a project management tool for any multi-disciplinary infrastructure project as an efficient management tool for project monitoring and control.

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