Does Project Performance Stability Exist?
…a re-examination of CPI and evaluation of SPI(t) stability

Kym Henderson
Vice President, Research and Standards
PMI College of Performance Management *

Dr. Ofer Zwikael
Victoria Management School
Victoria University of Wellington, New Zealand

Abstract. *The development of the Earned Schedule (ES) method by Lipke in 2003 has been shown to be an important extension to the Earned Value Management (EVM) method, increasing the utility of EVM data for project schedule analysis, control and oversight. As ES provides a reliable time-based indicator of Schedule Performance, the objective of this paper is to investigate whether the SPI(t) exhibited similar stability characteristics to those extensively reported for the Cost Performance Index (CPI) in EVM. This paper analyzes EVM data from three different countries for projects in three industry segments. 37 projects were examined for SPI(t) stability and 26 for CPI stability. It has been found that while the behavior of SPI(t) is broadly consistent with CPI, the widely reported CPI stability rule cannot be generalized even within the US Defense Department (US DoD) project portfolio. Further research is required to develop improved understanding of project performance characteristics and the behavior of CPI and the SPI(t).*

Introduction

The cancellation of the US Navy's A-12 Avenger II stealth aircraft program in January 1991 [1] [2] resulted in research during the 1990s, which investigated the reliability of Earned Value Management (EVM) cost prediction and the behavior of the Cost Performance Index (CPI) [1] using US Defense Department (US DoD) project [2] data. These research findings have come to be regarded as generally applicable across all project types using EVM across multiple industry sectors. A finding regarded as particularly significant was that CPI stabilizes by 20% of project completion.

Lipke proposed the ES method in 2003 to provide time based measures of schedule performance utilizing EVM data. Initial validation has shown that the time based ES derived Schedule Performance Index (time) (SPI(t)) to be reliable for both early and late finish projects. For a technical description of the ES method the reader is referred to Lipke's seminal paper, "Schedule is Different" [3]. For an excellent easy to read non-technical but comprehensive discussion of the ES method, refer to "Not Your Fathers Earned Value" [4] by Stratton.

Following the initial validation of ES, interest developed in ascertaining whether SPI(t) exhibited similar stability characteristics to those extensively reported for CPI. The objective of this research paper is to reexamine CPI stability and to compare the stability behavior of the SPI(t) with CPI.

This paper has found that while the behavior of the SPI(t) is broadly consistent with CPI, the widely reported CPI stability rule cannot be generalized to all projects utilizing the EVM method or even within the US DoD project portfolio. However, the consistent behavior to CPI demonstrated by SPI(t) provides further support for the validity of the SPI(t) metric and the ES method.

* **The contents of this paper are the author's personal views and conclusions which do not reflect an endorsed position of the PMI College of Performance Management.**

Additional analysis was unable to establish a correlation between achieving earlier CPI and SPI(t) stability and improved outcomes at completion. In certain cases where projects achieved either under budget and/or early finish outcomes with cost and/or schedule stability achieved late, earlier cost and/or schedule stability would have been disadvantageous to the actual final outcome(s) achieved. This is because CPI and/or SPI(t) progressively improved over the life of those projects.

This paper also demonstrates that by utilizing ES, research of schedule performance using EVM data is now possible, and leading to improved understanding of the dynamics of project schedule and project cost performance.

Background

The CPI has long been a key indicator used to analyze the cost performance of projects using Earned Value Management (EVM).

The first empiric confirmation of the widely reported and referenced CPI stability rule was by Christensen and Payne using data from 26 US Air Force completed contracts in 1992. The data used came from the cost library of the US Air Force Systems Command Aeronautical Systems Division [5].

Christensen and Templin conveniently summarized the series of research findings subsequent to that paper in 2002:

> … the range of the cumulative CPI from the 20 percent completion point to contract completion was less than 0.20 for every contract. This result is usually interpreted to mean that the cumulative CPI does not change by more than plus or minus 0.10 from its value at the 20 percent completion point, and is used to evaluate the reasonableness of projected cost efficiencies on future work. [6]

Christensen and Payne [5] made the following observations on the perceived importance of CPI stability:

- A stable CPI is evidence that the contractor's management control systems, particularly the planning, budgeting, and accounting systems, are functioning properly.
- A stable CPI may thus indicate that the contractor's estimated final costs of the authorized work, termed "Estimated at Completion," are reliable.
- In addition, knowing that the CPI is stable may help the analyst evaluate the capability of a contractor to recover from a cost overrun by comparing the CPI with other key indicators, such as the To-Complete Performance Index.

Over time, the widely reported CPI stability findings have been generalized as being applicable to all projects utilizing the EVM method [8] [9] [10] [11]. An extensive literature review has not found further empiric validation of the CPI stability rule beyond the project data obtained in the initial paper and data from the US DoD Defense Acquisition Executive Summary (DAES) database.

Concurrent research into the stability characteristics of the EVM Schedule Performance Index (SPI) was not possible because the SPI is known to fail as a statistical predictor because it always returns to unity at project completion irrespective of duration based delay. The SPI is also recognized as failing, nominally within the final third of the project and also fails after the project's Planned Duration has been exceeded.

Lipke proposed the ES method in 2003 as a solution to these limitations and flaws of the EVM schedule indicators [3]. A series of studies provided initial validation of the ES method, some by using real EVM project data, Henderson [12] [13] [14] and Vandevoorde and Vanhoucke [15] and also by using simulated network schedules, Vanhoucke and Vandevoorde [16]. The time based ES derived SPI(t) has been shown to be reliable for both early and late finish projects. The SPI(t) only reverts to unity at project completion if on time completion has been achieved.

A research study intended to validate the ES construct using DAES data was commissioned in 2004 and undertaken by a US Air Force Institute of Technology Masters student. Unfortunately, this study was discontinued after an independent review determined:

> Results: The historical data collection procedures for the DOD and USAF do not allow for sufficient testing of ES theory at this time. A statistical evaluation concluded that SPI(t) is different than SPI($); however, the two variables are highly correlated. The result of the analysis identified that SPI(t) performs similarly to SPI($) with the data contained in the DAES database. In order for the ES Theory to be fully investigated, additional data must be collected. This research shows that the necessary data may also not be available despite the best collection efforts. The original schedule and planned duration information is critical to successful evaluation of the ES methodology. [1]

However, early interest by the Project Management Institute College of Performance Management resulted in the principles of ES being included as an “Emerging Practice Insert” in the Practice Standard for Earned Value Management published in 2004. [18]

Following the initial validation of ES, interest developed in ascertaining whether the SPI(t) exhibited similar stability characteristics to those extensively reported for the Cost Performance Index. The objective of this research paper is to reexamine Cost Performance Index stability and to compare the stability behavior of the SPI(t) with CPI.

Method for Evaluating Stability

EVM project data was loaded into a Microsoft Excel “Stability Point Calculator” developed by Lipke. The calculator determines the observation number in a sequence of CPI and SPI(t) values at which all subsequent observations are within a defined stability limit. The stability limit used is .10. The calculator enables the associated percentage complete at which stability occurs to be determined.

This calculator has been placed into the public domain to encourage more broadly based CPI and SPI(t) stability research and is freely available from the ES website at http://www.earnedschedule.com/Calculator.shtml.

To determine the significance of the observations of stability for both CPI and SPI(t), statistical hypothesis testing is conducted. The test applied is the Sign Test at 0.05 level of significance [3] [19]. The Sign Test was used in this research because it does not depend upon the data having a normal distribution. In past research, the hypothesis test method chosen implied that the data was normally distributed; however, the normality of the data was not established. Research by Lipke also suggests that:

> Results indicate the logarithm data representations of the indexes are likely normally distributed, whereas the distributions for CPI, SPI, and CV are not. [20]

The question to answer regarding stability is "Can it be stated generally and reliably that the final value of the performance index is within 0.10 of its value when the project is 20 percent complete?" The answer to the question will be "yes" if the alternate hypothesis is satisfied:

$$H1(CPI): |CPI(final) - CPI(20\%)| < 0.10$$

$$H2\ (SPI(t)): |SPI(t)(final) - SPI(t)(20\%)| < 0.10$$

Two separate hypothesis tests are conducted, one for CPI and one for the SPI(t). The result from the hypothesis testing is recorded as Ha when the value of the test statistic is in the critical region (0.05) and Ho (null hypothesis) when it is not.

The Data

A composite EVM data set was assembled comprising commercial sector data samples obtained from:

- 24 United Kingdom (UK) construction projects
- 12 Israeli High Technology (Hi-Tech) projects
- 9 Australian Information Technology (IT) projects.

The EVM data consists of direct labor costs only with the:

- UK construction projects recorded in "person days" weekly with EVM values expressed as a percentage of the Budget at Complete to further maintain data anonymity,
- Israeli Hi-Tech projects recorded in United States dollars monthly, and
- Australian IT projects recorded in Australian dollars weekly.

An extensive review of the data was undertaken. Projects were excluded from the sample for a variety of reasons including:

- Lack of data integrity,
- Lack of Earned Value data at 20% of project completion,
- Partially incomplete Planned Value data, and
- Lack of required Actual Cost data.

Ten UK Construction projects are included in the CPI stability research sample. Five of these project were included although the final Actual Cost data available was between 96.7%, to 99.0% complete. Including those five projects is consistent with the approach adopted by Christensen and Payne's research [5] and assumes that the difference between CPI_{Final} and the latest available CPI has no material impact on the findings.

The outcome was a usable data sample of

- Twelve Israeli Hi-Tech projects for the SPI(t) and CPI stability research
- Twenty UK construction projects for the SPI(t) stability and ten for CPI stability research
- Five Australian IT projects for the SPI(t) stability and four for CPI stability research.

Stability Evaluation Results

The results of the Sign Tests for testing the hypothesis "can it be stated generally and reliably that the final value of the performance index is within 0.10 of its value when the project is 20 percent complete?" as previously described are tabulated in Table 1 below. Recall, the test result of Ha indicates stability of the performance indicators CPI and the SPI(t). As is shown, the test results did not have any test statistic in the critical region (0.05). As a result, none of the null hypotheses can be rejected, for any of the three samples as well as the composite of all samples. This means that stability was not achieved for either CPI or the SPI(t) by the time the project was 20 percent complete.

	***** CPI Stability ***** Test Statistic	Test Result	***** SPI(t) Stability ***** Test Statistic	Test Result
UK Construction	0.623	Ho	0.748	Ho
Australian IT	1.000	Ho	0.500	Ho
Israeli Hi Tech	0.806	Ho	0.613	Ho
Composite	0.916	Ho	0.629	Ho

Table 1: Hypothesis Test Results

This research does not support the previously referenced generalizations that the CPI stability rule has universal applicability for all projects utilizing the EVM method. Because the SPI(t) index demonstrates a similar lack of stability to that found for CPI, the validity of the SPI(t) metric is supported due to the consistent behavior demonstrated with CPI.

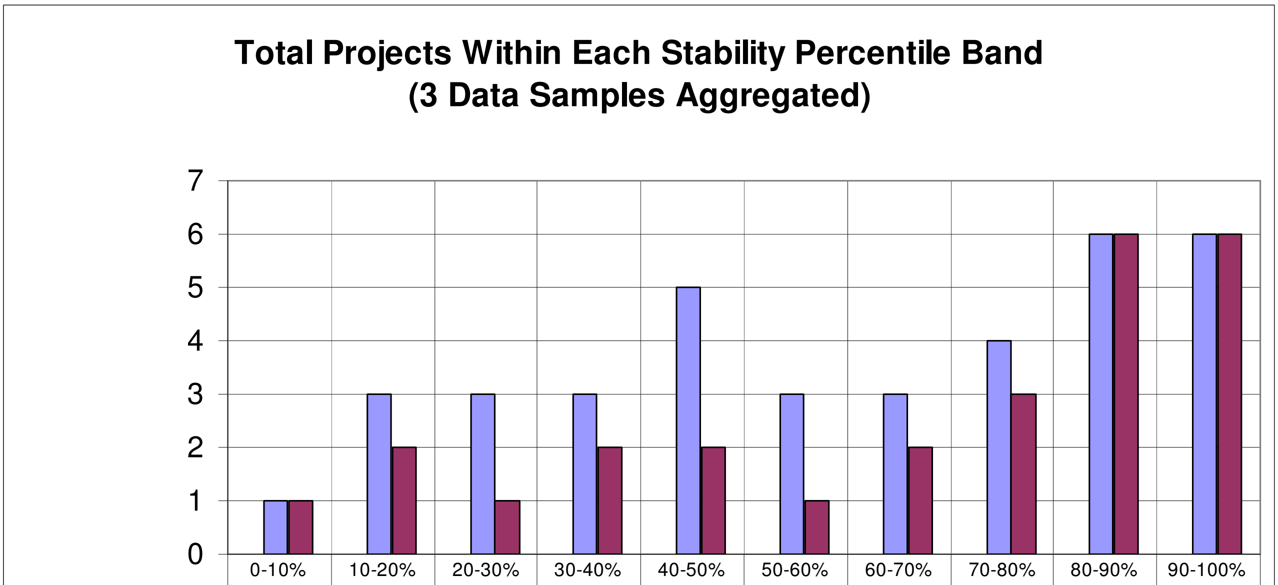
Stability Achieved		UK Construction	Australian IT	Israeli HI Tech	Composite
SPI(t) cum	**≤ 20%**	3	0	1	4
> 20%		17	5	11	33
CPI cum	**≤ 20%**	2	0	1	3
> 20%		8	4	11	23

Table 2: Summary of Stability Achievement Related to 20% Completion

Table 2 summarizes the raw data in relation to the numbers of projects that achieved stability before or after 20% completion for the SPI(t) and CPI by each project set and for the composite of all. It can be seen that the majority of projects reach stability only after the 20% completion point.

Figure 1 summarizes within each 10 percent complete percentile band where CPI and the SPI(t) stability occurred. This figure shows:

- The wide variability in the achievement of stability for both CPI and the SPI(t). Project performance heuristics or "rules of thumb" intended to be generally applicable (e.g. the CPI stability rule) require an empirically established consistency of behavior across a broad range of projects. These findings are a significant impediment to proposing and confirming broadly applicable CPI and SPI(t) stability heuristics
- That stability is usually achieved very late in the project lifecycle, often later than 80% complete for projects in these samples.



	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
UK Construction	1	2	2		3	2	2	1	3	4
Australian IT				1			1		3	
Israeli HI Tech		1	1	2	2	1		3		2
SPI(t) Stability Totals	1	3	3	3	5	3	3	4	6	6
UK Construction	1	1					2	1	2	3
Australian IT									1	3
Israeli HI Tech		1	1	2	2	1		2	3	
CPI Stability Totals	1	2	1	2	2	1	2	3	6	6

Figure 1: Total Projects CPI and SPI(t) Stability Within Each 10 Percentile Band

Zwikael *et al.* analyzed the Israeli hi-tech project sample using visual inspection of charts and suggested that CPI stability was, on average, achieved at the 60% completion point [21]. That analysis broadly confirms this paper's finding of CPI stability being achieved much later in the project lifecyle than previously reported.

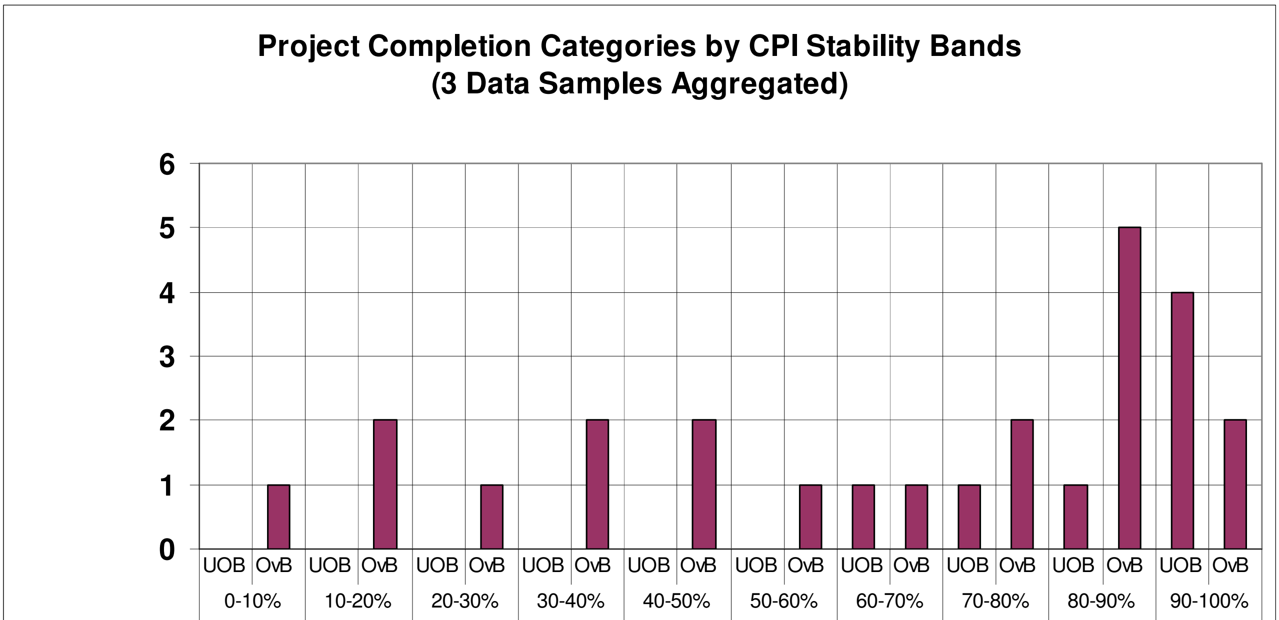
Additional Analysis

Following the lack of CPI and SPI(t) stability findings additional analysis was conducted. Within each 10% complete percentile bands projects were categorized as follows:

- Cost at completion:
  - Under or On Budget (UOB)
  - Over Budget (OvB).
- Schedule at completion:
  - Early or On Time finish (EOT)
  - Late Finish (LF).

The purpose of this analysis is to determine if there is a correlation between achieving earlier CPI and the SPI(t) stability and improved project outcomes.

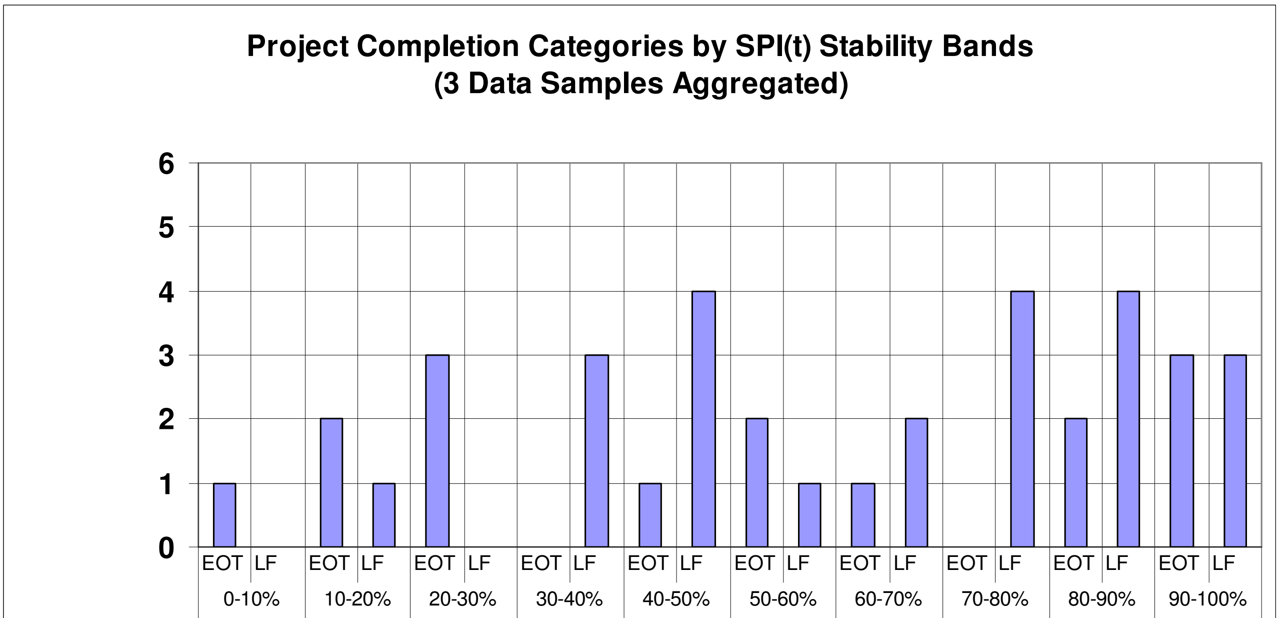
Figure 2 summarizes the analysis for CPI and Figure 3 does the same for the SPI(t). With the data samples utilized, achievement of earlier stability is not correlated with improved final cost and/or schedule outcomes.



	0-10%		10-20%		20-30%		30-40%		40-50%		50-60%		60-70%		70-80%		80-90%		90-100%	
	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB	UOB	OvB
Israeli HI Tech				1		1		2		2		1				2		3		
Australian IT																		1	2	1
UK Construction		1		1									1	1	1		1	1	2	1
Totals		1		2		1		2		2		1	1	1	1	2	1	5	4	2

Figure 2: Project Completion Categories by CPI Stability Band

For UOB and EOT projects where cost and schedule stability was achieved late (after say 60% completion) achieving earlier stability would have been disadvantageous to the final outcome(s) achieved because project performance progressively improved over the life of those projects.



	0-10%		10-20%		20-30%		30-40%		40-50%		50-60%		60-70%		70-80%		80-90%		90-100%	
	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF	EOT	LF
Israeli HI Tech				1	1			2		2		1				3			1	1
Australian IT								1					1				2	1		
UK Construction	1		2		2				1	2	2			2		1		3	2	2
Totals	1		2	1	3			3	1	4	2	1	1	2		4	2	4	3	3

Figure 3: Project Completion Categories by SPI(t) Stability Band

Figure 4 summarizes projects (with the required comparative data), which achieved SPI(t) or CPI stability first. Achieving SPI(t) stability first implies schedule management had a higher management priority, achieving CPI stability first implies cost management had the higher priority.

In the Australian IT projects sample, SPI(t) stability was achieved first for the preponderance of projects. For the other data samples the achievement of cost or schedule stability first occurred in roughly equal proportion. In only one project in these samples, an Australian IT project was the cost and schedule stability achieved simultaneously.

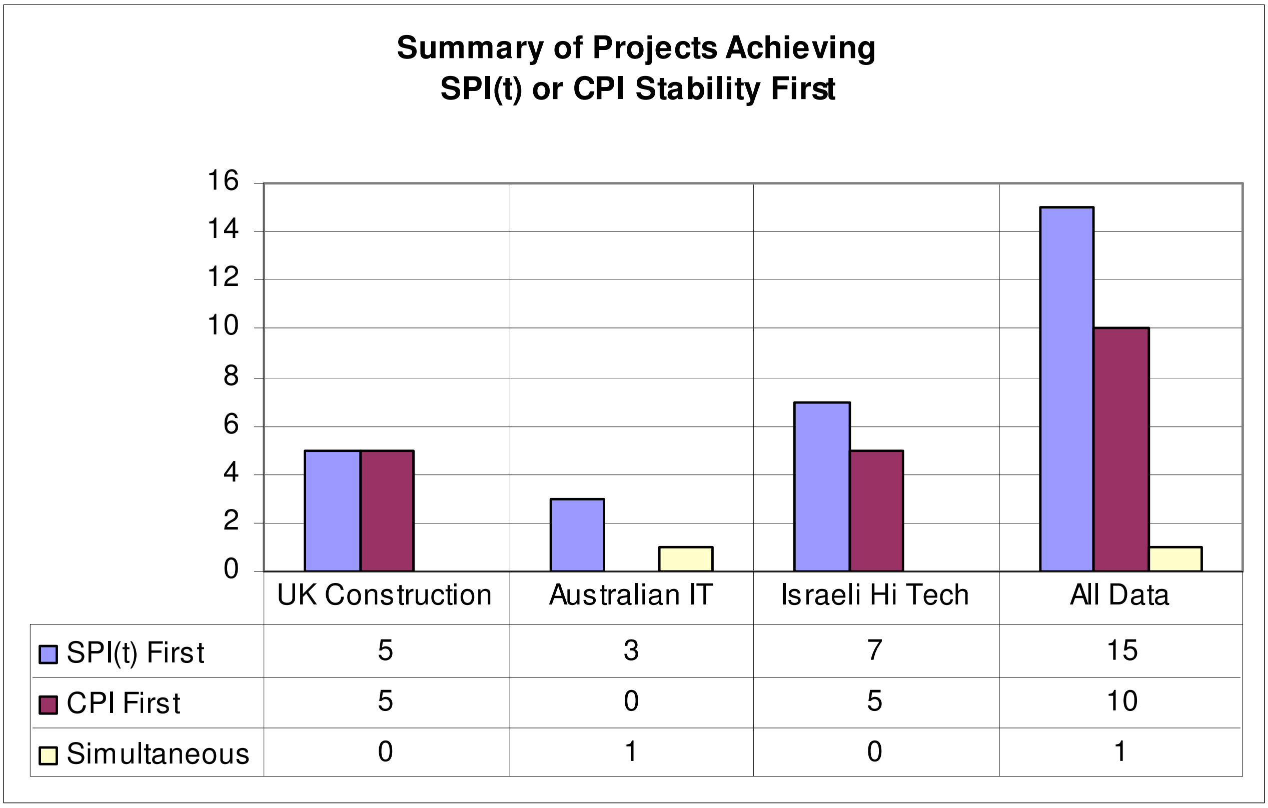


Figure 4: Summary of Projects Achieving SPI(t) or CPI Stability First

Corroboration with Other Research

Because of the comprehensive contradiction to the previously published CPI stability research findings, a further literature review was undertaken. This review obtained a most unexpected source of independent corroboration for this paper's CPI stability findings. In the mid 1990s Mr. Michael Popp initiated an internal US DoD research project within the US Naval Air Command (NAVAIR).

The output was an internal but unclassified NAVAIR report (the Popp report) which has, with Mr. Popp's permission, now been placed into the public domain on the PMI Sydney Chapter website. [22] The purpose of the Popp study was to develop probability distributions of cost Estimates at Complete (EACs) based on the CPI at complete, current CPI and percentage complete of projects based on history. As stated in the report:

> Given a program has a CPI of X and a percent complete of Y, what is the most likely finishing CPI. [22]

In contrast to Christensen and associates research, which used data from the DAES database, the data used by Popp was sourced from the Contracts Analysis System (CAS) database maintained by the Office of the Secretary of Defense Cost Analysis Improvement Group (CAIG).

The research undertaken by Popp did not focus on CPI stability. However, charts which can also be used for assessing CPI stability were completed as part of that study. These charts correlate the cumulative CPI for the percentage complete in each 10% complete percentile band to the CPI Final for all projects in that sample.

Figure 5 is the first chart of interest from the Popp report, as it shows the correlation between the cumulative CPI at 10-20% complete and the CPI Final for all projects in the sample.

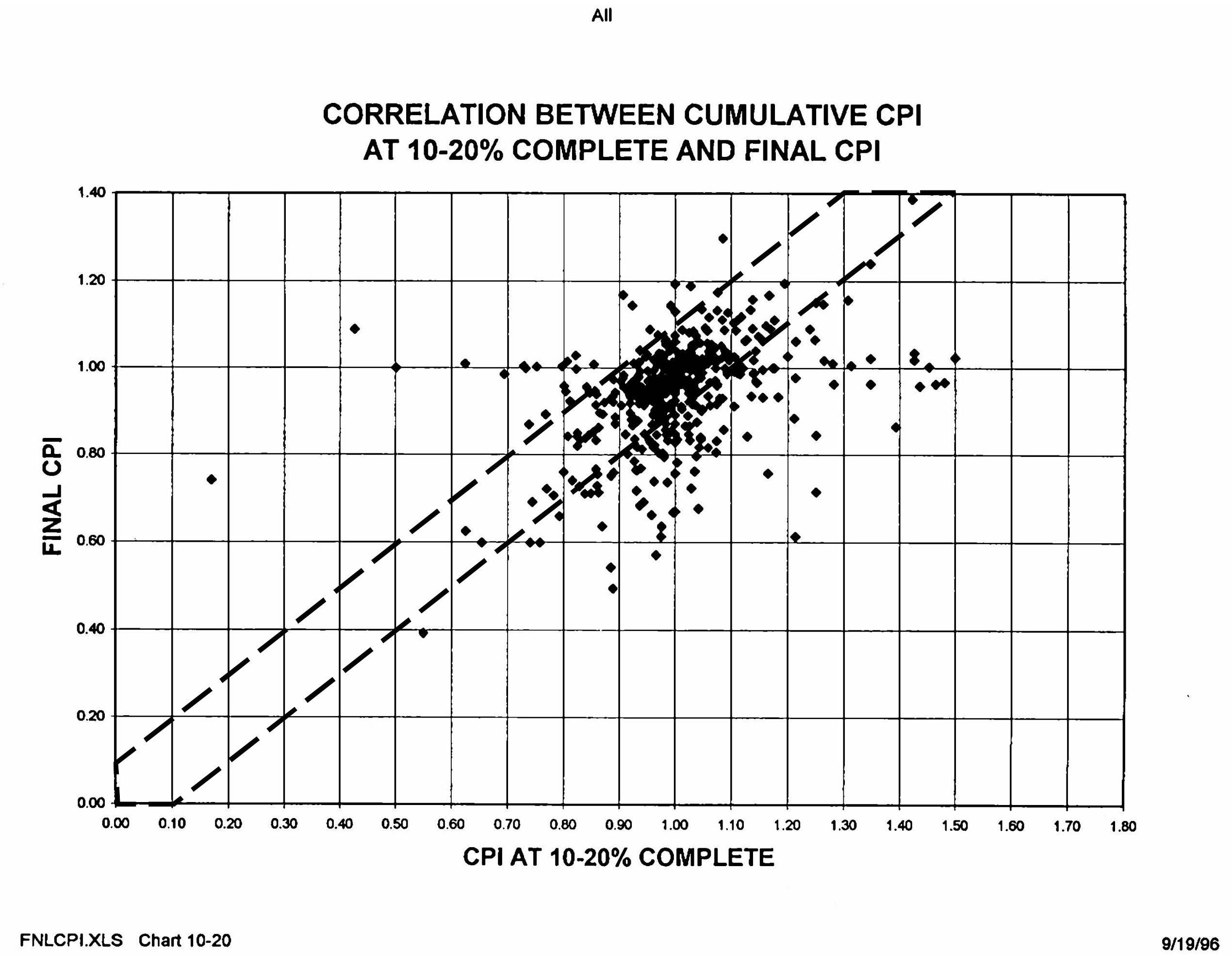


Figure 5: Correlation between Cumulative CPI at 10-20% Complete and Final CPI (Popp)

The area of the chart enclosed within the dashed lines bounds the area in which the correlation plots must occur for the Christensen derived CPI stability rule to apply. Those plots which occur outside the enclosed area are also in conflict with the Christensen derived CPI stability rule. The limited data samples used in this analysis are sufficient to show that the CPI stability rule cannot be generalized even within the US DoD project portfolio.

While research by Coleman *et. al.* [23] using the Popp report data sample was not principally directed at examining the validity of the CPI stability rule this research found that for:

- Development programs “at 20% (completion) , programs with a cumulative CPI below 0.89 improve” which was “close to Christensen, (findings) but with some exceptions”
- Production programs “at 20% (completion), programs with a cumulative CPI below 0.84 improve, again “close to Christensen, (findings) but with some exceptions”.

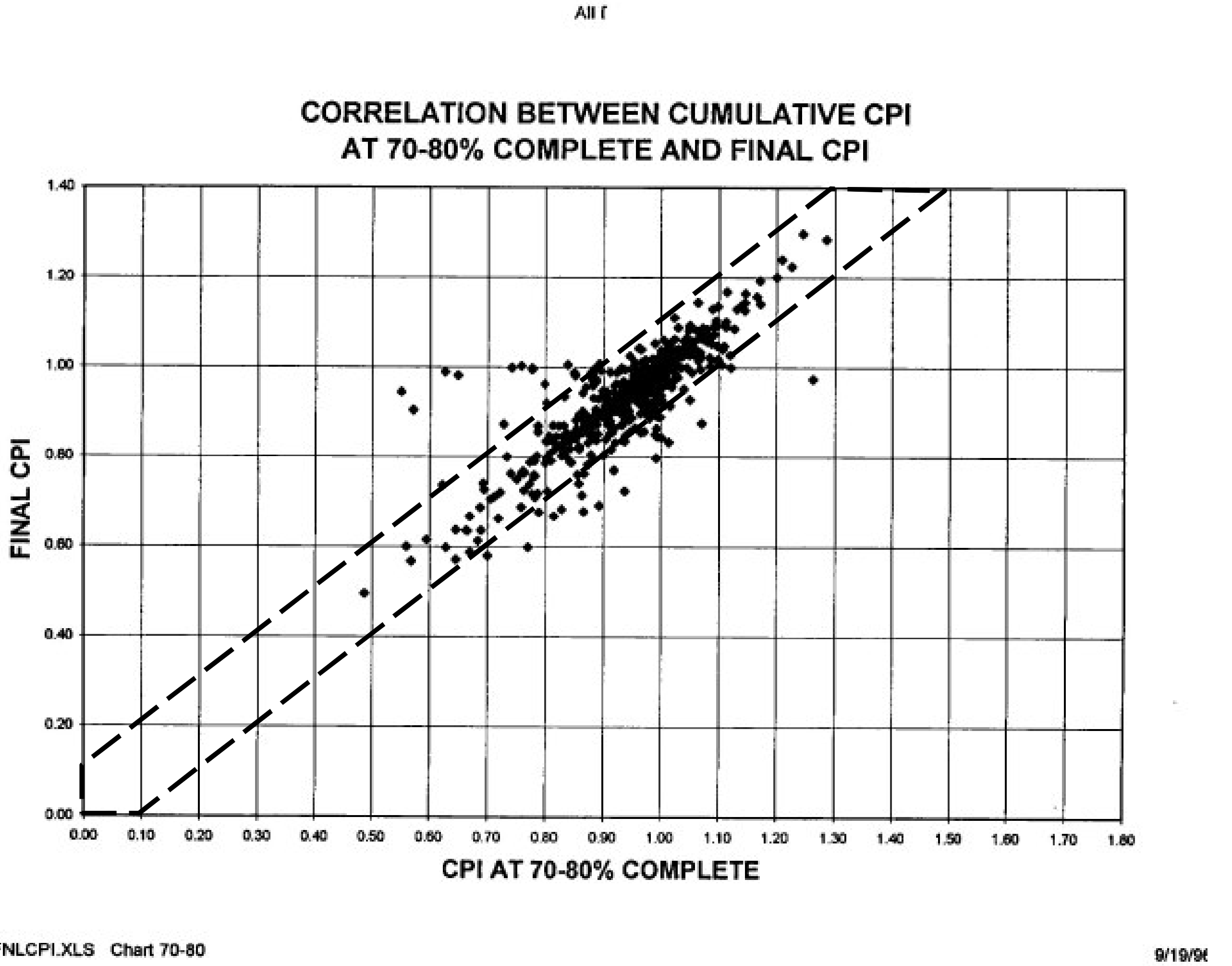


Figure 6: Correlation between Cumulative CPI at 70-80% Complete and Final CPI (Popp)

Using the “enclosure” technique, Figure 6 shows that the preponderance of plots, occur within the area where the CPI stability rule applies at 20% completion. The conclusion is that for the US DoD project data used by Popp, CPI stability was also achieved very late in the project lifecycle, often as late as 70-80% completion. This finding is consistent with the late CPI stability findings for the commercial sector project samples as shown in Figure 1.

While the underlying data was not available and further research is required, these findings also conflict with the US DoD research findings quoted in the Beach report into the A-12 cancellation that:

> DOD experience in more than 400 programs since 1977 indicates without exception that the cum CPI does not significantly improve during the period between 15% and 85% of contract performance; in fact, it tends to decline. [1]

Some projects in the Popp sample show a trend of CPI performance improvement, from CPI $_{20\%}$ and in a smaller number of cases, as late as CPI $_{80\%}$ to CPI $_{Final}$.

Summary and Conclusions

The initial objective of this paper, ascertaining whether the SPI(t) demonstrates similar stability characteristics to those extensively reported for CPI was not achieved. This paper has found that while the behavior of the SPI(t) is broadly consistent with CPI, the widely reported CPI stability rule cannot be generalized to all projects using the EVM method or even within the US DoD project portfolio. However, the consistent behavior to CPI demonstrated by the SPI(t) provides further support for the validity of the SPI(t) metric and the ES method.

Additional analysis was unable to establish a correlation between achieving earlier CPI and the SPI(t) stability and improved outcomes at completion. In cases where projects achieved either under budget and/or early finish outcomes with cost and/or schedule stability achieved late (ie. after say 60% completion), earlier cost and/or schedule stability would have been disadvantageous to the actual final outcome(s) achieved. This is because CPI and/or the SPI(t) were progressively improving over the life of those projects.

The findings and corroboration of this paper require significant review and revision to what has been regarded as a long settled EVM heuristic with regard to CPI stability and consequent practice including the use of a stable CPI as evidence that an EVM system is functioning properly and of a "reliable" EAC. [5]

Improvements to current EVM techniques for predicting future cost performance should be considered as current techniques have relied on generalizing research findings from limited data sources, principally the DAES database.

Alternatives methods of cost and schedule prediction using well-established statistical principles and methods developed by Lipke show promise as:

- These techniques allow generation of a range of cost and schedule predictions from user defined Confidence Limit(s)
- All information and data required for these predictions comes from within the project itself. This may reduce the current dependence on heuristics developed from external project data sources, which might not be applicable to the project of interest.

To promote trials of these statistical prediction techniques, a Microsoft Excel "Statistical Prediction Calculator" is also freely available from the ES website at http://www.earnedschedule.com/Calculator.shtml. An academic paper fully describing the statistical prediction techniques and the supporting rationales is "pending publication" as at 12th September 2007 [24]. The statistical prediction techniques developed have been summarized in a presentation by Henderson [25] which is available on the website.

A major advance to EVM practice and future research opportunities would be development of a broadly based EVM research database where completed EVM project data could be submitted anonymously for:

- Research purposes
- Benchmarking completed project performance
- Assisting in the sizing of projects.

Such knowledge bases are not unique in other disciplines, with an instructive Australian example being the International Software Benchmarking Standards Group (ISBSG), website at http://www.isbsg.org/.

Improved data collection techniques to ensure that baseline schedule information is captured and stored in the DAES database are also recommended.

Concluding Remarks and Future Research

While this paper has overturned long-standing findings and belief on CPI stability, it is important that the strengths and limitations of the EVM method are properly understood, particularly in an era of:

- Adoption of EVM by US Government agencies through Office of Management Budget Circular A-11 Part 7 mandate
- Advocacy of the use of EVM cost predictors to assess compliance to the Sarbanes Oxley Act [9]
- Increased interest and the adoption of EVM by organizations globally.

Where projects have not exhibited "CPI stability" EVM practitioners can now know that this is neither unique, nor is it necessarily an adverse reflection on the management or execution of those projects.

Various follow-on research opportunities arise from this paper, which may develop improved understanding of project performance characteristics and generalisable heuristics. Suggestions include examining the performance characteristics of projects where:

- The CPI stability rule does seem applicable (e.g. the subset highlighted in the Popp report data) to determine whether there are project characteristics which result in early CPI stability
- Early CPI stability was not achieved due to progressively improving CPI performance over the project lifecycle.

Academically oriented research aimed at establishing a theoretical rationale for project performance instability would be another useful addition to the project management body of knowledge.

While Coleman *et. al.* [23] provide the sobering assessment that consistent with Christensen's findings "average to good programs do not improve", an understanding of project characteristics, which result in progressively improving CPI would, if these characteristics could be emulated in other programs, be an extremely useful advance to practice. Such research could offer significant opportunities for tangibly improving project performance.

Research opportunities are equally applicable to project schedule performance. This paper also demonstrates that by using ES, research of schedule performance using EVM data is possible and already leading to improved understanding of the dynamics of project schedule and project cost performance.

Acknowledgements

This research has been made possible due to the generous assistance of the following individuals:

- The Project Controls Manager from the United Kingdom based construction company (who desire anonymity) for making available the UK construction projects EVM data
- Mr. Michael Popp of NAVAIR for making available the "Popp report" and providing permission for the report to be placed in the public domain on the PMI Sydney Chapter website.

The support, suggestions, general assistance, and review comments by the ES advocates and researchers, which significantly improved this paper is also appreciated. Responsibility for any errors, omissions or erroneous conclusions remains the sole responsibility of the authors.

Notes

1. Unless otherwise stated, all references to CPI and the SPI(t) refer to the cumulative values.
2. "Project" has been used consistently throughout this paper. In US Government, particularly the US DoD context, "program" may be the more appropriate term.
3. Applying the Sign Test at 0.05 level of significance means that the test is being applied at a 95% level of confidence

References

1. Beach, Chester Paul Jr. "A-12 Administrative Inquiry. Report to the Secretary of Navy" Department of the Navy, Washington DC, 1990. http://www.suu.edu/faculty/christensend/evms/beacha-1.pdf (12 Sep 2007)
2. Christensen, David S, PhD., "Using the Earned Value Cost Management Report To Evaluate The Contractor's Estimate at Completion", Acquisition Review Quarterly, Summer 1999: 283:295. http://www.dau.mil/pubs/arq/99arq/chrisevm.pdf (26 Nov 2007)
3. Lipke, Walt. "Schedule is Different," The Measurable News, 2003, March: 10-15. http://www.earnedschedule.com/Docs/Schedule%20is%20Different.pdf (12 Sep 2007)
4. Stratton, Ray. "Not Your Father's Earned Value," Projects@Work, (www.projectsatwork.com), 2005, Feb 24 http://www.earnedschedule.com/Docs/Not%20Your%20Father%27s%20Earned%20Value.PDF (14 Nov 2007)
5. Christensen, David S., Payne, Kirk. "Cost Performance Stability – Fact or Fiction?," Journal of Parametrics, (April 1992): 10:27-40. http://www.suu.edu/faculty/christensend/evms/CPIstabilityJP.pdf (12 Sep 2007)
6. Christensen, David S. PhD., Templin, Carl. PhD. "EAC Evaluation Methods: Do They Still Work?," Acquisition Review Quarterly, Spring 2002: 105:116. http://www.suu.edu/faculty/christensend/evms/eacevalmethods4.pdf (12 Sep 2007)
7. Christensen, D. S., Heise, S. R. "Cost Performance Index Stability," National Contract Management Journal, Vol 25, (1993): 7-15. http://www.suu.edu/faculty/christensend/evms/CPIstabilityNCMJ.pdf (12 Sep 2007)
8. Fleming, Quentin., Koppelmann, Joel. The Earned Value Body of Knowledge. *Proceedings of the 30th Annual Project Management Institute 1999 Seminars and Symposium*. Philadelphia, Pennsylvania, USA
9. Fleming, Quentin, Koppelmann, Joel. "Sarbanes-Oxley: Does Compliance Require Earned Value Management on Projects," Contracts Management, April 2004 26:28
10. Fleming, Quentin., Koppelmann, Joel. "If EVM is Good … Why Isn't it used on all Projects?," Contracts Management, April 2004: 26-28 http://www.suu.edu/faculty/christensend/evms/WhyEVM.pdf (12 Sep 2007)
11. Fleming, Quentin, & Koppelman, Joel. Earned Value Project Management. 3rd ed. Upper Darby, PA: Project Management Institute, 2005
12. Henderson, Kym. "Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data," The Measurable News, 2003, Summer: 13-23. http://www.earnedschedule.com/Docs/Earned%20Schedule%20-%20A%20Breakthrough%20Extension%20to%20EVM.pdf (12 Sep 2007)

13. Henderson, Kym. "Further Developments in Earned Schedule," *The Measurable News*, 2004, Spring, 15-22. http://www.earnedschedule.com/Docs/Further%20Developments%20in%20Earned%20Schedule.pdf (12 Sep 2007)
14. Henderson, Kym. "Earned Schedule in Action," *The Measurable News*, 2005, Spring: 23-30. http://www.earnedschedule.com/Docs/Earned%20Schedule%20in%20Action.pdf (12 Sep 2007)
15. Vanhoucke, Mario, Ph. D, Vandevoorde, Stephan. "A Comparison of Different Project Duration Forecasting Methods Using Earned Value Metrics," *International Journal of Project Management*, Volume 24, Issue 4 (May 2006): 289-302.
Note: This paper is available on-line at a cost of $USD 30 from Science Direct at: http://www.sciencedirect.com/
16. Vanhoucke Mario, Ph.D, Vandevoorde, Stephan. "A Simulation and Evaluation of Earned Value Metrics to Forecast Project Duration," *Journal of Operational Research Society*, Volume 58: 1361 - 1374, Issue 10 (October 2007); advance online publication, 13 September, 2006
Note: This paper is available on-line at a cost of $USD 10 at: www.palgrave-journals.com
17. Attachment to e-mail from Ed Witte, SAF/AQX to Walt Lipke dated 15th April 2005, "An analysis of the Schedule Performance Index (SPI) in units of time: Overcoming the SPI($) limitations to accurately portray schedule" performance.
Note: Summary of review findings leading to cancellation of AFIT research project into the Earned Schedule method.
18. Project Management Institute. *Practice Standard for Earned Value Management*. Project Management Institute 2004.
19. National Institute of Standards and Technology Dataplot, 2005. Sign Test. http://www.itl.nist.gov/div898/software/dataplot/refman1/auxillar/signtest.htm (12 Sep 2007)
20. Lipke, Walt. "A Study of the Normality of Earned Value Management Indicators," *The Measurable News*, 2002, December: 1-16. http://sydney.pmichapters-australia.org.au/programs/customer/v_filedown.asp?P=31&FID=89297847&FRF=n& (12 Sep 2007)
21. Zwikael, Ofer, et al. "Evaluation of Models for Forecasting the Final Cost of a Project," *Project Management Journal*, Volume 31, Number 1 (March 2000): 53-57.
22. Popp, Michael. ""Probability Distributions of CPI at Complete vs. CPI Today", Internal NAVAIR Report, *Unpublished*, 1996. http://sydney.pmichapters-australia.org.au/programs/customer/v_filedown.asp?P=31&FID=738016087&FRF=n& (12 Sep 2007)
23. Coleman et al., "Predicting Final CPI", Presentation to the 4th Joint Annual ISPA/SCEA International Conference, Orlando, Florida USA, June 2003
24. Lipke, Walt, et al., "Prediction of Project Outcome - The Application of Statistical Methods to Earned Value Management and Earned Schedule Performance Indexes," Publication pending.
25. Henderson, Kym. "Recent Advances in Project Prediction Techniques", Presentation to the IQPC IT Project Management Conference, Sydney Australia, 1 May 2007. http://www.earnedschedule.com/Docs/Recent%20Advances%20in%20Project%20Prediction%20Techniques.pdf (12 Sep 2007)

About the Authors

Kym Henderson

Kym Henderson is a practicing information technology project manager with significant experience in project recoveries utilizing simplified EVM techniques. He has a Bachelor of Business and a Master of Science (Computing) from the University of Technology, Sydney. Kym has presented at many conferences internationally and published papers in various publications and as proceedings of PMI Global Congresses. He published the first independent validation of the Earned Schedule method in 2003.

Kym is the Immediate Past Education Director (2003–2007) of the PMI Sydney Chapter and is the first non-US national elected to the board of the PMI College of Performance Management commencing office on 1st January 2008.

Ofer Zwikael

Dr. Zwikael is a senior lecturer at the Victoria Management School, Victoria University of Wellington, New Zealand. He also leads projects and program groups in dozens of organisations, in Asia and Europe. Ofer is an accredited PMP, has acted for two years as a vice president in the Executive Board of the PMI's Israeli chapter, and is currently a Director at the New Zealand PMI Executive Board.