May 25th, 7:30 AM

Advancing the Theory and Practice of Engineering Project Management by addressing the issue of CPI Stability and Hidden Project Performance

Michael Staley
PE, PMP Dean of the School of Engineering, Design, & Construction, Seminole State College Doctoral Research, Center for PM Research

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Advancing the Theory and Practice of Engineering Project Management by addressing the issue of CPI Stability and Hidden Project Performance.

Michael Staley, PE, PMP

24 May 2016
Overview

- **Literature Review**
  - Why EVM?
  - What is EVM?
  - Define the CPI Stability Issue

- **Research**
  - Propose a Solution
  - Illustrate with Case Study

- **Practice**
  - Application to Case Study
  - Identify Hidden Performance
Literature Review:

Why EVM?

- $12T in projects globally
- 62% of all projects studied use EVM
- U.S. government requires EVM on major projects...OMB, DoD, NASA, FAA, etc.
  - 69% of projects using EVM are voluntary adopters
- Usage not just in U.S., but globally, e.g., UK, Australia, New Zealand, Japan, Hong Kong, Sweden, UAE, Saudi Arabia, India, Pakistan...

As defined by *PMBOK® Guide*, Earned Value Management is a “management methodology for integrating scope, schedule, and resources, and for objectively measuring project performance and progress…”

EVM requires an integrated baseline!

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*PMBOK® is a registered mark of Project Management Institute, Inc.*
Literature Review: What is EVM?

- Three key terms

  - **Earned Value (EV)** is
    “The value of work performed expressed in terms of the approved budget assigned to that work completed”

  - **Actual Cost (AC)** is
    “Total costs actually incurred and recorded in accomplishing work performed…”

  - **Planned Value (PV)** is
    “The authorized budget assigned to the scheduled work to be accomplished…”

Literature Review: What is EVM?

Measure performance and progress

Plan Value

Project Task

Actual Cost

Earned Value

75% Complete

EV = $75

CV = EV - AC

CV = - $5

CPI = EV / AC

CPI = 0.9375

SV = EV - PV

SV = - $25

SPI = EV / PV

SPI = 0.75


EVM: CPI Stability & Hidden Performance

Cornell University 04-2015

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Literature Review: What is EVM?

- Forecast depends upon CPI Stability:
  - EAC = AC + (BAC - EV)/CPI = BAC/CPI

S-Curves are whole-project... all tasks in aggregate.

CV & SV are the vertical distance between curves.


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4. Determine Project Performance

Where we are now.

Where will we end up?
CPI Stability Rule

- CPI stabilizes by the time a project is 20% complete.

Stability test for CPI

- $\text{CPI}_{\text{final}}$ does not change by more than ±.10 from $\text{CPI}_{20\%}$

- CPI does not change by more than ±10% from 20% complete through project completion

CPI Stability Rule

- Christensen and Payne (1992)
  First empirical confirmation of CPI stability rule based upon 26 projects from USAF Systems Command Aeronautical Systems Division.

- Fleming and Koppelmann (1999)
  Generalized CPI stability rule to all projects

- Christensen and Templin (2002)
  Summarized findings...some projects improve

Literature Review: CPI Stability

CPI Stability Rule Questions

- **Michael Popp (1995)**
  Plotted $CPI_{20}$ vs $CPI_{final}$ NAVAIR internal unclassified report.

- **David Christensen (1999 & 2002)**
  Using data from Michael Popp research, found that CPI stability could not be generalized.

- **Henderson & Zwikael (2008)**
  Analyzed 45 projects from 3 countries...87% Stable @20%
  Some projects did not stabilize until 70-80%.

- **Czarnirowska, Jaskowski & Biruk (2011)**
  Whole-project measures can be misleading “...poor performance may be compensated by good performance.”

Is CPI stable?
Michael Popp chart shows a significant number of projects presenting unstable CPI’s

Working Hypothesis:

- **CPI is stable at the performance unit level.**
  - Performance Unit is a collection of resources working on the same task(s).

- **Each performance unit** within a project may have **different** cost and schedule **performance**, each requiring a unique management response.

- **Hidden Performance** - Good performing units hide poor performing units at the whole-project level.

- **We can develop alternative whole-project CPI formulae** based upon each unit’s performance...better stability compliance.
Here we see a project that presents a CPI greater than 1.0 at 20% complete. However by the time the project finishes, the CPI has eroded to less than 1.0.

How can Stable Performance Unit CPI’s present an unstable whole-project CPI?

Answer: The whole-project CPI is a weighted average...

Performance Unit CPI’s can identify hidden performance issues in time to correct them!
**Research: Case Study**

**Mini Case Study A2D:** You are the project manager of an A/E building design project. Task 1 is completed by the same team as Task 4.

### Simple Baselines

<table>
<thead>
<tr>
<th>WBS</th>
<th>ES</th>
<th>EF</th>
<th>Budget</th>
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| Period PV | 35 | 160 | 135 | 115 |
| Cum PV    | 35 | 195 | 330 | 445 |

### Project Status Report end of wk 2

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**Calculate the CV, CPI, SV, and SPI for the whole project.**

**Then calculate the same values for each of the performance units and compare the results.**
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<thead>
<tr>
<th>WBS</th>
<th>BAC</th>
<th>EV</th>
<th>AC</th>
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The whole-project CPI is > 1.0

EAC = BAC/CPI = 445,000/1.0124 = $439,546

Task 3’s poor performance is masked by the good performance of the other units.

The sum of the performance unit EAC’s is $486,101.
Alternative Whole-Project CPI Formulae

- **CPI¹ = EV/AC** (Traditional CPI)

- **CPI² = \( \sum \left( \frac{BAC_{PU}}{BAC_{total}} \right) \times CPI_{PU} \)**
  
  - Where CPI² is the sum of the performance unit CPI’s weighted as a proportion of relative size

- **CPI³ = \( \frac{BAC_{total}}{\left( \sum \left( \frac{BAC_{PU}}{CPI_{PU}} \right) \right)} \)**
  
  - Where CPI³ is an estimate of final CPI instead of a cumulative to date metric
**Research: Case Study**

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

\[ \text{CPI}_{\text{final}} = \frac{\text{BAC}}{\text{AFC}}, \quad \text{where EV} \rightarrow \text{BAC} \text{ and AC} \rightarrow \text{AFC} \]

\[ \text{CPI}_{\text{EstFinal}} = \frac{\text{BAC}}{\text{EAC}} \quad \text{Whole Project} \]

\[ \text{where EAC} = \frac{\text{BAC}}{\text{CPI}} \]

\[ \sum_{\text{pu}=a}^{z} \text{EAC}_{\text{PU}} = \sum_{\text{pu}=a}^{z} \frac{\text{BAC}_{\text{PU}}}{\text{CPI}_{\text{PU}}} \quad \text{Performance Unit} \]

\[ \because \text{ CPI}^3 = \frac{\sum_{\text{pu}=a}^{z} \frac{\text{BAC}_{\text{Total}}}{\text{BAC}_{\text{PU}}} \text{ CPI}_{\text{PU}}}{\sum_{\text{pu}=a}^{z} \frac{\text{BAC}_{\text{PU}}}{\text{CPI}_{\text{PU}}}} \]
**Mini Case Study A2D**

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**CPI**

- **CPI\(^1\) = 1.0124**
- **CPI\(^2\) = 0.9416**
- **CPI\(^3\) = 0.9155**

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*EVM: CPI Stability & Hidden Performance*  
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Aerospace Laboratory Case Study

- Multi-functional Propulsion Research Laboratory.
- Unique environment where synergism among different advanced propulsion technologies can be exploited and used to expedite development.
- Supports exploratory research and feasibility investigations of a wide range of high-payoff propulsion technologies.
Practice: Case Study

Advanced Propulsion Research Technologies, including:

- Beamed Energy (Laser)
- Antimatter
- Chemical Synthesis
- Magnetohydrodynamics
- Simulated Fission
- High Power Plasma (Fusion)
- Propulsion Physics
- Solar Thermal
Practice: Case Study

Facility Design Goals and Principles

- Stimulating Environment for Research
- Building Flexibility for Changing Research
- Sustainable Facility Design
- Safe Laboratory Environment
### Work Breakdown Structure

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**Construction Documents for $22,000,000 Plant**

- **Architectural & Engineering**
  - **Architectural**
    - Schematic or Conceptual Des (1.1.1.1)
    - Arch Design Development (1.1.1.2)
    - Arch 60% Construction Doc's (1.1.1.3)
    - Arch 90% Construction Doc's (1.1.1.4)
    - 100% Construction Doc's (1.1.1.5)
- **Structural, Mech, Elect, Plumb**
  - Engr Design Development (1.1.2.1)
  - Engr 60% Construction Doc's (1.1.2.2)
  - Engr 90% Construction Doc's (1.1.2.3)
  - 100% Construction Doc's (1.1.2.4)
- **Industrial Engineering (IE)**
  - Plant Layout, Equipment, Process (1.2.1)
  - IE Design Development (1.2.1.1)
  - IE 60% Construction Doc's (1.2.1.2)
  - IE 90% Construction Doc's (1.2.1.3)
  - 100% Construction Doc's (1.2.1.4)

---

EVM: CPI Stability & Hidden Performance

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Aerospace Laboratory Case Study

1. CPI\(^1\) does not drop below 1.0 until month 4 of 5. CPI\(^2\) and CPI\(^3\) reveals poor performance in month 2.

2. Performance Unit analysis reveals which unit is performing poorly.

<table>
<thead>
<tr>
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**Case Study**

EVM: CPI Stability & Hidden Performance

Cornell University 04-2015

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- **Performance Unit CPI’s are stable**
- **Each performance unit has a different CPI**
- **Good performance is hiding poor performance**
Alternate Whole-Project CPI’s are stable

CPI³ produces best fit
Conclusion:

Working Hypothesis:

- **CPI is stable at the performance unit level.**
  - Performance Unit is a collection of resources working on the same task(s).

- **Each performance unit** within a project may have **different** cost and schedule performance, each requiring a unique management response.

- **Hidden Performance** - Good performing units hide poor performing units at the whole-project level.

- **We can develop alternative whole-project CPI formulae** based upon each unit’s performance...better stability compliance.
Take Aways:

✓ **Use Limit States to identify project performance issues and management responses**

✓ Each performance unit within a project may have different cost and schedule performance, each requiring a unique management response.

✓ **Hidden Performance** - Good performing units hide poor performing units at the whole-project level.

✓ **Drill down to the performance unit analysis level to identify hidden performance issues.**


