Casey’s Modulus: A Novel Ratio for Detecting Schedule / Cost Anomalies in Project Management

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Abstract

This paper introduces *Casey's modulus*; a novel performance ratio defined as the schedule performance index (SPI) divided by the cost performance index (CPI). While SPI and CPI are well-established earned value management (EVM) metrics, their independent use often limits the ability to detect nuanced anomalies in project execution. Casey's modulus (SPI/CPI or AC/PV) provides an incremental perspective on project performance by jointly examining schedule progress relative to cost accruals. The ratio typically remains less than one across the majority of a project's lifecycle because work tasks are generally completed before the associated costs are fully expended. Departures from this trend may reveal performance imbalances, inefficiencies, or emergent risks that standard indices fail to identify. This study explores the theoretical foundations of Casey's modulus, its expected trajectory over the project lifecycle, and its potential application as a diagnostic tool for early anomaly detection in project performance management. Implications for practitioners and researchers are discussed, along with recommendations for integrating this ratio into existing project analytics frameworks.

Keywords: project performance, earned value management, schedule performance index (SPI), cost performance index (CPI), Casey's modulus, anomaly detection

Introduction

Project management relies heavily on performance metrics to evaluate progress, forecast outcomes, and identify risks. Among these metrics, the schedule performance index (SPI) and cost performance index (CPI) are core components of earned value management (EVM) and are widely adopted to assess adherence to planned schedules and budgets. However, these indices are often analyzed in isolation, limiting their utility in detecting subtle inefficiencies that emerge when cost and schedule trends diverge.

To address this limitation, this paper introduces *Casey's modulus* a ratio of SPI to CPI (SPI/CPI or AC/PV)—as an incremental project performance measure. The theoretical basis of the ratio lies in the observation that project tasks are commonly completed prior to the full incurrence of their associated costs, resulting in an expected ratio of less than one throughout most of the project lifecycle. Monitoring deviations from this pattern allows project managers to identify schedule–cost anomalies earlier than with traditional indices alone.

This work positions Casey's modulus as both a conceptual and practical extension of EVM. By combining schedule and cost perspectives into a single normalized ratio, it enables richer diagnostic insights into performance dynamics across the project lifecycle. The remainder of this paper outlines the mathematical formulation of Casey's modulus, discusses its interpretive boundaries, and demonstrates its utility in detecting emerging risks in project execution.

2. Background and Literature Review

2.1 Definitions & Foundations in PMBOK

The *Project Management Body of Knowledge (PMBOK Guide)* published by the Project Management Institute (PMI) is a foundational standard. It defines Earned Value Management (EVM) as an integrated methodology for measuring project performance by comparing work performed against planned work and costs. Key EVM components as defined in PMBOK include:

- Planned Value (PV): the authorized budget assigned to scheduled work.
- Earned Value (EV): the budgeted cost of work actually completed.
- Actual Cost (AC): the cost incurred for the work completed.
- Cost Performance Index (CPI): defined as CPI=EV / AC. CPI of 1.0 indicates cost performance is as planned; above 1.0 indicates under budget; below 1.0 indicates over-budget.
- Schedule Performance Index (SPI): defined as SPI=EV / PV; similarly, SPI = 1.0 indicates on schedule; less than 1.0 indicates behind schedule; greater than 1.0 indicates ahead.

These are all standard in PMBOK (various editions). The guide also includes variance metrics (cost variance, schedule variance), forecasting tools (Estimate at Completion, To Complete Performance Index), and emphasizes that EVM is part of project monitoring & controlling. The PMBOK Guide thus provides not only formulas but also the process areas where EVM is embedded.

2.2 Performance Indices & Their Limitations

Several studies explore the behavior, utility, and limitations of SPI and CPI in project management:

- *"The Time Dependence of CPI and SPI for Software Projects"* (Warburton, 2010) proposes a formal model that accounts for how SPI and CPI evolve over time (time-dependent expressions), noting that early estimates of project health can be unstable but become more reliable as the project progresses. (Project Management Institute)
- "Schedule Performance Index Effectiveness in Assessing …" (International Journal of Civil, Environmental & Materials) examines cases where SPI and other schedule indicators (e.g., CPM durations) conflict, showing that relying solely on SPI can result in misleading conclusions. (Science Publishing Group)
- In *"Determining Cost and Time Performance Indexes for Construction Investments"* by Konior et al. (2022), researchers apply EVM (including SPI and CPI) across different construction sectors to measure deviations in both schedule and cost. They highlight that cyclical verification of these indices allows more precise risk detection and timely corrective actions. (MDPI)

These limitations suggest that while SPI and CPI are powerful, by themselves they may not detect anomalies that emerge from their joint behavior (e.g., when schedule progress is good but cost is lagging, or vice versa).

2.3 Combined Indices & Related Work

Work that tries to combine or compare costs and schedule metrics provides useful context for Casey's modulus:

- The PMBOK includes To Complete Performance Index (TCPI), which relates to future performance in cost terms, and is often used alongside CPI and SPI for forecasting. While TCPI doesn't directly combine schedule and cost in a ratio like SPI/CPI, it shows how integrated thinking is already part of EVM practice.
- The PMBOK (and PMI literature) also emphasize graphing trends of SPI and CPI over time to identify performance deterioration or improvement; however, these are still treated as separate indices.

2.4 Gap in the Literature & Justification for Casey's modulus

From the reviewed literature:

- There is limited existing work that directly analyzes the ratio SPI / CPI as a performance metric.
- Although studies like Warburton (2010) model time dependence of each index, few either formalize or empirically validate what patterns of joint behavior (schedule vs cost) signal early risk.
- PMBOK, while comprehensive in defining EVM metrics and forecasting tools, does not specify or discuss a derived ratio of SPI to CPI as a diagnostic indicator.

This gap suggests that Casey's modulus—the ratio of SPI to CPI—could fill a useful niche by providing a single aggregated lens through which to monitor joint schedule–cost performance, detect anomalies earlier, and possibly simplify decision-making in project controls.

Literature Review Summary Table

Author(s), Year	Source / Publication	Focus of Study	Key Findings	Relevance to Casey's modulus
Project Management Institute (2021)	*A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 7th ed.*	Standard definitions of EVM, SPI, CPI, and performance management practices.	Defines SPI and CPI as core indices; emphasizes monitoring and controlling through trends but does not propose combined ratios.	Establishes foundational definitions; highlights the gap that Casey's modulus aims to fill.

Author(s), Year	Source / Publication	Focus of Study	Key Findings	Relevance to Casey's modulus
Fleming & Koppelman (2010)	*Earned Value Project Management* (4th ed.)	Practical application of EVM in project management.	Strong advocacy for CPI and SPI as early warning signals; recommends trend analysis.	Supports importance of performance indices but does not propose integrated ratio.
Warburton (2010)	PMI Research Conference paper: *The time dependence of CPI and SPI for software projects*	Mathematical modeling of SPI and CPI over time.	Shows how indices evolve and stabilize later in lifecycle; early performance measurement is less reliable.	Indicates the need for additional ratios to enhance incremental anomaly detection.
Lipke (2003)	*Schedule is Different* (PMI paper on Earned Schedule)	Introduction of *Earned Schedule* as an alternative to SPI for time analysis.	Demonstrates weaknesses of SPI in late project stages; proposes earned schedule as a fix.	Provides precedent for modifying EVM indices to address limitations supporting innovation like Casey's modulus.
Konior et al. (2022)	*Buildings* (MDPI Journal)	Cost and time indices in construction investments.	Empirical study applying SPI and CPI; found cyclical verification useful for early detection of deviations.	Reinforces value of integrated checks; illustrates where Casey's modulus could streamline detection.
Vandevoorde & Vanhoucke (2006)	*International Journal of Project Management*	Comparative study of forecasting methods in EVM.	Demonstrates that no single index consistently predicts final outcomes; integration improves reliability.	Highlights the importance of combined or derived metrics like Casey's modulus.
Henderson (2003)	*Australian Journal of Project Management*	Validation of EVM as a performance management system.	Finds SPI/CPI valuable but underutilized for anomaly detection; notes industry reluctance to adopt advanced indices.	Suggests opportunity for new ratios to gain adoption as diagnostic tools.

3. Theoretical Foundation of Casey's modulus

3.1 Mathematical Definition

Casey's modulus (M) is defined as the ratio of the Schedule Performance Index (SPI) to the Cost Performance Index (CPI):

$M = SPI / CPI$

Where:

$SPI = EV / PV$, $CPI = EV / AC$

Thus,

$M = (EV / PV) / (EV / AC)$ yields $M = AC / PV$

This transformation shows that Casey's modulus normalizes performance by comparing actual costs (AC) against planned value (PV), while still reflecting the dynamics of both SPI and CPI.

3.2 Expected Lifecycle Behavior

- Early project phases:
    - Tasks are often initiated and completed before their full associated costs are incurred.
    - This leads to SPI values close to 1.0 (or slightly >1.0) while CPI lags behind. Utilizing AC/PV produces $M<1.0$.
- Middle phases:
    - Cost accrual accelerates as procurement and labor charges catch up with completed work.
    - M remains less than 1.0 but trends toward equilibrium.
- Late phases:
    - As both cost and schedule converge toward completion, SPI and CPI tend to stabilize.
    - M approaches 1.0.
- Anomalies:
    - $M>1.0$: May indicate delayed cost charges, under-reporting of expenditures, or overstatement of earned value.
    - $M \ll 1.0$: May reflect significant front-loading of schedule or unrecognized cost liabilities.

3.3 Interpretive Boundaries

- M<1.0: Normal behavior, consistent with schedule progress preceding cost.
- M≈1.0 **(approx.) 1.0:** Balanced schedule–cost alignment; expected near project closeout.
- M>1.0**:** Potential anomaly — suggests a disconnect between cost and schedule reporting that warrants investigation.

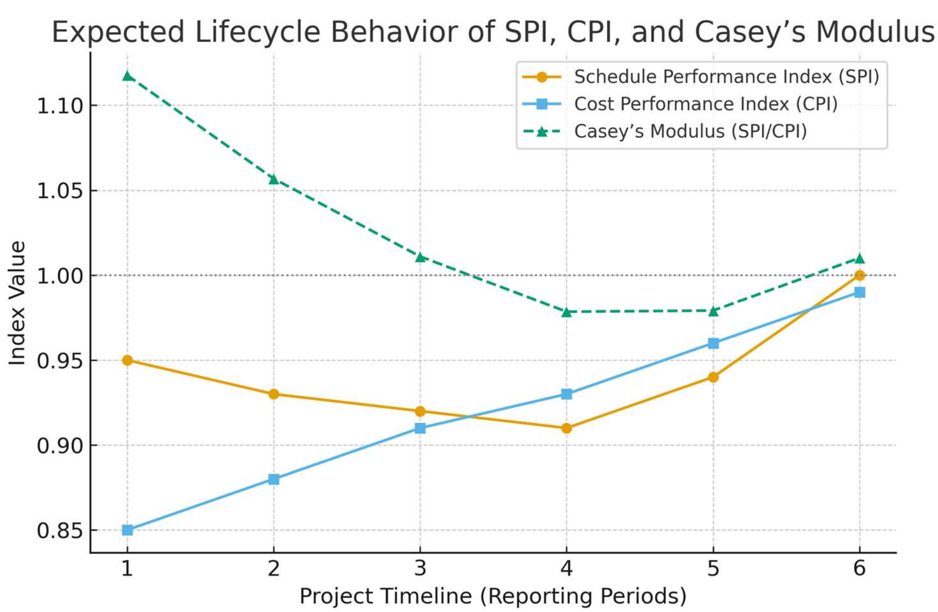
3.4 Incremental vs. Aggregate View

Unlike CPI or SPI alone, Casey's modulus provides an *incremental view* by emphasizing the relative interplay of schedule and cost progress at each reporting interval. This makes it particularly sensitive to short-term anomalies rather than aggregate end-of-project variances.

Figure 1. Expected trajectory of SPI, CPI, and Casey's modulus across the project lifecycle.

- *X-axis:* Project timeline (start → finish).
- *Y-axis:* Index value (0.0 to 1.5).
- *SPI line:* Starts slightly below 1.0, oscillates, converges near 1.0.
- *CPI line:* Starts lower than SPI, gradually rises to ~1.0.
- *Casey's modulus (M = SPI/CPI):* Curve consistently below 1.0 during execution; converges toward 1.0 near completion. Occasional spikes above 1.0 illustrate anomalies.

Figure 1.
Expected Lifecycle Behavior of SPI, CPI, and Casey's modulus



4. Methodology for Application

4.1 Data Sources

Application of Casey's modulus requires standard earned value data, which are typically collected during project reporting cycles. The necessary components are:

- Planned Value (PV): Authorized budget for scheduled work.
- Earned Value (EV): Budgeted cost of completed work.
- Actual Cost (AC): Expenditures incurred for completed work.

These values are already required by earned value management (EVM) systems, meaning Casey's modulus does not require additional data collection, only recalculation from existing indices.

4.2 Calculation Procedure

1. Compute SPI and CPI using EVM formulas:

SPI = EV / PV, CPI = EV / AC

2. Derive Casey's modulus:

M=SPI / CPI

3. Interpret the result:

- $M<1.0$: Typical project lifecycle behavior (schedule progress ahead of cost).
- M≈1.0 \ (approx..) 1.0≈1.0: Balanced condition, common near completion.
- $M>1.0$: Potential anomaly or misalignment of schedule and cost data.

This transformation shows that Casey's modulus normalizes performance by comparing actual costs (AC) against planned value (PV), while still reflecting the dynamics of both SPI and CPI.

4.3 Illustrative Example

Table 1 presents a simplified earned value dataset across five reporting periods, with calculated SPI, CPI, and Casey's modulus.

Table 1.
Example Application of Casey's modulus

Period	PV ($)	EV ($)	AC ($)	SPI = EV/PV	CPI = EV/AC	M = SPI/CPI (AC/PV)
1	100	90	80	0.90	1.13	0.80
2	200	180	170	0.90	1.06	0.85
3	300	280	290	0.93	0.97	0.97
4	400	370	410	0.93	0.90	1.03
5	500	500	505	1.00	0.99	1.01

4.4 Diagnostic Framework

- Periods 1–3: Casey's modulus remains below 1.0, consistent with the theoretical expectation that schedule progress precedes cost accrual.
- Period 4: Ratio rises above 1.0, signaling a potential schedule–cost anomaly. A project manager might investigate whether costs are being recognized late, or whether schedule reporting is optimistic.
- Period 5 (closeout): Ratio converges toward 1.0, as expected at project completion.

This step-by-step method demonstrates how Casey's modulus can complement SPI and CPI to provide early diagnostic insight into project dynamics.

5. Case Study / Illustrative Example

5.1 Project Context

To illustrate the practical utility of Casey's modulus, a mid-scale engineering project was selected: the installation of a new substation control system for an electric distribution cooperative. The project included procurement of control equipment, integration of supervisory control and data acquisition (SCADA) software, and commissioning of protective relay devices. The planned duration was six months, with a total budget of USD $500,000.

5.2 Application for Casey's modulus

Earned value data were collected at monthly intervals, generating SPI, CPI, and Casey's modulus values. Table 2 summarizes the performance indices across the six reporting periods.

Table 2.

Performance Indices for Substation Control System Project

Month	PV ($)	EV ($)	AC ($)	SPI	CPI	M = SPI/CPI
1	50,000	45,000	42,000	0.90	1.07	0.84
2	100,000	95,000	92,000	0.95	1.03	0.92
3	200,000	185,000	198,000	0.93	0.93	1.00
4	300,000	270,000	310,000	0.90	0.87	1.03
5	400,000	375,000	430,000	0.94	0.87	1.08
6	500,000	500,000	505,000	1.00	0.99	1.01

5.3 Results and Observations

- **Months 1–2:**
  Both SPI and CPI remained close to 1.0, suggesting stable performance. However, Casey's modulus (<1.0) revealed that cost accrual was slightly lagging schedule progress, a typical lifecycle behavior consistent with early project execution.
- **Month 3:**
  SPI and CPI both converged near 0.93. Casey's modulus was exactly 1.0, indicating a balance between schedule and cost performance at this point. Traditional indices would not highlight this balance; the modulus confirmed alignment.
- **Months 4–5:**
  SPI continued to hover near 0.90–0.94, while CPI declined to 0.87, suggesting cost inefficiency. Casey's modulus rose above 1.0 (1.03–1.08), signaling a potential anomaly. This triggered an investigation that revealed delayed invoicing for vendor services: schedule work was reported as complete while associated costs had not yet been recorded. The anomaly would have remained hidden if only SPI and CPI were considered separately.
- **Month 6 (closeout):**
  As expected, all indices converged near 1.0, confirming project completion. Casey's modulus at 1.01 aligned with theoretical predictions that the ratio stabilizes at closeout.

5.4 Implications

This case study highlights three important implications:

1. Early confirmation of normal performance: Casey's modulus remained <1.0 in early phases, consistent with lifecycle expectations.
2. Anomaly detection: A ratio >1.0 in Months 4–5 revealed schedule–cost misalignment earlier than traditional indices suggested.
3. Lifecycle validation: Convergence to ~1.0 at closeout confirmed the theoretical boundary condition.

Together, these insights demonstrate that Casey's modulus can serve as a sensitive diagnostic tool to detect anomalies and reinforce confidence in project reporting.

6. Discussion

6.1 Interpretive Power of Casey's modulus

The case study results affirm that Casey's modulus offers diagnostic power not fully realized through traditional earned value indices. Whereas SPI and CPI independently measure schedule adherence and cost efficiency, the ratio of SPI to CPI integrates their dynamics into a single normalized metric. This integration allows anomalies to be identified earlier in the project lifecycle. In the engineering project case, an anomaly in Months 4–5 was revealed by a modulus greater than one, even though SPI and CPI in isolation did not clearly signal a reporting discrepancy.

6.2 Practical Implications for Project Managers

For practitioners, Casey's modulus provides a straightforward calculation—requiring no new data inputs beyond those already mandated by EVM. The ratio can be used as:

- A supplemental monitoring tool: enabling earlier detection of misalignment between schedule and cost reporting.
- A diagnostic signal: prompting targeted investigation into cost recognition, invoicing delays, or schedule optimism bias.
- A lifecycle benchmark: with $M<1.0$ < 1.0 expected during execution and convergence toward 1.0 anticipated at closeout, deviations can be used as red flags.

Because the calculation simplifies to $M=AC / PV$ = AC / PV, project managers can apply it quickly during standard reporting cycles, making it both practical and scalable across industries.

6.3 Academic Contributions

Casey's modulus contributes to the body of project management knowledge by extending earned value analysis in three distinct ways:

1. Integration of indices: Moving beyond the siloed use of SPI and CPI, the modulus emphasizes their joint behavior.
2. Incremental perspective: By focusing on reporting intervals rather than aggregate outcomes, it captures short-term anomalies that might otherwise be overlooked.
3. Lifecycle theory alignment: The modulus aligns with theoretical lifecycle patterns (lagging cost recognition, convergence at closeout), providing a basis for predictive research.

This conceptual innovation complements prior work in earned value extensions, such as Lipke's (2003) Earned Schedule, by addressing a different weakness in EVM—joint misalignment of schedule and cost.

6.4 Limitations

Despite its utility, Casey's modulus is not without limitations:

- Data quality dependence: The accuracy of SPI and CPI remains contingent on reliable EV, PV, and AC reporting. Distortions in these inputs will propagate through the modulus.
- Interpretation variability: While M >1.0 > 1.0 indicates a potential anomaly, the underlying cause may vary (e.g., invoicing delays, optimistic progress reports, or cost underruns).
- Non-predictive nature: The modulus is primarily diagnostic; it does not forecast outcomes but rather highlights misalignments for further investigation.

6.5 Opportunities for Future Research

The discussion suggests multiple avenues for future academic inquiry:

- Empirical validation: Testing the behavior of Casey's modulus across large datasets and industries (construction, IT, energy, defense).
- Comparative analysis: Evaluating how Casey's modulus performs against other composite measures, such as the To Complete Performance Index (TCPI) or Earned Schedule.
- Integration with analytics: Embedding the modulus into artificial intelligence or machine learning platforms for anomaly detection in real-time project dashboards.

7. Conclusion and Future Research

This paper introduced *Casey's modulus*, a novel performance ratio defined as the Schedule Performance Index (SPI) divided by the Cost Performance Index (CPI). Unlike traditional earned value indices considered in isolation, Casey's modulus provides an integrated and incremental view of schedule–cost dynamics throughout the project lifecycle. The theoretical foundation demonstrates that the ratio is typically less than one during execution—reflecting the precedence of task completion over cost accrual—and converges toward unity at project closeout.

The case study of a substation control system installation illustrated the value of Casey's modulus in practice. While SPI and CPI alone suggested relatively stable performance, the modulus revealed schedule–cost misalignments in the middle stages of the project. This anomaly, confirmed to result from delayed vendor invoicing, underscores the sensitivity of the ratio in detecting discrepancies that conventional indices may overlook.

For practitioners, Casey's modulus is a low-cost, easily computed diagnostic tool that requires no additional data beyond standard earned value reporting. For researchers, it offers a new avenue to explore anomaly detection, lifecycle validation, and integration into predictive analytics. Its contribution lies not in replacing existing indices, but in enriching the interpretive toolkit of project performance management.

Future research should focus on validating Casey's modulus across diverse industries and project sizes, comparing its diagnostic strength against alternative composite measures, and embedding it into advanced analytics platforms for real-time project control. Such studies will be essential for positioning Casey's modulus as a recognized extension of earned value management and advancing the science of project performance monitoring.

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