مدیریت مالی، حسابداری و هزینه در پروژه ها و سازمان‌های پروژه‌محور

بخش نهم:

مدیریت هزینه: مدیریت هزینه پروژه

ارائه دهنده:

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(PhD, PMP, CMIT)

What you will learn?

- Purpose of this session
- Roadmap
- Why cost control is important?
- What are the purposes of cost control?
- How the costs of a project are controlled?
- Importance of cost code
- Monitoring and controlling material, labor, subcontracts, and equipment costs
- Monitoring and controlling project overhead and general overhead costs
- Monitoring project profitability
- How to manage the sources of cost overrun
- Cost-loaded schedule
- Earned value management system (EVMS)
- Target levels for cost performance index (CPI)
- Target levels for schedule performance index (SPI)
- Project closeout audit

Earned value management system (EVMS)

GAO

EVM Process

The EVM process can be broken down into thirteen fundamental activities, outlined and described in this section:

1. define the scope of effort with a WBS;
2. identify who in the organization will perform the work;
3. schedule the work to a timeline;
4. estimate resources and authorize budgets;
5. determine objective measures of earned value;
6. develop the performance measurement baseline;
7. execute the work plan and record all costs;
8. analyze EVM performance data and record variances from the performance measurement baseline (PMB) plan;
9. forecast estimates-at-completion (EACs) using EVM;
10. conduct an integrated cost-schedule risk analysis;
11. compare EACs from EVM (9) with EAC from risk analysis (10);
12. take management action to respond to risks; and
13. update the performance measurement baseline as changes occur.

STEP 6: Develop the performance measurement baseline

Contingency	In this *Cost Guide*, contingency represents funds held at or above the government program office for "unknown unknowns" that are outside a contractor's control. In this context, contingency funding is added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows are likely to result in additional costs.
Management reserve (MR)	Management reserve funds are for "known unknowns" that are tied to a contract's scope and managed at the contractor level. Unlike contingency, which is funding related, management reserve is budget related. The value of the contract includes these known unknowns in the budget base, and the contractor decides how much money to set aside.

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In this definition, GAO has assumed no management reserve for contractor and the definition of MR means the same contingency for contractors!

STEP 6: Develop the performance measurement baseline

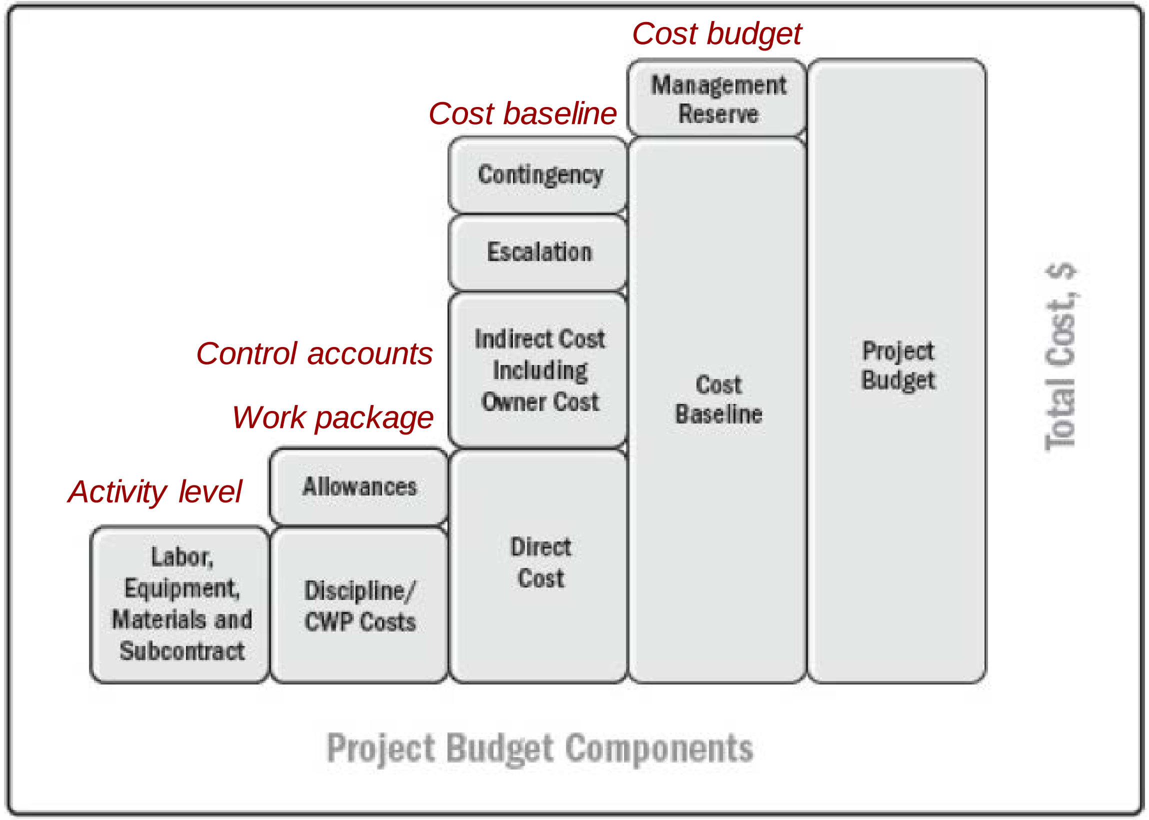
- The performance measurement baseline does **not include**
  - General overhead
  - Management reserve (or contingency in GAO)

HOW ABOUT CONTINGENCY (OR MANAGEMENT RESERVE IN GAO)?

Next session is very very very important!

DO NOT MISS IT FROM THE OUTSET!

STEP 6: Develop the performance measurement baseline

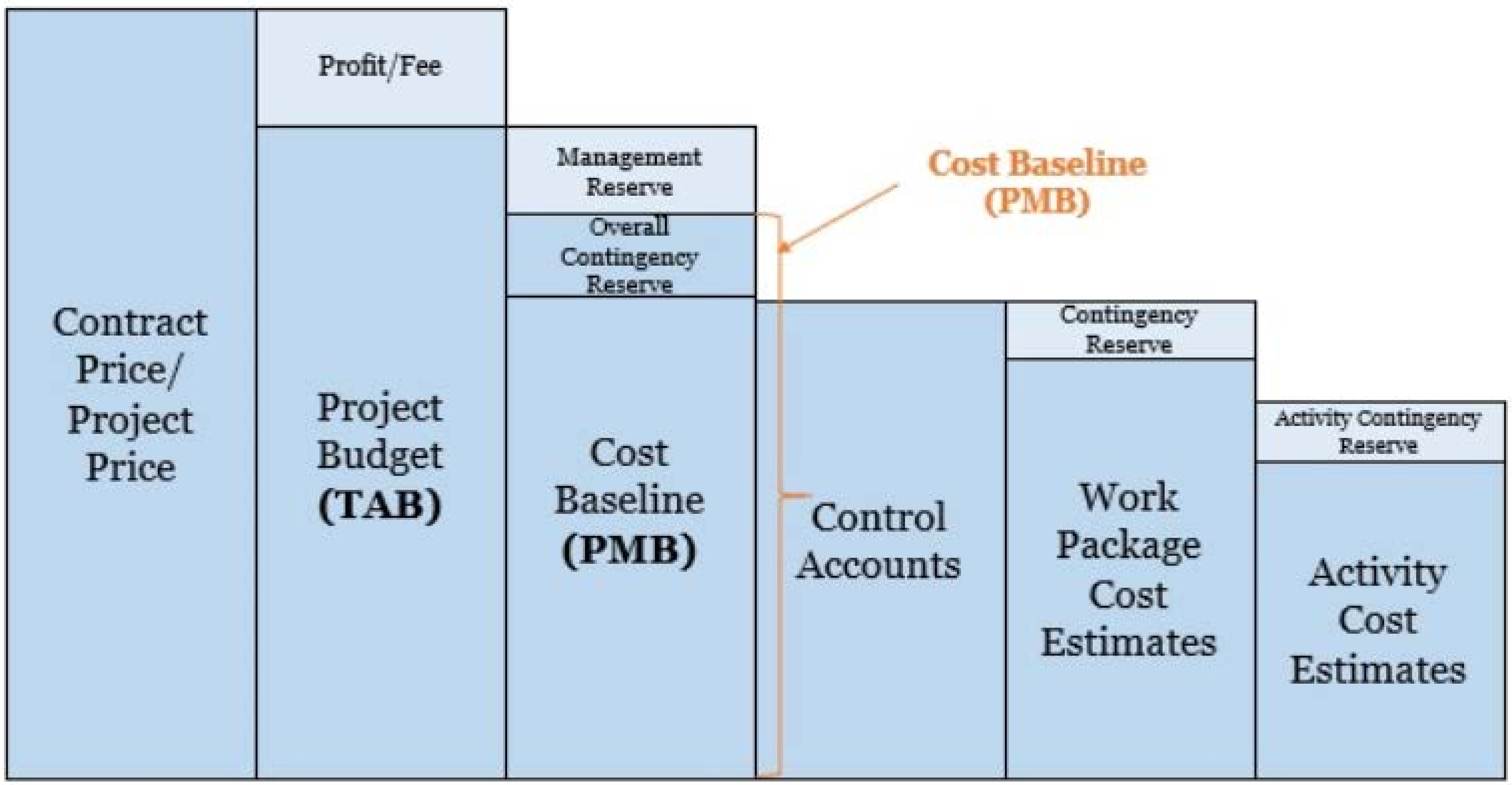


EPC Project Budget Components

STEP 6: Develop the performance measurement baseline

https://www.mpug.com/contingency-reserve-management-reserve/

DOES THIS MODEL INCLUDE GENERAL OVERHEAD?



STEP 6: Develop the performance measurement baseline

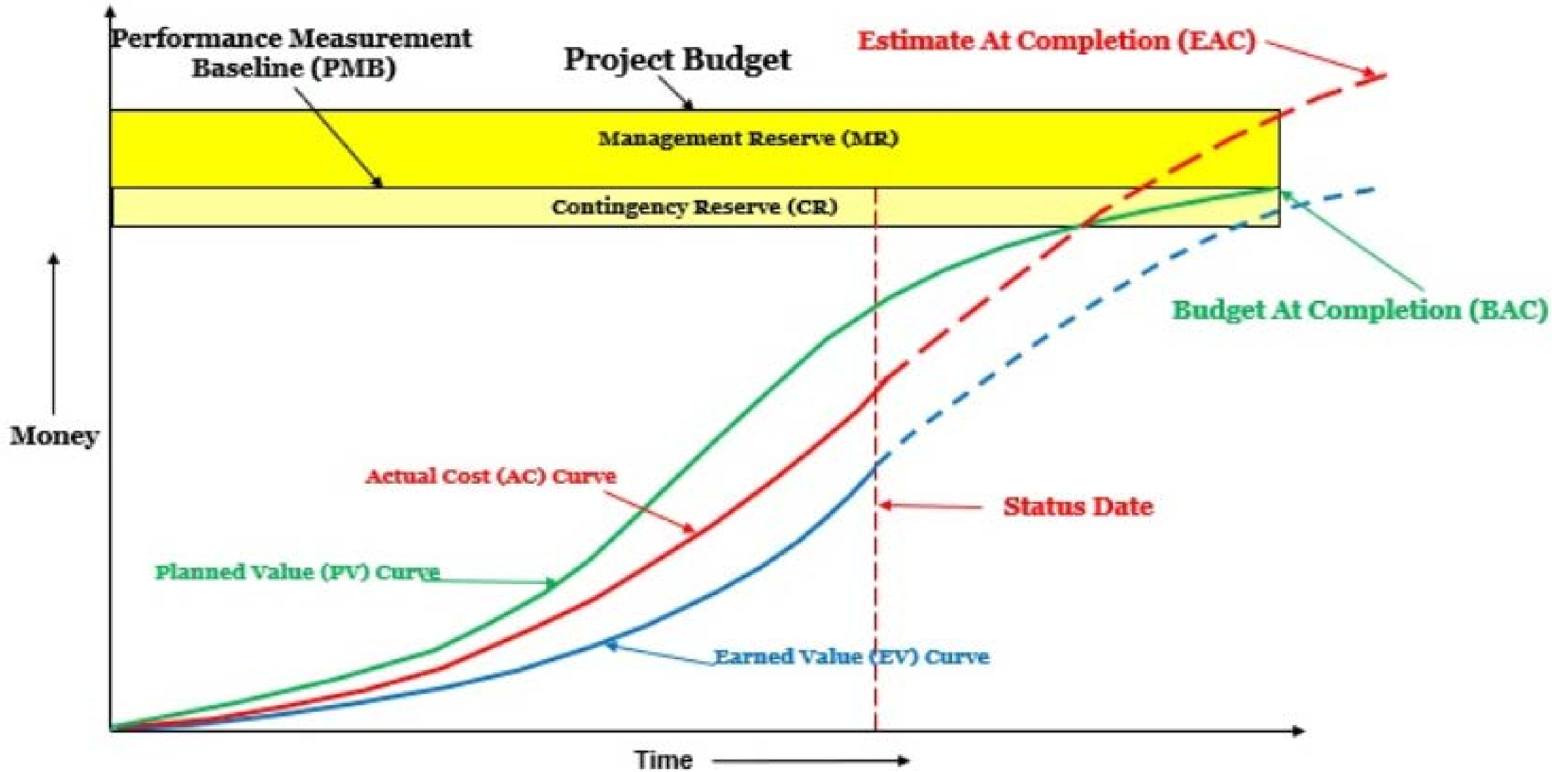
Committed Cost Worksheet

	A	B	C	D	E	F	G	H	I	J	K	L
1									Total		Total	
2									Committed		Estimated	
3								Non-	and Non-	Estimated	Cost	Variance
4					Total		Committed	Committed	Committed	Cost	at	Over /
5			Original	Change	Estimate	Committed	Costs	Costs	Costs	To	Completion	(Under)
6	Code	Description	Estimate	Orders	(C + D)	Costs	Invoiced	Invoiced	(F + H)	Complete	(I + J)	(K - E)
7					—				—		—	—
8					—				—		—	—
9			—	—	—	—	—	—	—	—	—	—

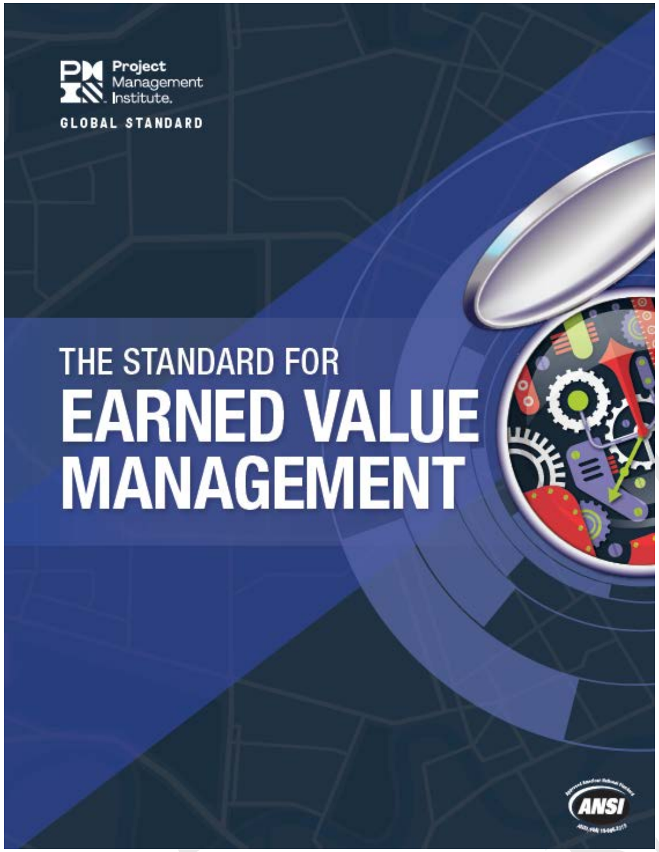
STEP 6: Develop the performance measurement baseline

https://www.mpug.com/contingency-reserve-management-reserve/

1. DOES THIS MODEL INCLUDE GENERAL OVERHEAD?
2. COULD WE COMPARE EAC ACHIEVED HERE WITH WHAT ACHIEVED IN COMMITTED COSTS?



STEP 6: Develop the performance measurement baseline



Let's see what PMI says!
Published in 2019

STEP 6: Develop the performance measurement baseline

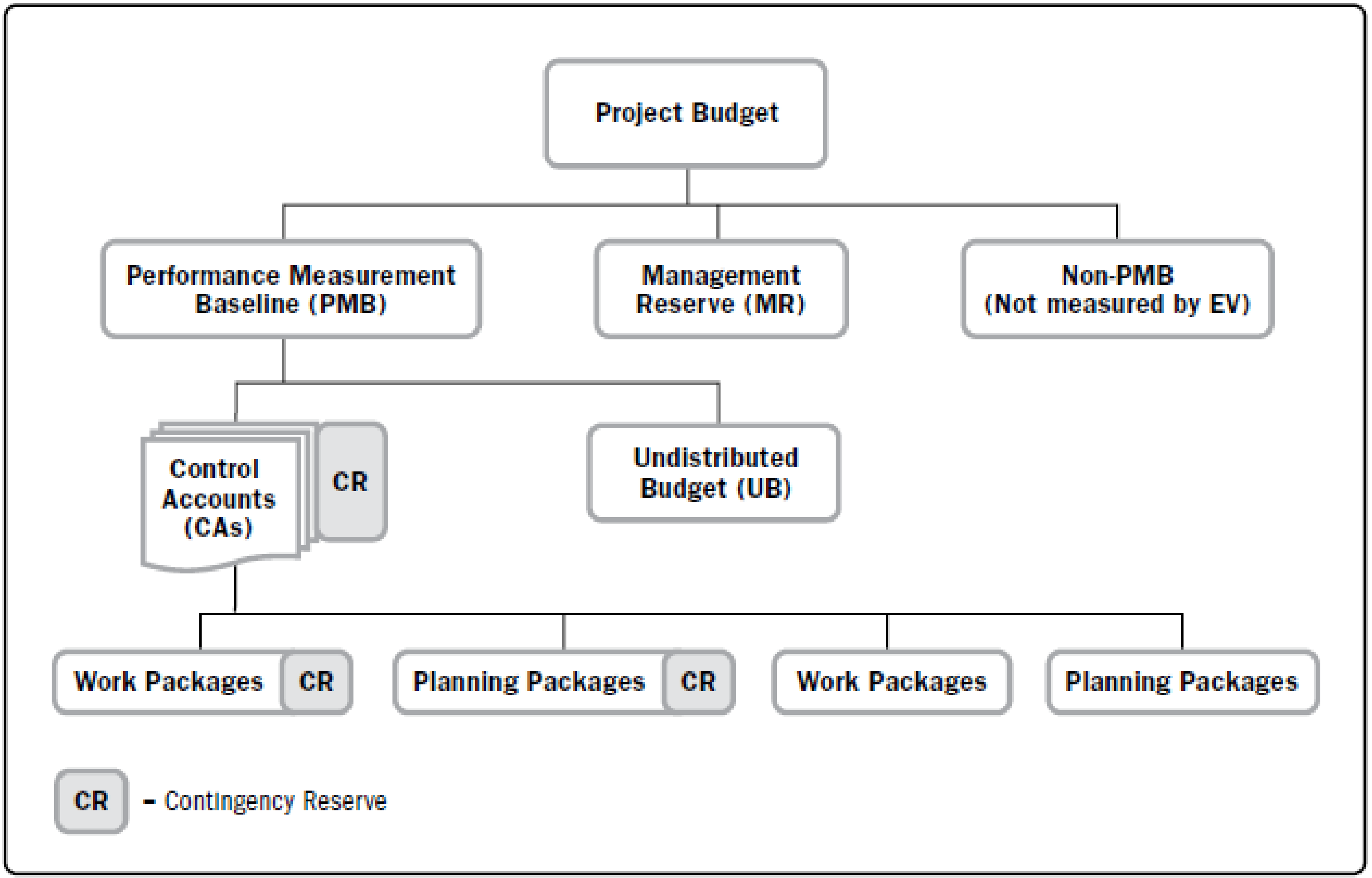


Figure 3-4. Performance Measurement Baseline (PMB) Creation

Usually a management reserve (MR) has been determined, which is also typically outside of the cost baseline. The project team also determines whether all or just a portion of the costs will be included in the integrated PMB.

STEP 6: Develop the performance measurement baseline

These provide the scope and schedule baselines that are integrated for the PMB. Note that contingency reserves can be allocated at either the control account, work package, or planning package levels. During the planning process, some scope/budget may not yet be distributed to a particular CA, but may be considered as part of the PMB. In this case, the scope and its allocated costs are held in what is often known as undistributed budget (UB). One can look at undistributed budget as a special CA that is holding scope with associated activities and costs that have not been scheduled, therefore are not yet time phased into a planning or work package within a particular CA.

The management reserve and the budget for the PMB are components of the project budget. The management reserve is typically not time phased and is not part of the PMB. As with contingency reserve, management reserve should not be used to mask performance-related overrun conditions. Rather, the contingency reserve is intended to be a budget for risk responses within the project charter's statement of work. The management reserve is for unforeseen risks that have had no anticipated risk responses established in the project management plan.

STEP 6: Develop the performance measurement baseline

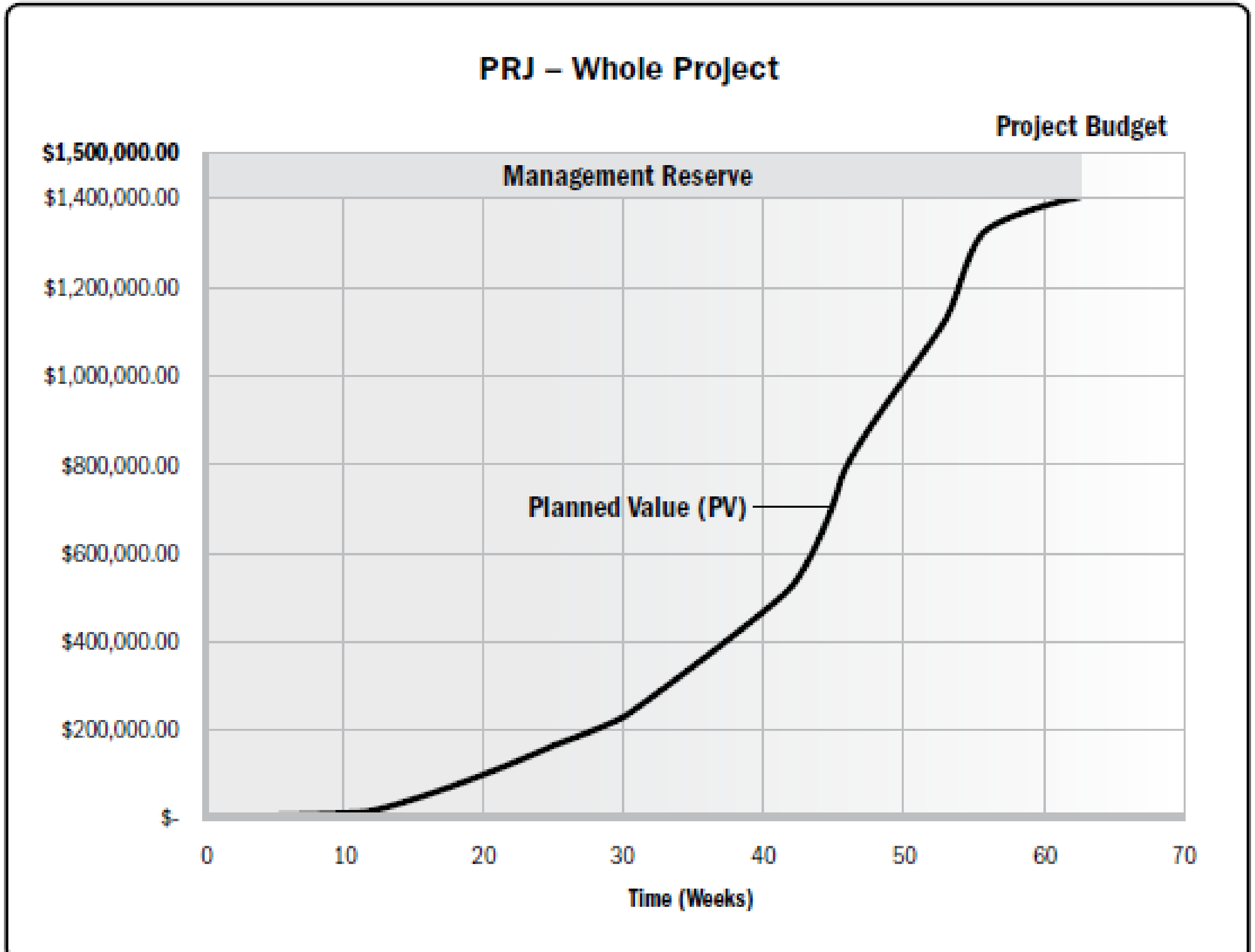


Figure 3-8. Performance Measurement Baseline (PMB)—The Planned Value (PV)

STEP 6: Develop the performance measurement baseline

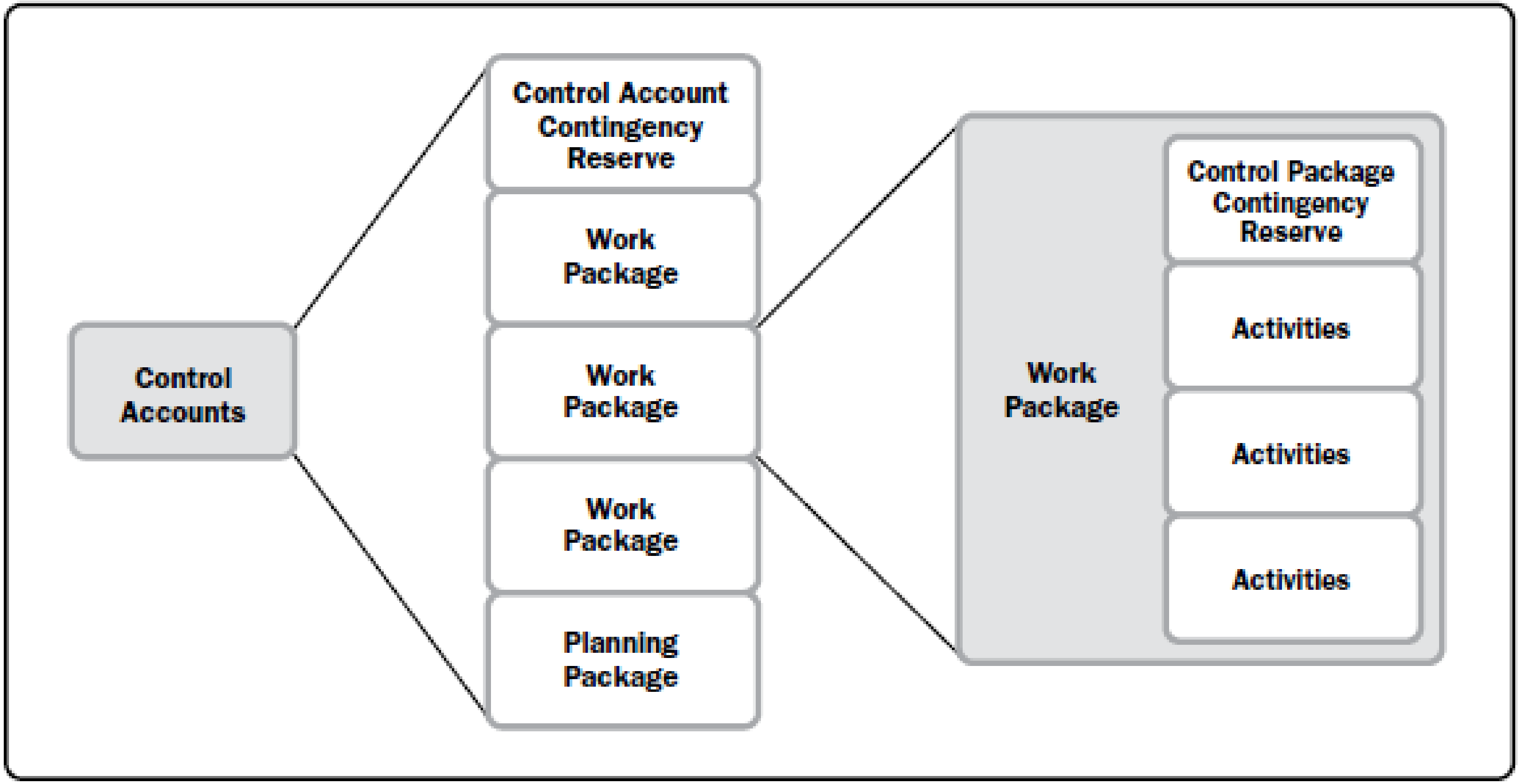


Figure 3-5. Control Account Components

STEP 6: Develop the performance measurement baseline

Let’s see what GAO says!

STEP 6: Develop the performance measurement baseline

Contingency	In this *Cost Guide*, contingency represents funds held at or above the government program office for "unknown unknowns" that are outside a contractor's control. In this context, contingency funding is added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows are likely to result in additional costs.
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In this definition, GAO has assumed no management reserve for contractor and the definition of MR means the same contingency for contractors!

STEP 6: Develop the performance measurement baseline

GAO

Management reserve should be included in the budget to cover uncertainties such as unanticipated effort resulting from accidents, errors, technical redirections, or contractor-initiated studies. When a portion of the management reserve budget is allocated to one of these issues, it becomes part of the performance measurement baseline that is used to measure and control program cost and schedule performance. Management reserve provides management with flexibility to allocate budget to mitigate problems and control programs. However, it can be applied only to in-scope work and cannot be used to offset or minimize existing cost variances.

How to calculate?

STEP 6: Develop the performance measurement baseline

GAO

Programs with greater risk, such as development programs, usually require higher amounts of management reserve than programs with less risk, such as programs in production. Two key issues associated with management reserve are how much should be provided to the program and how it should be controlled. Research has found that programs typically set their contract value so they can set aside 5 to 10 percent as management reserve. This amount may not be sufficient for some programs and may be more than others need. One way to derive the amount of management reserve needed is to conduct a risk analysis for schedule (to determine the schedule reserve needed) and for cost (to determine the management reserve for cost).

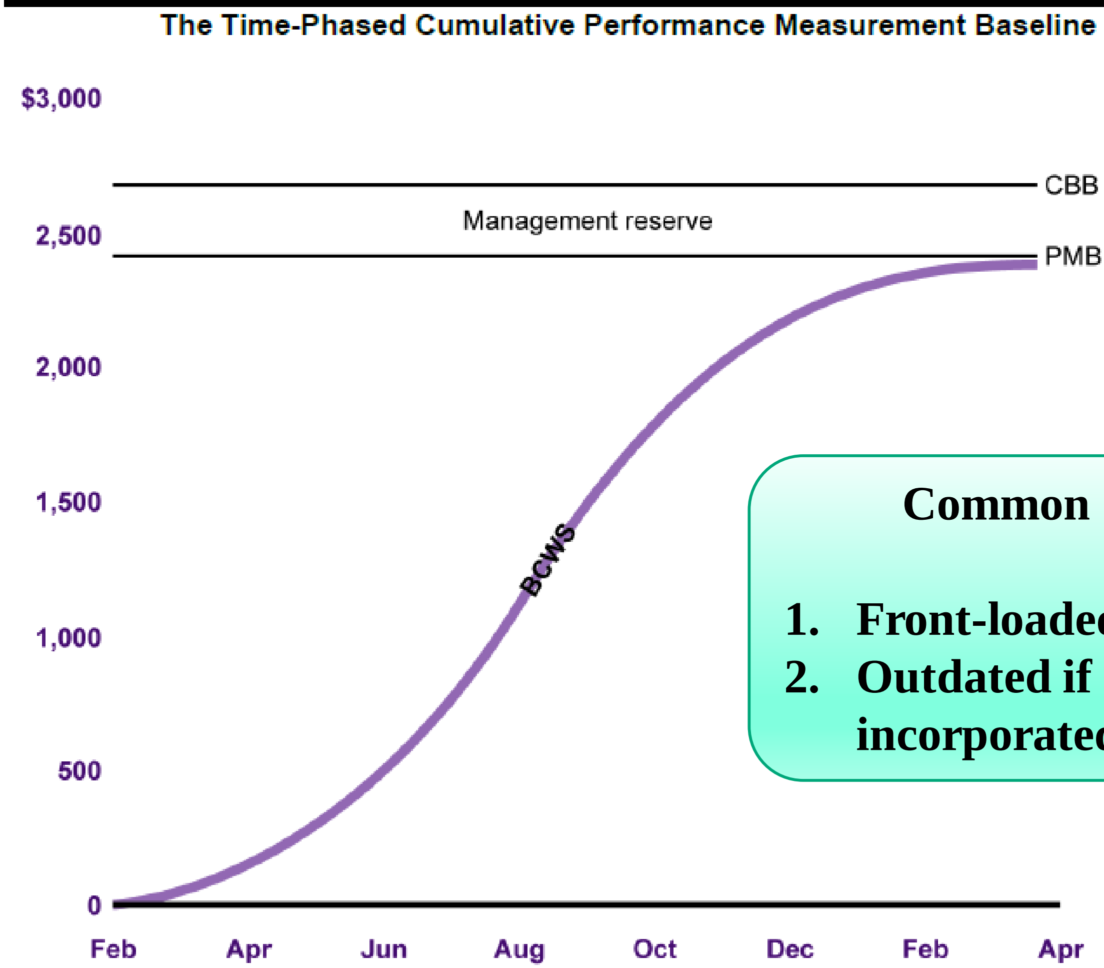
How to control?

STEP 6: Develop the performance measurement baseline

GAO

The performance measurement baseline does not include management reserve or any fee and thus does not equal the program contract value. Because the budget for management reserve is accounted for outside the performance measurement baseline, it cannot be associated with any particular effort. Once a risk is realized and recovery actions identified, then the management reserve is distributed to the appropriate control account. The management reserve and performance measurement baseline values together make up the contract budget base which in turn represents the total cost of the work. Fee is added to the contract budget base to reflect the total contract price.

STEP 6: Develop the performance measurement baseline



Source: ICEAA (International Cost Estimating and Analysis). Cost Estimating Body of Knowledge. Vienna, Va.: 2013. | GAO-20-195G

Note: BCWS = budgeted cost for work scheduled; CBB = contract budget base; PMB = performance measurement baseline.

Common problems?

1. **Front-loaded**
2. **Outdated if changes are not incorporated quickly**

Let’s see another view!

STEP 6: Develop the performance measurement baseline

- If these reserves are **not included**, the **baseline** will probably **not be met**, because risks may be occurred.

  - But, **including** the reserves lead to **two problems (Wilko Reinck from Germany)**:

    1) The **EVM** and specially the forecasts calculated from the EVM will **not deliver correct results.**

    2) According to **Parkinson's law** ("**work expands** so as to **fill the time available** for its completion") the reserves will be used if risks will occur or not.

      - ✓ This will result in an **exceedance of the baseline**, especially if **risks occur** at the **end of the project**.

STEP 6: Develop the performance measurement baseline

How should we perform EVM if contingency not included and happens to the project?

STEP 6: Develop the performance measurement baseline

How should we perform EVM if contingency not included and happens to the project?

- Use the **PMB without the contingency** reserves

  and then **increase the PMB** with the reserves as soon as **risks occur**

Here the EAC in committed costs should not differ…

STEP 6: Develop the performance measurement baseline

Committed Cost Worksheet

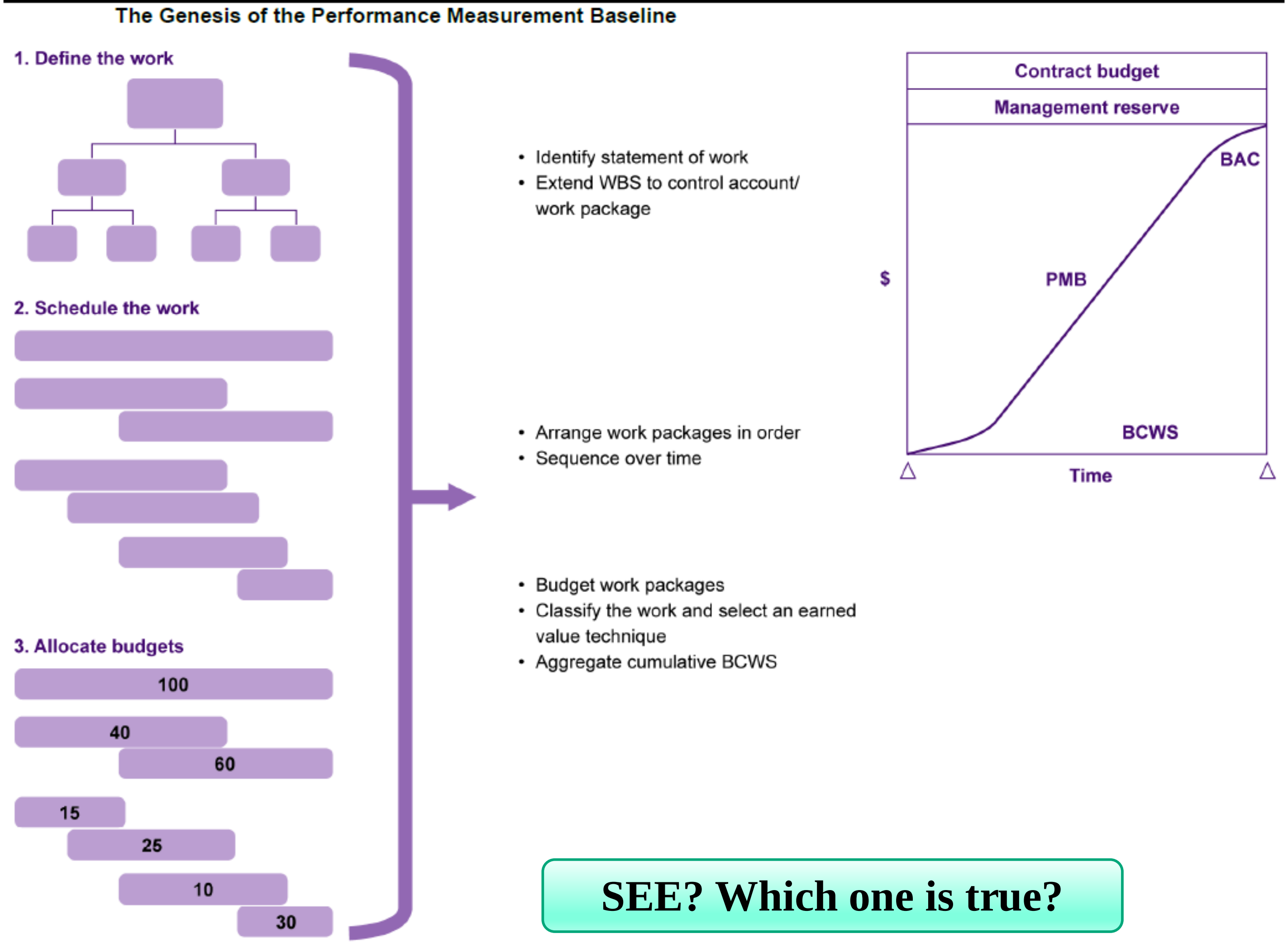
	A	B	C	D	E	F	G	H	I	J	K	L
1									Total		Total	
2									Committed		Estimated	
3								Non-	and Non-	Estimated	Cost	Variance
4					Total		Committed	Committed	Committed	Cost	at	Over /
5			Original	Change	Estimate	Committed	Costs	Costs	Costs	To	Completion	(Under)
6	Code	Description	Estimate	Orders	(C + D)	Costs	Invoiced	Invoiced	(F + H)	Complete	(I + J)	(K - E)
7					—				—		—	—
8					—				—		—	—
9			—	—	—	—	—	—	—	—	—	—

STEP 6: Develop the performance measurement baseline

This figure shows how it **integrates**

1. Cost,
2. Schedule,
3. Technical effort

into a single baseline.



SEE? Which one is true?

Note: BCWS = budgeted cost for work scheduled; BAC = budget at complete; PMB = performance measurement baseline; WBS = work breakdown structure.

STEP 6: Develop the performance measurement baseline

So far we have talked about contingency in EVM.

However, the question is

1. **Should we use contingency as a single line item or**
2. **Distributed among control accounts?**

STEP 6: Develop the performance measurement baseline

- CII RS-6-8: Management of Project Risks and Uncertainties, 2010

Abbott	AMEC
Air Liquide	AZCO
Air Products and Chemicals	Aker Solutions
Alcoa	Alstom Power
Ameren Corporation	Atkins Faithful+Gould
American Transmission Company	BIS Frucon Industrial Services
Anheuser-Busch InBev	Baker Concrete Construction
Aramco Services Company	Barton Malow Company
Archer Daniels Midland Company	Bateman Engineering
BP America	Bechtel Group
Barrick Gold Corporation	Bentley Systems
Bristol-Myers Squibb Company	Black & Veatch
CITGO Petroleum Corporation	Bowen Engineering Corporation
Cargill	Burns & McDonnell
Chevron	CB&I
Codelco-Chile	CCC Group
ConocoPhillips	CDI Engineering Solutions
Constellation Energy	CH2M HILL
DFW International Airport	CSA Group
The Dow Chemical Company	Day & Zimmermann
DuPont	Dresser-Rand Company
Eastman Chemical Company	eProject Management, LLC
ExxonMobil Corporation	Emerson Process Management
GlaxoSmithKline	Fluor Corporation
Hovensa	Foster Wheeler USA Corporation
International Paper	GS Engineering & Construction Corporation
Kaiser Permanente	Grinaker-LTA/E+PC
Eli Lilly and Company	Gross Mechanical Contractors
Marathon Oil Corporation	Hargrove Engineers + Constructors
National Aeronautics & Space Administration	Hilti Corporation

STEP 6: Develop the performance measurement baseline

- CII RS-6-8: Management of Project Risks and Uncertainties, 2010

Naval Facilities Engineering Command
NOVA Chemicals Corporation
Occidental Petroleum Corporation
Ontario Power Generation
Petroleo Brasileiro S/A - Petrobras
Praxair
The Procter & Gamble Company
Progress Energy
SABIC - Saudi Basic Industries Corporation
Sasol Technology
Shell Global Solutions US
Smithsonian Institution
Southern Company
Sunoco
Tennessee Valley Authority
TransCanada Corporation
U.S. Architect of the Capitol
U.S. Army Corps of Engineers
U.S. Department of Commerce/NIST/
Building and Fire Research Laboratory
U.S. Department of Energy
U.S. Department of Health and Human Services
U.S. Department of State
U.S. General Services Administration

JMJ Associates
Jacobs
KBR
Lauren Engineers & Constructors
McDermott International
M. A. Mortenson Company
Mustang
R. J. Mycka
Omniware
Oracle USA
Parsons
Pathfinder
Pegasus Global Holdings
S&B Engineers and Constructors
SNC-Lavalin
The Shaw Group
Siemens Energy
Technip
URS Corporation
Victaulic Company
Walbridge
Wanzek Construction
The Weitz Company
WorleyParsons
Zachry
Zurich

STEP 6: Develop the performance measurement baseline

- **CII RS-6-8: Management of Project Risks and Uncertainties, 2010**
- The **choice** becomes one of managing it as
  1. A **single line** item account or
  2. Somehow **distributing** it to parallel other accounts.

STEP 6: Develop the performance measurement baseline

- **CII RS-6-8: Management of Project Risks and Uncertainties, 2010**
- Managing contingency as a single account has **these disadvantages**:
  1. There will be a **natural tendency** to draw down the account on a **first-come, first-served basis.**
     - This carries with it the **potential for exhaustion** of contingency funds well **before the project is over**.
     - Also, as this is happening, **managers may feel** a project is in **better position** cost-wise than it really is because **early losses are being covered**.
       - ✓ This may **delay initiation** of needed **corrective action**.

STEP 6: Develop the performance measurement baseline

- **CII RS-6-8: Management of Project Risks and Uncertainties, 2010**
- Managing contingency as a single account has **these disadvantages**:

2. There will be a **problem of control**.
   - **Every control account** in a project, risk or otherwise, should be the responsibility of **one individual to manage**.
   - The **only person** that can manage a **project-wide account** is the **project manager.**
     - ✓ Such assignment will add to the **heavy responsibilities** already associated with that function and may **cause contingency account management** to be **neglected**.
     - ✓ If **contingency account control** is **left open**, there will be **no control.**

STEP 6: Develop the performance measurement baseline

- **CII RS-6-8: Management of Project Risks and Uncertainties, 2010**
- **Recommended approach based on CII**
  - Contingency should **not be used** to **cover losses** in accounts **outside the group** for which contingency was established;

    cost performance in these should be reported in terms of **positive or negative variance.**
  - **When losses** in a contingent account **exceed available contingency** for that account,

    a **negative variance** will be **reported** for this account.
    - ✓ If **contingency funds still remain** after the **cost accounts** they protect are **completed**,

      excess is transferred to a **general contingency account**.

STEP 6: Develop the performance measurement baseline

- **CII RS-6-8: Management of Project Risks and Uncertainties, 2010**
- **Recommended approach based on CII**
  - During the **course of a project** the risks should be
    1. **Regularly reviewed** and
    2. Contingency accounts **adjusted**,

    if necessary, to **cover remaining risks**.

How about PMB?

Does it change what we have said so far?

STEP 6: Develop the performance measurement baseline

سلام دکتر جان، عرض ادب
استاد یه سوال دارم اگه امکانش باشه لطف کنید راهنمایی بفرمایید ممنون میشم.
جرایم یا بونوس هایی که پیمانکار از سمت کارفرما مشمول پرداخت یا دریافت اون میشه، میبایست در محاسبه CPI در مدیریت ارزش کسب شده، هم آورده شود؟ مثلا در CPI، جرایم به AC اضافه شود و بونوس ها به EV ?

شرمنده بابت پرسش این سوال، وقتتون گرفته میشه ولی خیلی حیاتی بود نیاز بود از فرد خبره سوال بشه

STEP 7: Execute work plan and record all costs

- **For this step,**

1. **Program personnel** **execute** their **tasks** according to the **performance measurement baseline**.
2. **Actual costs** are **recorded** by the **accounting system** and are **reconciled** with the **value of the work performed** so that effective **performance measurement** can occur.
   - A **job cost ledger** must be **set up before** the work **begins**, to ensure that actual costs can be compared with the associated budgets.
     - ✓ In particular, **accounting for material costs** should be consistent with how the budget **was established**.

STEPS 8-11: EVM analysis

1. Analyze performance:

- check data to see if they are valid,
- determine what variances exist,
- probe schedule variances to see if activities are on the critical path,
- develop historical performance data indexes,
- graph the data to identify any trends,
- review the variance analysis for explanations and corrective actions.

2. Project future performance:

- identify the work that remains,
- calculate a range of EACs and compare the results to available funding,
- determine if the contractor’s EAC is feasible, and
- calculate an independent date for program completion.

STEPS 8-11: Analyze performance

Check to see if the data are valid

- To determine if the data are valid, they should be **checked at levels of the WBS**, focusing on whether there are errors or data anomalies such as
  - negative values for ACWP, BAC, BCWP, BCWS, or EAC;
  - unusually large performance swings (BCWP) from month to month;
  - BCWP and BCWS data with no corresponding ACWP;
  - BCWP with no BCWS;
  - BCWP with no ACWP;
  - ACWP with no BCWP;
  - ACWP that is way above or below the planned value;
  - inconsistency between EAC and BAC—for example, no BAC but an EAC or a BAC with no EAC;
  - ACWP exceeds EAC;
  - BCWP or BCWS exceed BAC.

STEPS 8-11: Analyze performance

- **Determine what variances exist**
  - **Cost and schedule deviations** from the baseline plan give management about where **corrective actions** are needed to
    1. Bring the program back on track
    2. Update completion dates and EACs

STEPS 8-11: Analyze performance

- **Probe schedule variances for activities on the critical path**
  - **Schedule variances** should be investigated to see if the **effort** is on the **critical path**.
  - If it is, then the **whole program** will be **delayed**.
    - ✓ Any **delay** in the program usually **will result in additional cost** .
    - ✓ The **following methods** are often used to **mitigate schedule problems**:
    - ■■ consuming schedule reserve if it is available,
    - ■■ diverting staff to work on other tasks while dealing with unforeseen delays,
    - ■■ preparing for follow-on activities early so that transition time can be reduced,
    - ■■ consulting with experts to see if process improvements can reduce task time,
    - ■■ adding more people to speed up the effort, and
    - ■■ working overtime.

STEPS 8-11: Analyze performance

- **Develop historical performance data indexes**
  - **Performance indexes** are necessary for understanding the effect a **cost or schedule variance** has on a program.
    - The **cost performance index (CPI)** and **schedule performance index (SPI)** in particular can be used
      1. Independently
      2. Together

      to **forecast** a range of **statistical cost estimates** at **completion**.
    - They also give managers **early warning** of **potential problems** that need **correcting** to avoid adverse results.

Let's see how to calculate the indexes!

STEPS 8-11: Analyze performance – How to measure ACWP?

- The **ACWP** comes from the **accounting system** and **job cost ledger** and represents the **actual costs spent** on the project work up to a **specific date**.

- **When determining the ACWP**, the cost for work that **has not been performed**— such as **materials** whose costs are **included** in the **accounting reports** **but** **have not been incorporated into the project**—

  should not be **included** in the costs.

  Unless they separated as an activity!

  Job cost ledger would be helpful in this case!

STEPS 8-11: Analyze performance – Purchase of inventory

- A company **purchases materials and places them in inventory until it is ready to use them**.
  - **When** the materials are **received** they are **recorded** as an **asset in the inventory** category.
    - ✓ Purchased by **cash (reduce asset)** or **credit (increase accounts payable-trade)**
    - ✓ **Equity not reduced** because material is **still in inventory** and **not used**

BALANCE SHEET			INCOME STATEMENT		JOB COST
ASSETS	LIABILITIES		EXPENSES	REVENUES	EXPENSES
130 Inventory 5,000.00	310 Accounts Payable - Trade 5,000.00				
	EQUITY		PROFIT		
	430 Current Period Net Income 0	=	0		
5,000.00 =	5,000.00		0 =	0	

STEPS 8-11: Analyze performance – How to measure ACWP?

- Additionally, **care** must be taken to ensure that **costs for all of the completed work** are **included** in the **actual costs.**
  - Often **subcontractors may bill only once a month**.
    - If the **actual costs** are measured **between subcontractor's bills**, **work** has been **completed** by the **subcontractor** for which the **company** does **not have costs**.

*It is important that the **costs** are **up-to-date** for the management to accurately determine the **CPI**.*

Job cost ledger would not help if the bill has not been recorded!

Interim bill needed.

STEPS 8-11: Analyze performance – How to measure BCWS?

- The BCWS comes from the **cost-loaded schedule** and is the **budgeted** or **estimated cost** for **each of the tasks in the schedule** that:
  1. Should have been **completed** as of the **date selected**, or
  2. Should have been **partially completed** as of the **date selected**
     - ✓ For **partially completed tasks**, the budgeted cost is determined by
       - ***Budgeted cost*** *of the task × task's* ***scheduled percentage of completion***.
       - Task of installing doors has a budget of **$5,000** and is **scheduled** to be **20% complete today**, then the **BCWS** for the task is **$1,000 ($5,000 × 0.20)**.

- It is important to note that the costs used here are **budgeted costs**, **not actual costs**.

STEPS 8-11: Analyze performance – How to measure BCWP?

- The **BCWP** is determined by taking the **budget cost** from the **cost-loaded schedule** for **each of the activities** on the schedule and **multiplying** them by **their percentage of completion** as of the date selected.
  - ***Budgeted cost*** *of the task × task's* ***completion percentage***
  - For example, if the task of installing doors has a budget of **$5,000** and is **30%** complete **to date**, then the BCWP for the task is **$1,500** ($5,000 × 0.30).
    - *Again, it is important to note that the costs used here are* ***budgeted costs****,* ***not actual costs****.*

Before we can calculate the SPI and the CPI, we must know how to prepare a cost-loaded schedule.

STEPS 8-11: Analyze performance – Cost – loaded schedule

- A **cost-loaded schedule** is a schedule that **shows**:
  - **Time frame** when a task is to be completed
  - **Cost of the work** so that the cost of the work completed **each week** or **month** **can** be **estimated**.

- A **cost-loaded schedule** is **prepared** by:
  1. First **preparing** a **schedule** for the project
  2. Then **assigning** **dollar estimates** to each of the tasks
  3. The costs for each task are **spread out** **over the duration** of the task, resulting in a **daily**, **weekly**, or **monthly** cost for each of the tasks.
  4. The **total cost** of the work performed for each week or month may be obtained by **adding up** the weekly or monthly costs for each of the **individual tasks**.

- **Scheduling packages**, such as **Microsoft Project**, **spread** the costs **equally** over the duration of the task.
- The **choice to use** days, weeks, or months **depends** on how **often we want to monitor** the project.

STEPS 8-11: Analyze performance – Cost – loaded schedule

Example: Determine the estimated cost of the each week given the tasks—with their associated costs and schedules—shown in Table.

❖ **Remember** when a task spans **more than one week**, the costs should be **divided equally among the weeks**.

Task	Cost ($)	Week Start	Week Finish
Mobilization	2,000	1	1
Grubbing	5,000	1	1
Bridge Excavation	2,000	2	2
Install Prefabricated Bridge	47,000	2	2
Backfill Bridge	2,000	2	2
Install Culverts	10,000	3	3
Rough Excavate Roadway	112,000	3	6
Install Sanitary Sewer	57,000	6	7
Install Water Lines	69,000	7	8
Install Storm Drains	15,000	8	8
Grade and Roll Sub Grade	12,000	8	9
Place and Compact Road Base	42,000	9	9
Place and Compact Asphalt	48,000	9	9
Grade Shoulders	3,000	10	10
Clean Up	1,000	10	10
Demobilize	2,000	10	10

STEPS 8-11: Analyze performance – Cost – loaded schedule

- **BCWS** calculated as follows.
- **A cost-loaded schedule** may be developed in a scheduling software package such as **Microsoft Project.**
- **A cost-loaded schedule** may also be developed in **Microsoft Excel.**

Cost-Loaded Schedule for Example

Week	Cost ($)	Week	Cost ($)
1	7,000	6	56,500
2	51,000	7	63,000
3	38,000	8	55,500
4	28,000	9	96,000
5	28,000	10	6,000

Cost-Loaded for Example

Task	Cost	Start	Finish	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Mobilization	2,000	Week 1	Week 1	2,000									
Grubbing	5,000	Week 1	Week 1	5,000									
Bridge Excavation	2,000	Week 2	Week 2		2,000								
Install Prefabricated Bridge	47,000	Week 2	Week 2		47,000								
Back Fill Bridge	2,000	Week 2	Week 2		2,000								
Install Culverts	10,000	Week 3	Week 3			10,000							
Rough Excavate Roadway	112,000	Week 3	Week 6			28,000	28,000	28,000	28,000				
Install Sanitary Sewer	57,000	Week 6	Week 7						28,500	28,500			
Install Water Lines	69,000	Week 7	Week 8							34,500	34,500		
Install Storm Drains	15,000	Week 8	Week 8								15,000		
Grade and Roll Sub Grade	12,000	Week 8	Week 9								6,000	6,000	
Place and Compact Road Base	42,000	Week 9	Week 9									42,000	
Place and Compact Asphalt	48,000	Week 9	Week 9									48,000	
Grade Shoulders	3,000	Week 10	Week 10										3,000
Clean Up	1,000	Week 10	Week 10										1,000
Demobilize	2,000	Week 10	Week 10										2,000
	429,000			7,000	51,000	38,000	28,000	28,000	56,500	63,000	55,500	96,000	6,000

ACEMI

STEPS 8-11: Analyze performance – Monthly program assessment using earned value

❑ What is the importance of resource allocation?

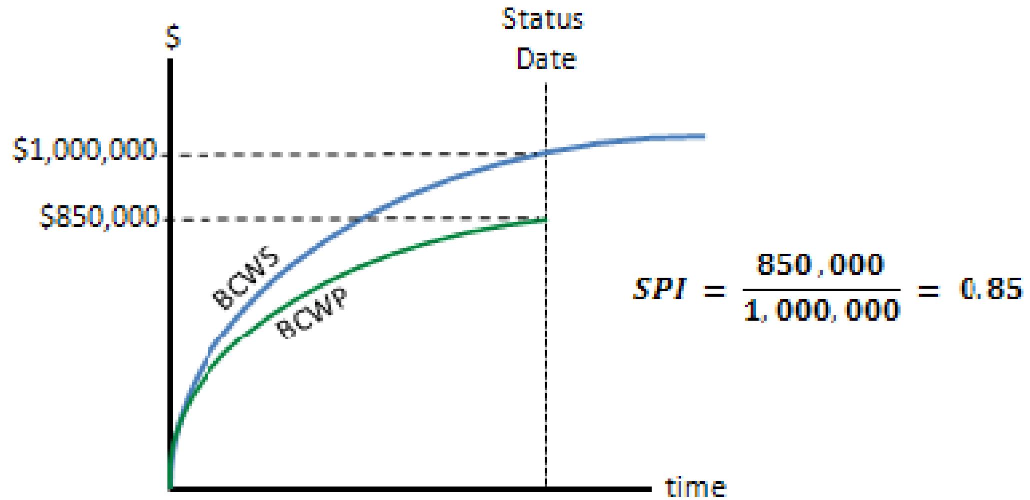
Task description	J	F	M	A	M	J	J	A	S	O	N	D	Budgeted	% Complete	Earned
Concrete	3,000	5,000	2,000										$10,000	100%	$10,000
Framing		5,000	10,000	5,000									20,000	60	12,000
Roofing			1,000	8,000	6,000								15,000	30	5,000
Electrical					10,000	15,000	15,000						40,000		
Plumbing							6,000	12,000	12,000	5,000			35,000		
Interior										8,000	12,000	15,000	35,000		
Monthly budget	$3,000	$10,000	$13,000	$13,000	$16,000	$15,000	$21,000	$12,000	$12,000	$13,000	$12,000	$15,000			
Cum budget (PMB)	3,000	13,000	26,000	39,000	55,000	70,000	91,000	103,000	115,000	128,000	140,000	155,000			
Earned value (BCWP)	1,000	5,000	15,000	27,000											$27,000
Actual cost (ACWP)	2,000	7,000	19,000	33,000											

Source: Naval Air Systems Command (NAVAIR).

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

- **Schedule performance index (SPI)**

$$SPI = \frac{BCWP}{BCWS}$$



We have taught SPI(t) in <u>advanced level</u> of planning and scheduling!

https://dralavipour.com/applied-tutorials/show/web23

ACEMI

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

Schedule performance index (SPI)

SPI Value	Implication
> 1.00	**FAVORABLE** - The effort on average is being accomplished at a faster rate than planned
= 1.00	**ON TRACK** - The effort on average is performing to plan
< 1.00	**UNFAVORABLE** - The effort on average is being accomplished at a slower rate than planned

SPI Value	Implication
> 1.05	**BLUE** ("too good?") - Exceptional performance, but can also indicate a higher likelihood of poor planning (overly-conservative) and/or poor prioritization ("cherry-picking")
1.00 - 1.05	**GREEN** ("on track) - On average, the effort is progressing on or slightly ahead of plan
0.95 - 0.99	**YELLOW** ("caution") - On average, the effort is progressing slightly behind the plan
< 0.95	**RED** ("warning") - Indication of poor execution and/or poor planning (overly-aggressive)

Is SPI always a good indicator of schedule performance?

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

Strength of SPI?

- Using SPI does **not allow noncritical tasks** to be **ignored**.
  - Because it **takes all tasks with costs into account**, **not only** the tasks on **critical path.**

Weakness of SPI?

- It is possible to have an **SPI greater than one** while being **behind on the critical path.**
- It **ignores tasks** that have a **budgeted cost of zero** (e.g., tasks dealing with **submittals** and the **ordering of materials**)

Because of these reasons the SPI should be used in conjunction with the critical path to determine the success of a project's management team to complete the work on time.

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

Schedule performance index (SPI)

You should be careful about this limitation!

Caveats/Limitations/Notes

Due to the inherent nature of the SPI formula, no matter how early or late a program completes, SPI calculations will eventually equal 1.00, as shown in Figure 2. Because of this, over the final third of a project, the utility of SPI degrades, rendering SPI less and less effective as a management tool.

SPI is based on average schedule performance across the entire project to date. This can create a misleading perception of project performance if non-critical future tasks are being "cherry picked" to bolster BCWP. So, for example, if performance along the critical path has been significantly worse than schedule progress on the whole, SPI will be skewed upward and thus may not fully convey the magnitude of the schedule performance deficiencies.

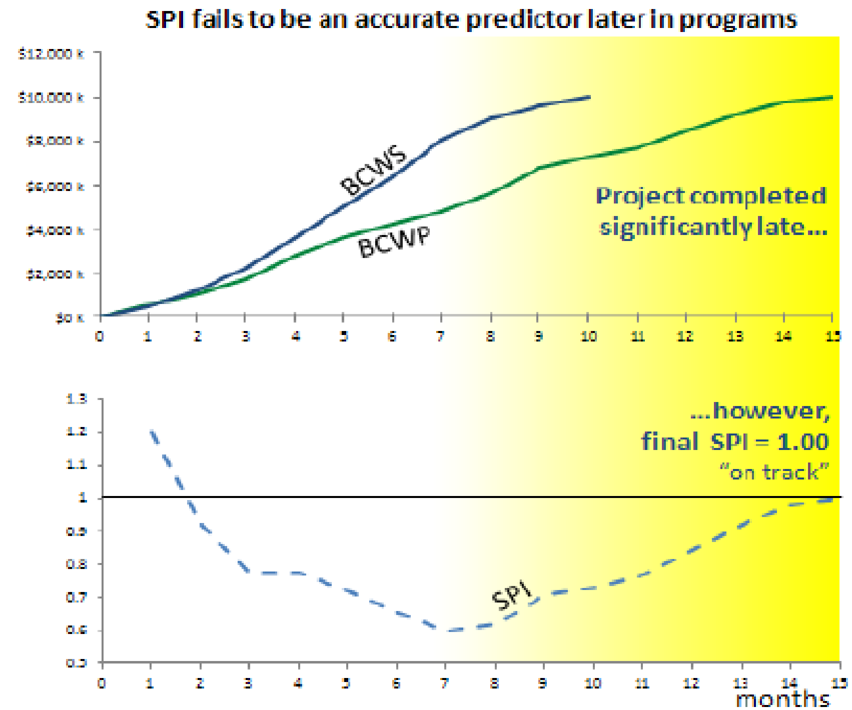


Figure 2. SPI Limitations

SPI is susceptible to being dampened by LOE. As the percentage of LOE on a project increases, the metric's results are pushed toward 1.0. To mitigate this issue, SPI can be calculated using BCWS and BCWP for discrete effort only.

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

- **Schedule performance index (SPI)**
  - **SPI** should be used **in conjunction** with
    1. Sound critical path analysis
    2. Schedule risk assessments, and

    never as a stand-alone indicator of the health of a program.
  - **Other metrics** such as **BEI** can be calculated as often as **the status of the IMS** is **assessed**,

    which is **commonly more frequent** than the **project's EV cycle.**

STEPS 8-11: Analyze performance – Schedule performance index (SPI)

Example: A project consists of three tasks. Task A is scheduled to begin at the start of Week 1 and finish at the end of Week 2. Task B is scheduled to begin at the start of Week 1 and finish at the end of Week 1. Task C is scheduled to begin at the start of Week 2 and end at the end of Week 2. The budgeted cost for Task A is $3,000, for Task B is $1,000, and for Task C is $500. At the end of the first week Task A is 45% complete, Task B is 100% complete, and Task C is 10% complete. What is the SPI for the project at the end of the first week?

BCWS = $1,500 + $1,000 + $0 = $2,500

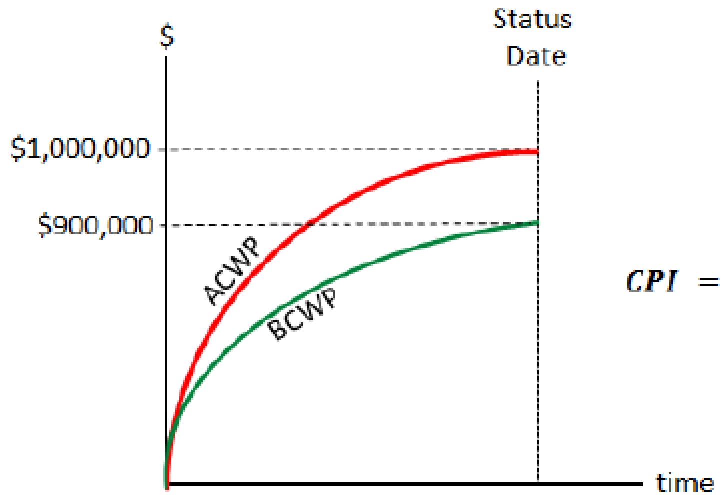
BCWP = $3,000(0.45) + $1,000(1.00) + $500(0.10) = $2,400

SPI = $2,400 / $2,500 = 0.96

STEPS 8-11: Analyze performance – Cost performance index (CPI)

- Cost performance index (CPI)

$$CPI = \frac{BCWP}{ACWP}$$



$$CPI = \frac{900,000}{1,000,000} = 0.90$$

STEPS 8-11: Analyze performance – Cost performance index (CPI)

Cost performance index (CPI)

- **Budgeted Cost for Work Performed (BCWP)**
  - The value of completed work expressed as the value of the performance budget assigned to that work. This is equal to the sum of the budgets for completed work packages and the completed portions of open work packages.
  - Typically represent cumulative to-date values unless some other time period is specified.
  - Also referred to as the EV.
- **Actual Cost of Work Performed (ACWP)**
  - The sum of the actual costs incurred for all work performed with a given time period. This includes the actual costs for completed work packages, as well as the cost to perform the completed portions of open work packages.
  - Typically represent cumulative to-date values unless some other time period is specified.
  - Also referred to as the AC.

STEPS 8-11: Analyze performance – Cost performance index (CPI)

Cost performance index (CPI)

CPI Value	Implication
> 1.00	FAVORABLE - The effort on average is being accomplished more efficiently than planned
= 1.00	ON TRACK - The effort on average is being accomplished at the planned efficiency
< 1.00	UNFAVORABLE - The effort on average is being accomplished less efficiently than planned

CPI Value	Implication
> 1.05	BLUE ("too good?") - Exceptional efficiency and/or poor planning ("padded" budgets)
1.00 - 1.05	GREEN ("on track) - On average, the effort is being accomplished at or slightly ahead of the planned efficiency
0.95 - 0.99	YELLOW ("caution") - On average, the effort is being accomplished slightly less efficiently than planed
< 0.95	RED ("warning") - Indication of poor efficiency and/or poor planning (overly "challenged" budgets)

STEPS 8-11: Analyze performance – Cost performance index (CPI)

Weakness of CPI?

- It **cannot** be calculated **until all the costs** for a specific period have been entered **into the accounting system**
  - ✓ Because some **bills are submitted or approved late**, it is hard to get the **ACWP current to a specific date.**
  - ✓ Because **suppliers** and **subcontractors** often **submit their bills only once a month**,

CPI can <u>only</u> be calculated <u>monthly</u>, **limiting** its use as a **<u>cost control tool</u>**.

STEPS 8-11: Analyze performance – Cost performance index (CPI)

So how to solve?

Ask suppliers and subcontractors to submit their bills more frequently.

STEPS 8-11: Analyze performance – Cost performance index (CPI)

Example: The ACWP at the end of the first week for the project in previous Example is $2,350. Determine the CPI for the project.

CPI = BCWP / ACWP

CPI = $2,400 / $2,350 = 1.02

STEPS 8-11: Analyze performance – Cost performance index (CPI)

Tabulation of CPI vs. SPI by Discipline

	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall Average per Discipline
Road Pavement Works	SPI	1.004	1.000	1.000	0.993	0.980	1.006	1.012	1.045	1.039	1.062	1.018	0.962	1.013
	CPI	1.010	0.995	0.989	1.025	1.020	1.028	1.045	0.991	1.010	0.992	0.986	0.976	1.006
Drainage Works	SPI	1.010	1.025	1.026	1.000	0.995	0.985	1.018	0.990	1.065	1.073	1.025	0.983	1.016
	CPI	1.000	1.030	1.050	1.040	1.036	1.034	1.049	1.058	1.036	0.933	0.976	0.950	1.016
Earthworks	SPI	0.995	1.030	1.056	1.050	0.978	0.970	1.009	1.099	0.993	1.050	1.038	0.994	1.022
	CPI	1.005	1.021	1.002	1.035	1.010	1.055	1.070	1.075	0.992	0.994	0.981	0.997	1.020
Bridges and Structures	SPI	1.020	1.025	1.029	1.036	0.985	0.960	1.039	1.065	1.082	1.055	1.039	0.999	1.028
	CPI	1.005	1.015	1.000	1.039	1.014	1.082	1.055	1.017	1.000	0.999	0.996	0.998	1.018
Utilities (Lighting, Services, Barriers, etc.)	SPI	1.021	1.021	1.036	1.029	0.989	0.981	1.021	1.052	1.046	1.061	1.031	0.987	1.023
	CPI	1.004	1.015	1.007	1.034	1.021	1.051	1.058	1.034	1.014	0.982	0.986	0.978	1.015

Tabulation of Averaged CPI vs. SPI

	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall Average
Overall	SPI	1.010	1.020	1.035	1.020	0.985	0.980	1.020	1.050	1.045	1.060	1.030	0.985	1.020
	CPI	1.005	1.015	1.010	1.035	1.020	1.050	1.055	1.035	1.010	0.980	0.985	0.980	1.015

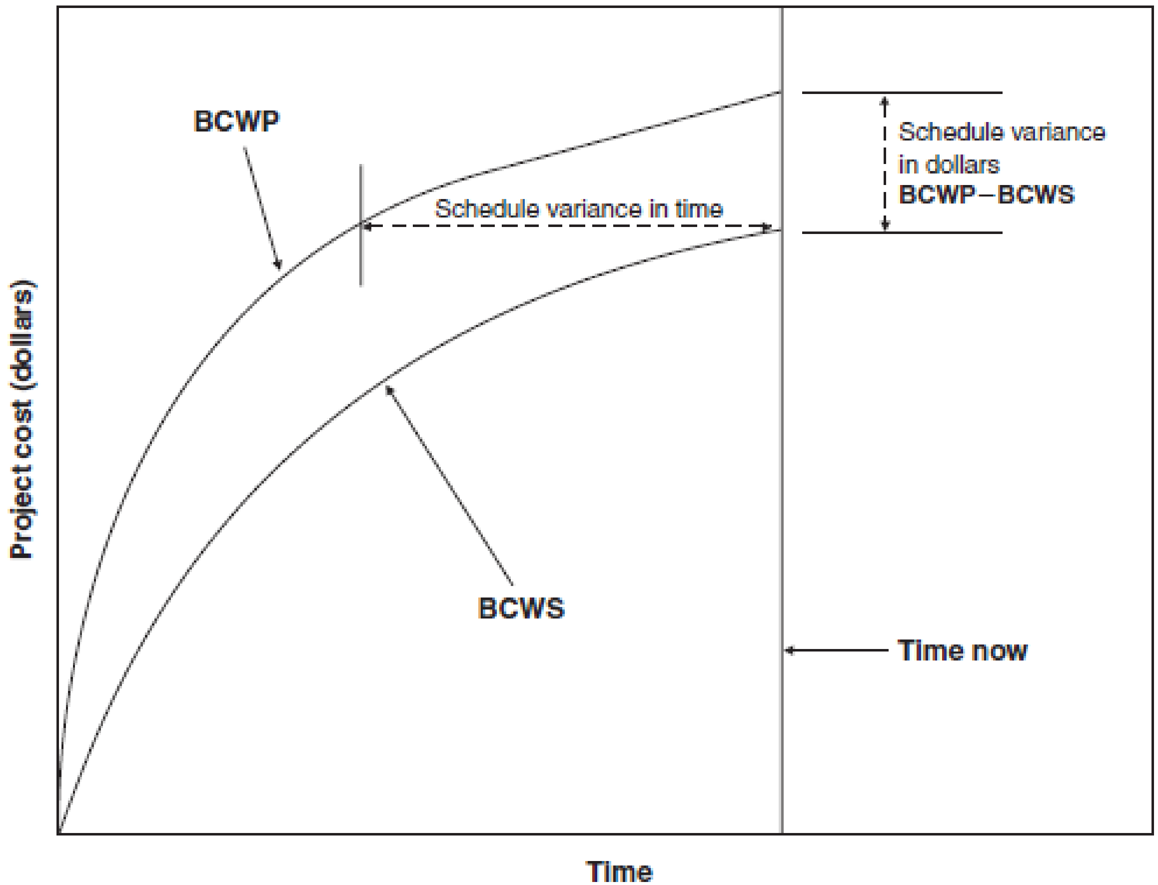
STEPS 8-11: Analyze performance – Schedule variance (SV) and cost variance (CV)

- **Schedule variance (SV)** is calculated as a **currency value <u>rather</u>** than as a **division of time**.
  - ***SV = BCWP – BCWS***
    - If SV > 0, you are ahead of schedule.
    - If SV < 0, you are behind schedule.
    - If SV = 0, you are on schedule.

- **Cost variance (CV)** is calculated using:
  - ***CV = BCWP – ACWP***
    - If CV > 0, you are under budget.
    - If CV < 0, you are over budget.
    - If CV = 0, you are on budget.

STEPS 8-11: Analyze performance – Schedule variance (SV) and cost variance (CV)

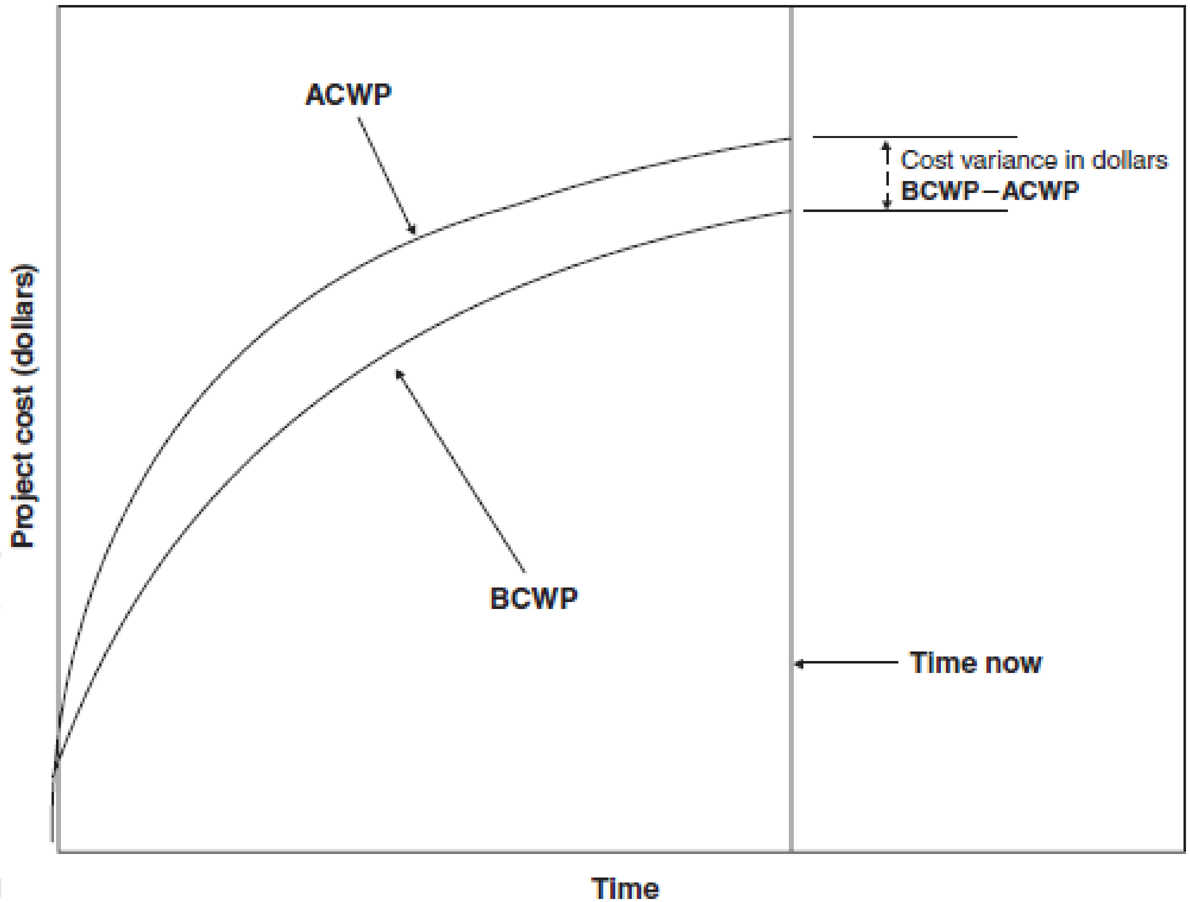
❑ Schedule variance (SV)



Earned Value Analysis Showing a Project that Is Ahead of Schedule.

STEPS 8-11: Analyze performance – Schedule variance (SV) and cost variance (CV)

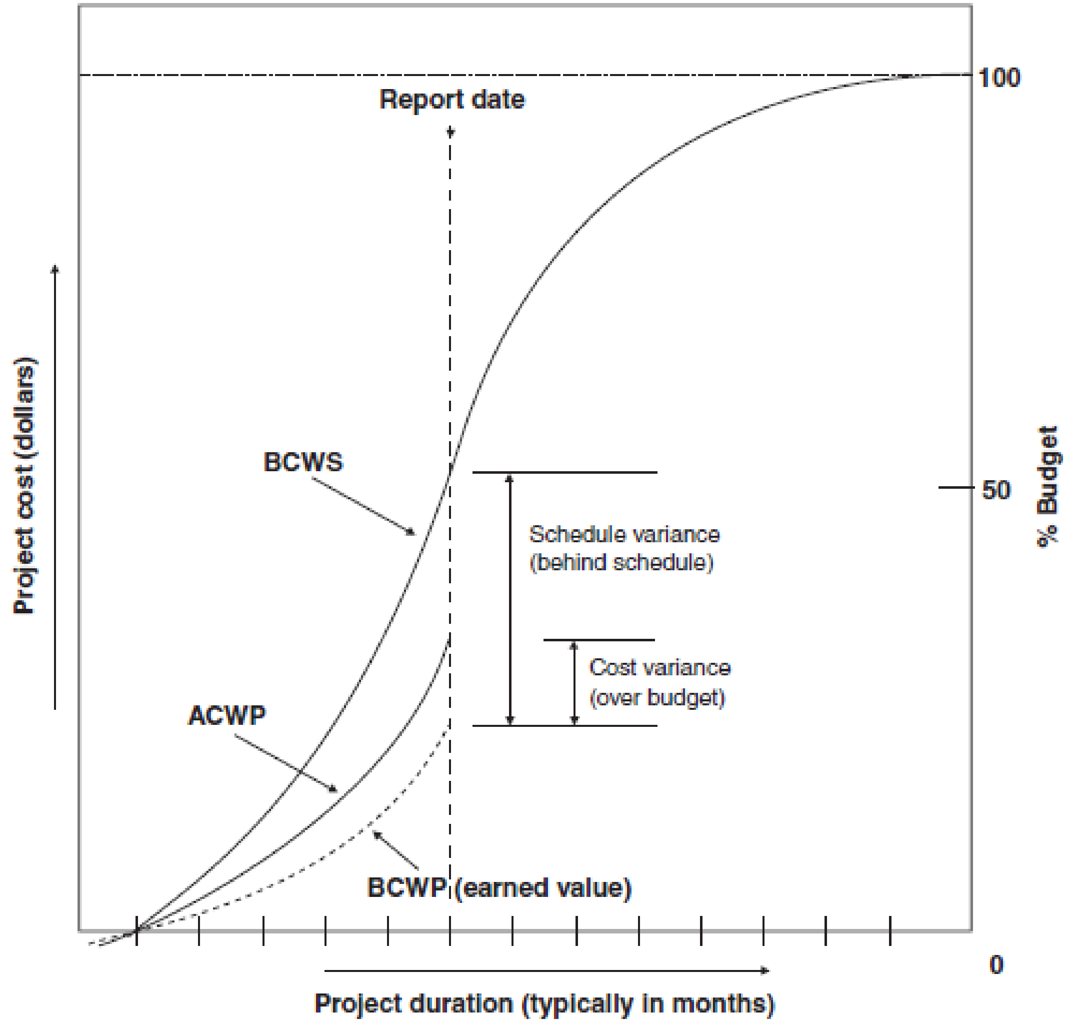
❑ Cost variance (CV)



Earned Value Analysis Showing a Project that Is Over Budget.

STEPS 8-11: Analyze performance – Schedule variance (SV) and cost variance (CV)

❑ Integrating cost and schedule



General Concepts of Earned Value Analysis.

STEPS 8-11: Analyze performance – Schedule variance (SV) and cost variance (CV)

Understanding program performance growth by plotting cost and schedule variance

Source: GAO.

Note: The trend examples , shown for learning purposes, are drawn from GAO, *Uncertainties Remain Concerning the Airborne Laser's Cost and Military Utility*, GAO-04-643R (Washington, D.C.: May 17, 2004), pp. 17–20.

STEPS 8-11: Analyze performance – Schedule and cost performance

Holm

Earned value performance matrix

Schedule Status:		Ahead of Schedule	On Schedule	Behind Schedule
Cost Status:	Under Budget	1	2	3
	On Budget	4	5	6
	Over Budget	7	8	9

STEPS 8-11: Analyze performance – Schedule and cost performance

Holm

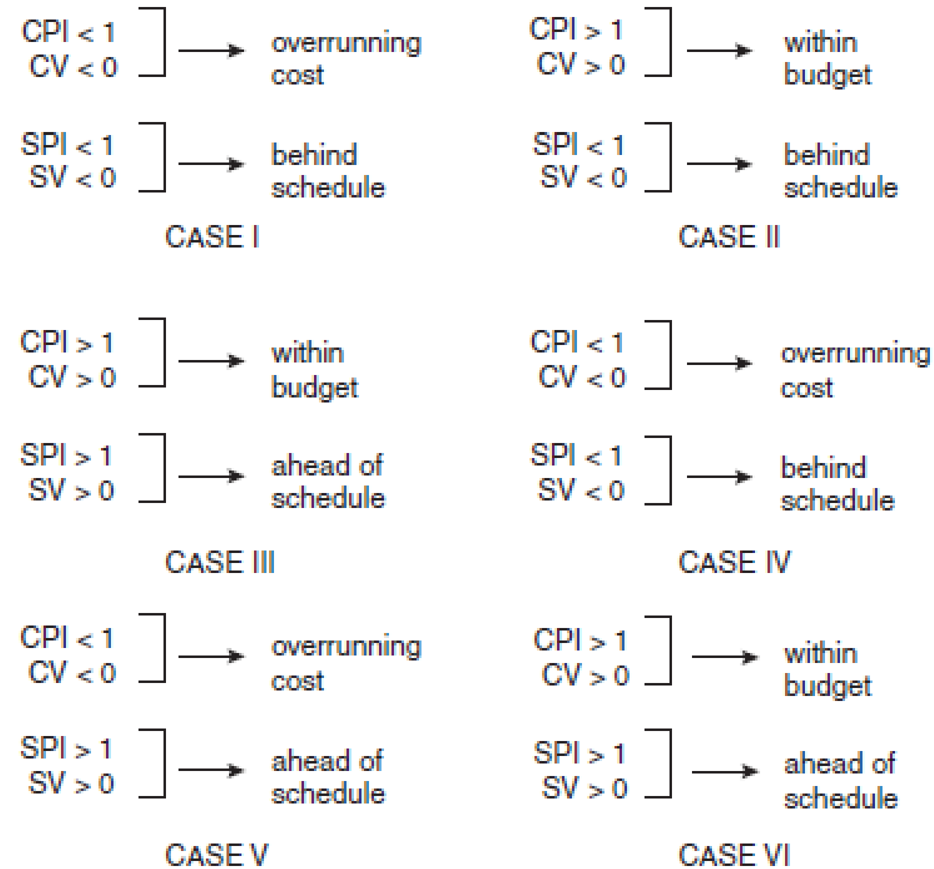


Figure 5.16 Values of CPI, CV, and SPI, SV for the six scenarios (Singh, 1991). Reprinted with the permission of AACE International, 209 Prairie Ave., Suite 100, Morgantown, WV 25601 USA. Phone 800-858-COST/304-296-8444. Fax: 304-291-5728. Internet: http://www.aacei.org. E-mail: info@aacei.org. Copyright © by AACE International; all rights reserved.

STEPS 8-11: Analyze performance – Schedule and cost performance

What if we calculate based on hours and why?

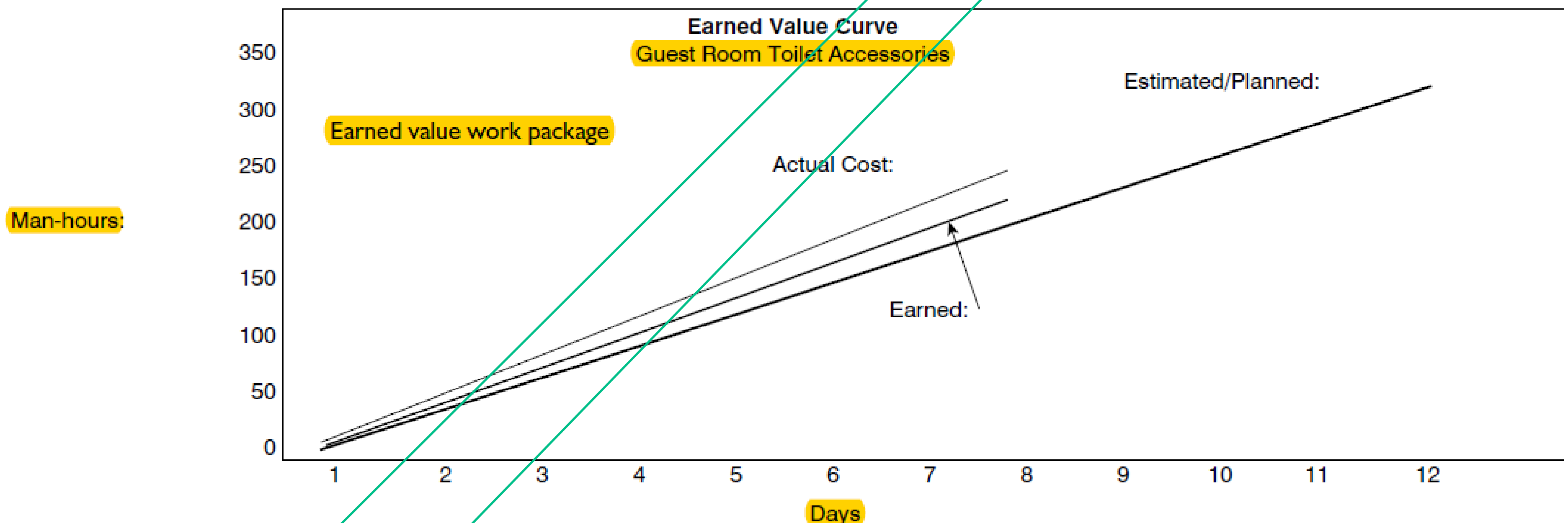
STEPS 8-11: Analyze performance – Schedule and cost performance

Holm

Earned value (EV), also known as earned value management or earned value analysis, is one technique used by some contractors to determine the estimated value of the work completed to date (or earned value) and compare it with the actual cost of the work completed. The most effective use of EV to a general contractor's (GC's) jobsite financial management team is to track direct labor, which represents the construction contractor's greatest cost risk. Man-hours (MHs) and not labor cost is best used for monitoring direct labor as every project and every crew will have a different mix of apprentices, journeymen, and foremen and associated wage rates.

STEPS 8-11: Analyze performance – Schedule and cost performance

Work Days:	1	2	3	4	5	6	7	8	9	10	11	12	Totals
Estimated Hours/Day	16	16	24	24	30	30	30	30	30	32	32	31	
Cumulative Hours	16	32	56	80	110	140	170	200	**230**	262	294	325	325
Actual Hours/Day	16	24	32	32	32	34	40	40					
Cumulative Hours	16	40	72	104	136	170	210	**250**					250
Earned Hours/Day	16	24	30	32	32	32	32	32					
Cumulative Hours	16	40	70	102	134	166	198	**230**					230

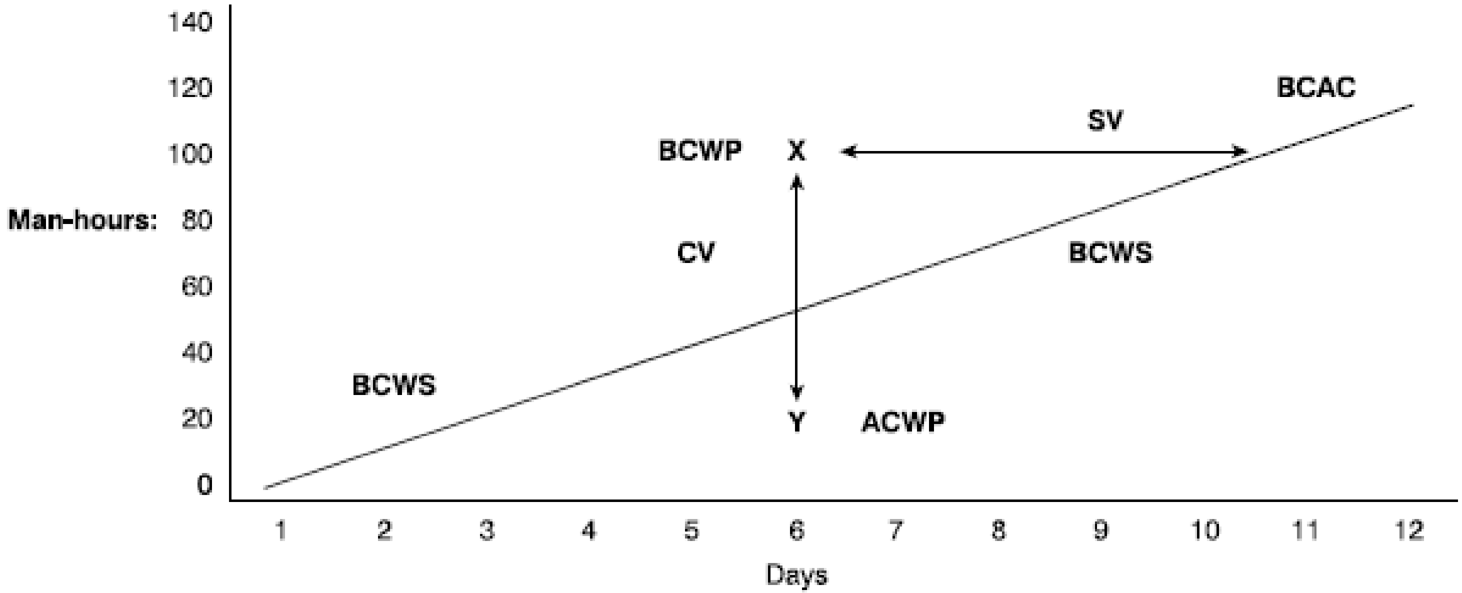


Simple Analysis:

Cost: On day eight, the foreman had spent 250 hours, but earned 230, therefore he was 20 hours over budget. This is the vertical measurement between the actual and earned curves.

Schedule: On day eight, the foreman had earned 230 hours but was not scheduled to have done so until approximately day nine, therefore he is approximately one day ahead of schedule. This is the horizontal measurement.

STEPS 8-11: Analyze performance – Schedule and cost performance

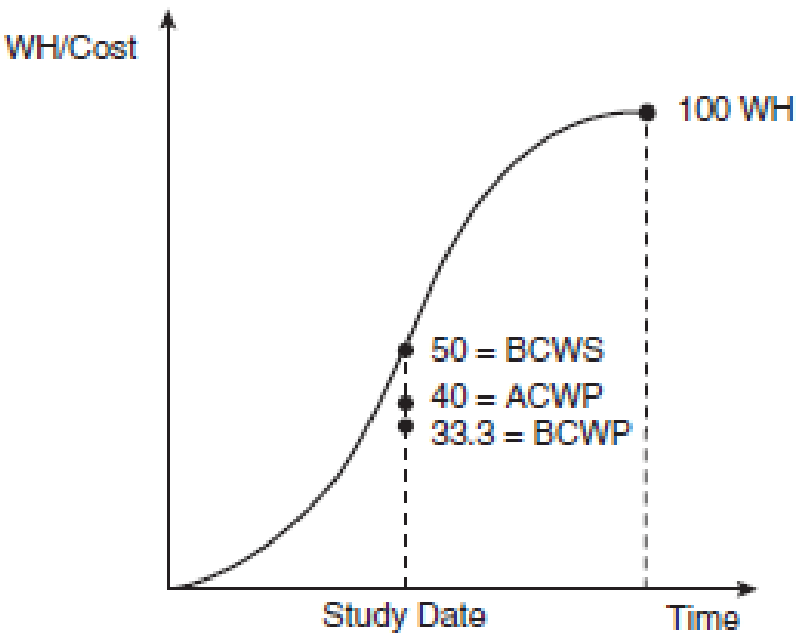


Earned value indices curve

Answering the questions of, "are we over or under budget and by how much and are we ahead or behind schedule and by how much?" can now be accomplished mathematically using these indices. The CPI for Figure 9.1 would be 230/250 = 0.92, which is less than one, and therefore over budget. Solving for CV is 230–250 = <20> which is less than zero and also over budget. The SPI for Figure 9.1 would be 230/200 = 1.15, greater than one, therefore ahead of schedule. SV also reflects ahead of schedule as 230–200 = +30 which is greater than zero. This confirms the approach that was used earlier, when we simply just compared horizontal and vertical differences between the three curves.

STEPS 8-11: Analyze performance – Schedule and cost performance

Halpin



$$CV = BCWP - ACWP = -6.7$$

$$CPI = \frac{BCWP}{ACWP} = \frac{33.3}{40} < 1.0$$

Over Budget

$$SV = BCWP - BCWS = -16.7$$

$$SPI = \frac{BCWP}{BCWS} = \frac{33.3}{50} < 1.0$$

Behind Schedule

STEPS 8-11: Analyze performance – Schedule and cost performance

How about material?

STEPS 8-11: Analyze performance – Schedule and cost performance

Material quantities can be used in lieu of hours or dollars with earned value analysis as well. The letter Q is inserted instead of C in the earlier acronyms, which reflects measurements of quantities scheduled and installed. These acronyms are presented in the following list. Quantity measurements may be based upon percent scheduled and completed. If there are 1,000 cubic yards (CY) of concrete estimated at an assembly unit price of $500/CY for a total of $500,000 and 300 yards of concrete are in place, then 30% (300/1,000) of the estimated $500,000, or $150,000, has been earned. The alternative is to track exactly how much concrete had been placed. This is sometimes done with a concrete log or by counting concrete trucks and multiplying their load size, such as 40 trucks times 9 CY per truck indicates 360 CY of concrete has been delivered and placed. Due to waste and spillage, this quantity of concrete may be slightly greater than the quantity reflected in the formwork.

- AQWP: Actual quantity of the work performed,
- BQAC: Budgeted quantity of the work at completion,
- BQWP: Budgeted quantity of the work performed, and
- BQWS: Budgeted quantity of the work scheduled.

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

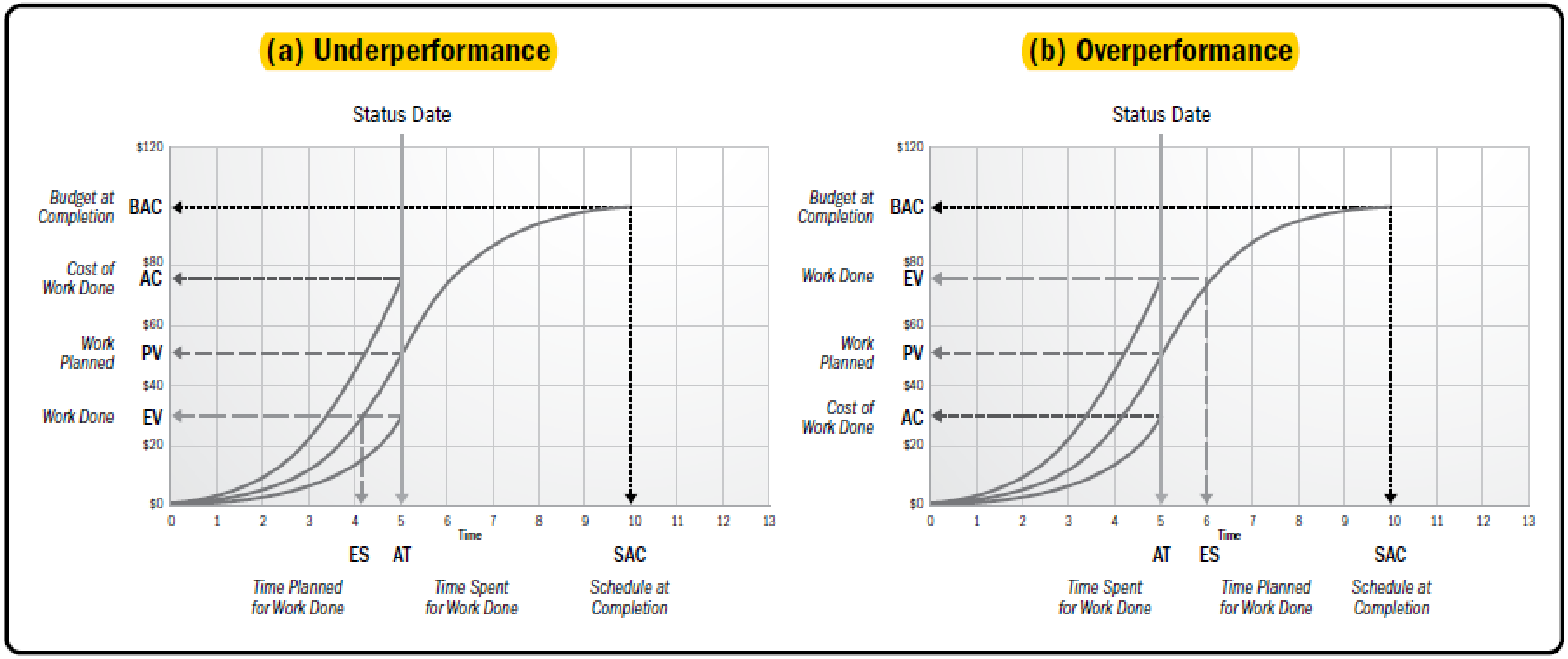


Figure 4-2. Graphical View of the EVM Performance Data Points

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

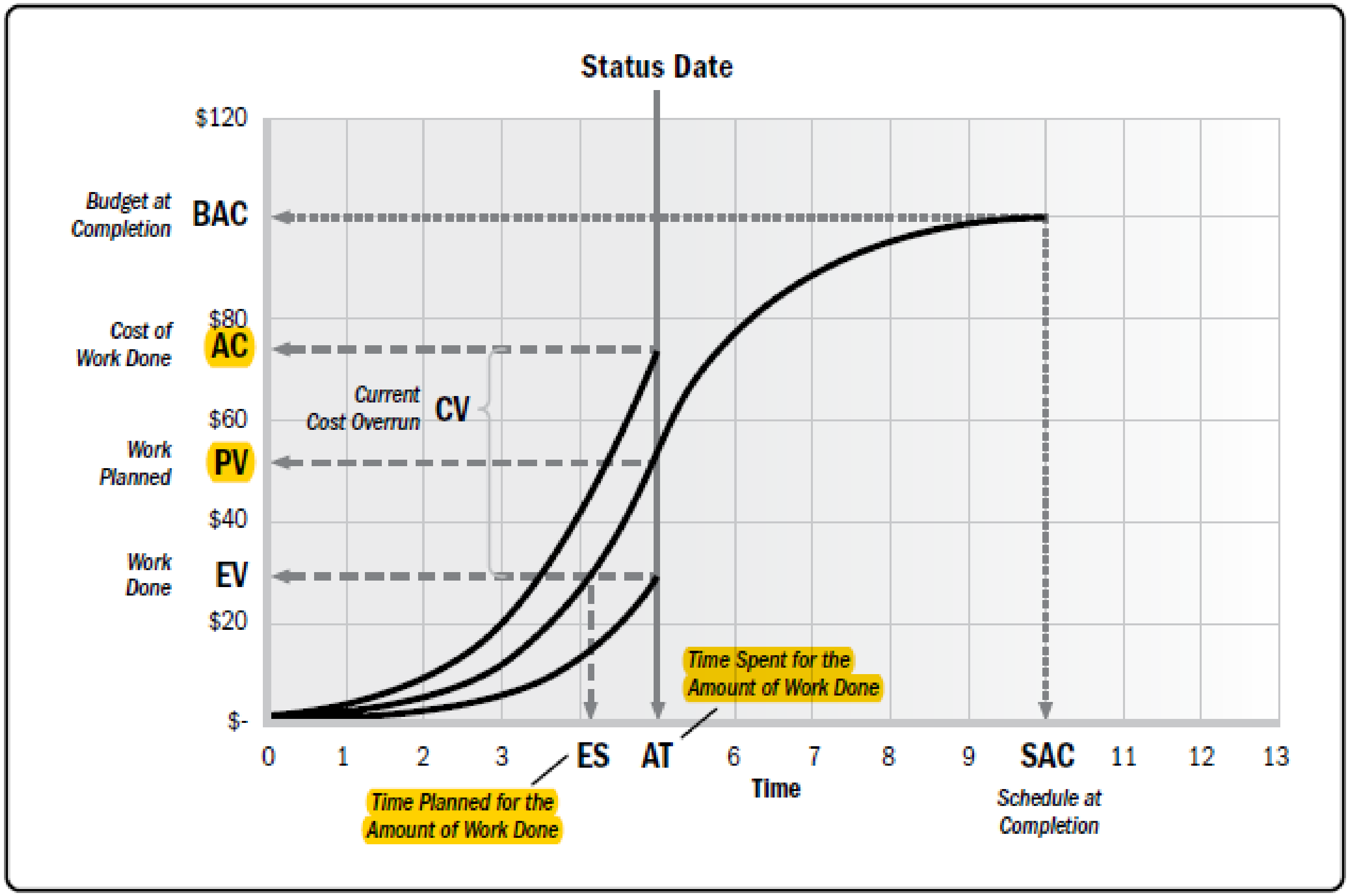


Figure 4-3. Graphical View of the EVM Cost Variance (CV) Metric

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

- **Schedule variance expressed in volume (SV_w).** When expressed in volume, SV_w is a measure of *work volume variance*. It measures the deficit or the abundance of work accomplishment over time.

  The equation used to express schedule variance as of the date of examination is:

  $SV_w = EV - PV$

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

- **Schedule variance expressed in time (SV_t).** When expressed in time, SV_t is a measure of time variance. It measures the excess, or the savings of time, consumed with the work accomplished. It is based on the concept of ES.

EVM includes the concept of ES where time is used for measuring schedule variance and performance, instead of using work. Most EVMS use the concept of work volume to measure time performance, as previously described by measuring SV in the budget (Y) axis. Schedule variance can also be measured in the time (X) axis by considering the difference between the time already spent with the amount of work accomplished, and the time (according to the baseline) that was expected to be spent to accomplish the same amount of work (but not necessarily that same work). In this approach, SV_t is a measure of time variance.

The equation used to express schedule variance in this way as of the date of examination is:

$$SV_t = ES - AT$$

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

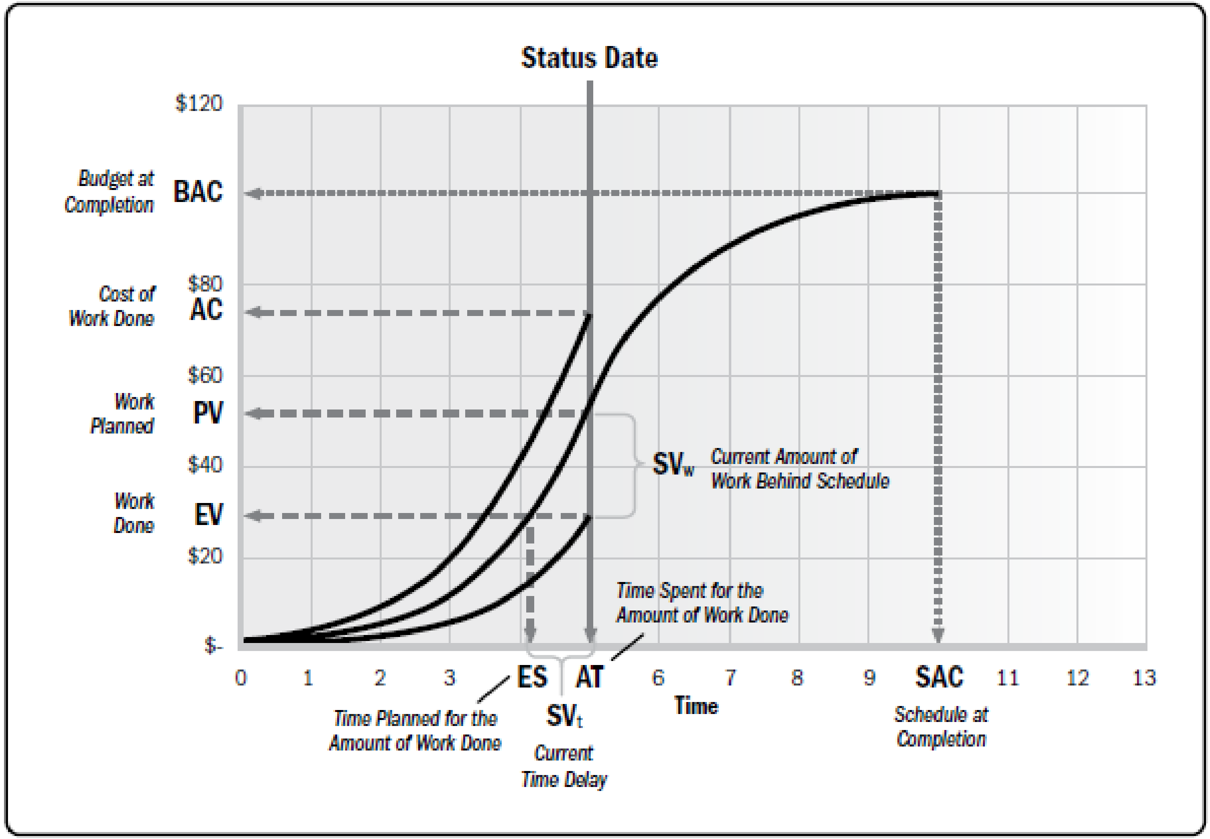


Figure 4-4. Graphical View of the EVM Schedule Variance Metrics

Both schedule variances can also be expressed in percent relative to the PV and ES:

$SV_w\% = SV_w/PV$ = amount of work variance / planned value

$SV_t\% = SV_t/ES$ = time variance / earned schedule

Which one?

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

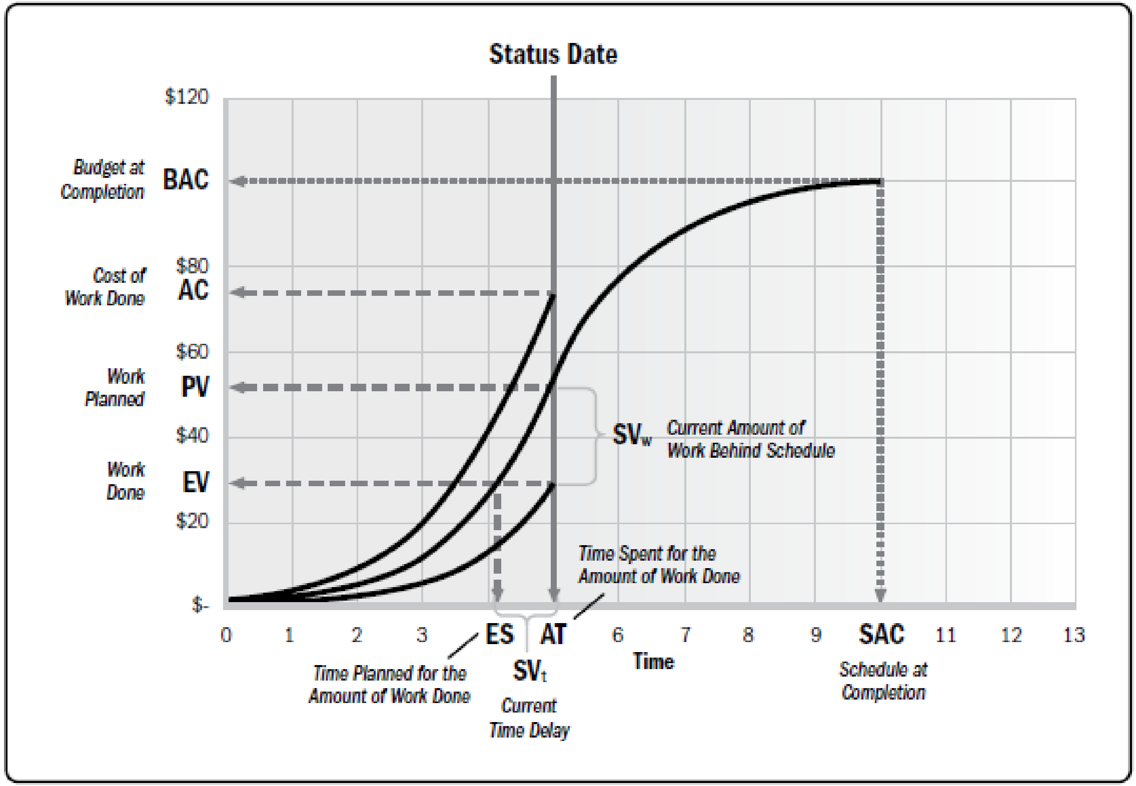


Figure 4-4. Graphical View of the EVM Schedule Variance Metrics

- **SV_w vs. SV_t.** Both variances are useful for the purpose of variance analysis and response, since they provide complementary information from two different dimensions that matter for the purpose of performance management.

  For example, 20% less work was accomplished than the work that was planned to date, and it has taken 1 extra month so far. In this example, $SV_w\% = -20\%$ and $SV_t = -1$ month. Figure 4-4 illustrates these two variances in absolute value.

ACEMI

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

SPI_w (schedule performance index expressed in work volume variance) = EV / PV

- SPI equals the amount of work accomplished / amount of work planned to be accomplished.
- SPI measures, on average, the fraction of work that is being accomplished in each unit of time where 1 unit of work should have been accomplished according to the baseline. SPI measures the actual rate at which the work is being accomplished relative to the expected work rate in the baseline.

For example, SPI = 0.6 means that, on average, for every unit of time where 1 unit of work should have been accomplished, only 0.6 units of work was actually accomplished. The actual work rate is only 60% of what was planned in the baseline; therefore, the work is getting done slower at a 60% rate.

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

SPI_t (schedule performance index) = ES / AT

- SPI_t equals time planned for the amount of work accomplished / time actually spent for the amount of work accomplished.
- SPI_t measures, on average, the fraction of the time elapsed to accomplish each unit of work.

For example, $SPI_t = 0.7$ means that only 70% of the time was actually spent with every unit of work accomplished. For example, 10 days are being spent for each unit of work, when only 7 days should have been spent). On average, more time is being spent with each unit of work than planned in the baseline (10 days as opposed to 7); therefore, the work is getting done slower:

STEPS 8-11: Analyze performance – Schedule and cost performance

PMI

While less intuitive, the use of the time-based schedule performance indices, as an alternative to the traditional volume-based indices for time-performance measurement, has been receiving some attention from a community of EVM practitioners. The main argument is related to the natural tendency of volume-based SPI to float toward 1 when the work is behind schedule beyond the baseline completion date; therefore, it is not a reliable predictor of final variance at completion. However, for forecasting purposes, in such behind-schedule scenarios, the volume-based SPI can be adjusted to deliver consistent and valid future trends.

$$SPI = (EV / PV) \times (SAC / AT)$$

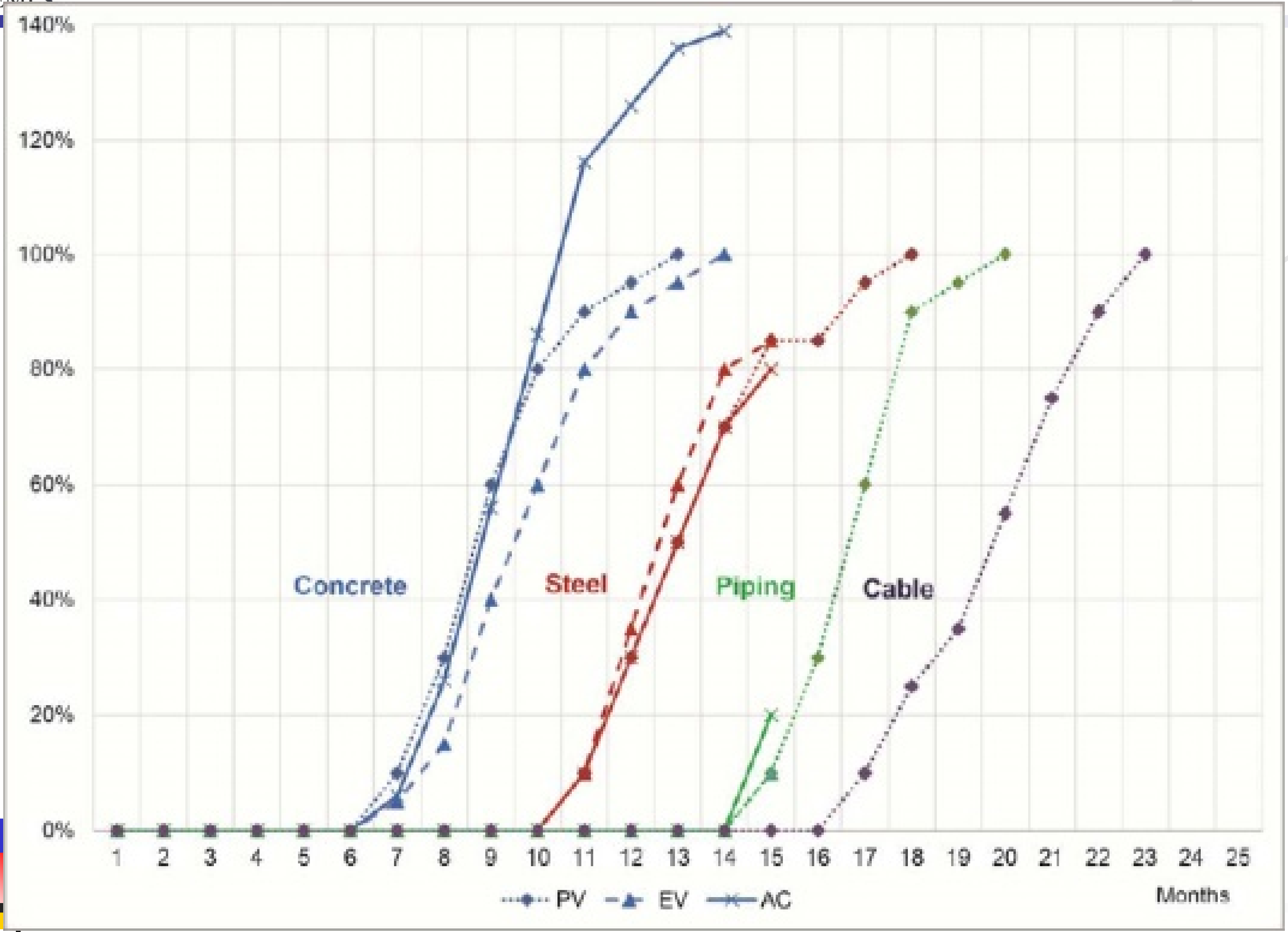
Where: $AT > SAC$, as the baseline completion date overrun.

STEPS 8-11: Analyze performance – Schedule and cost performance

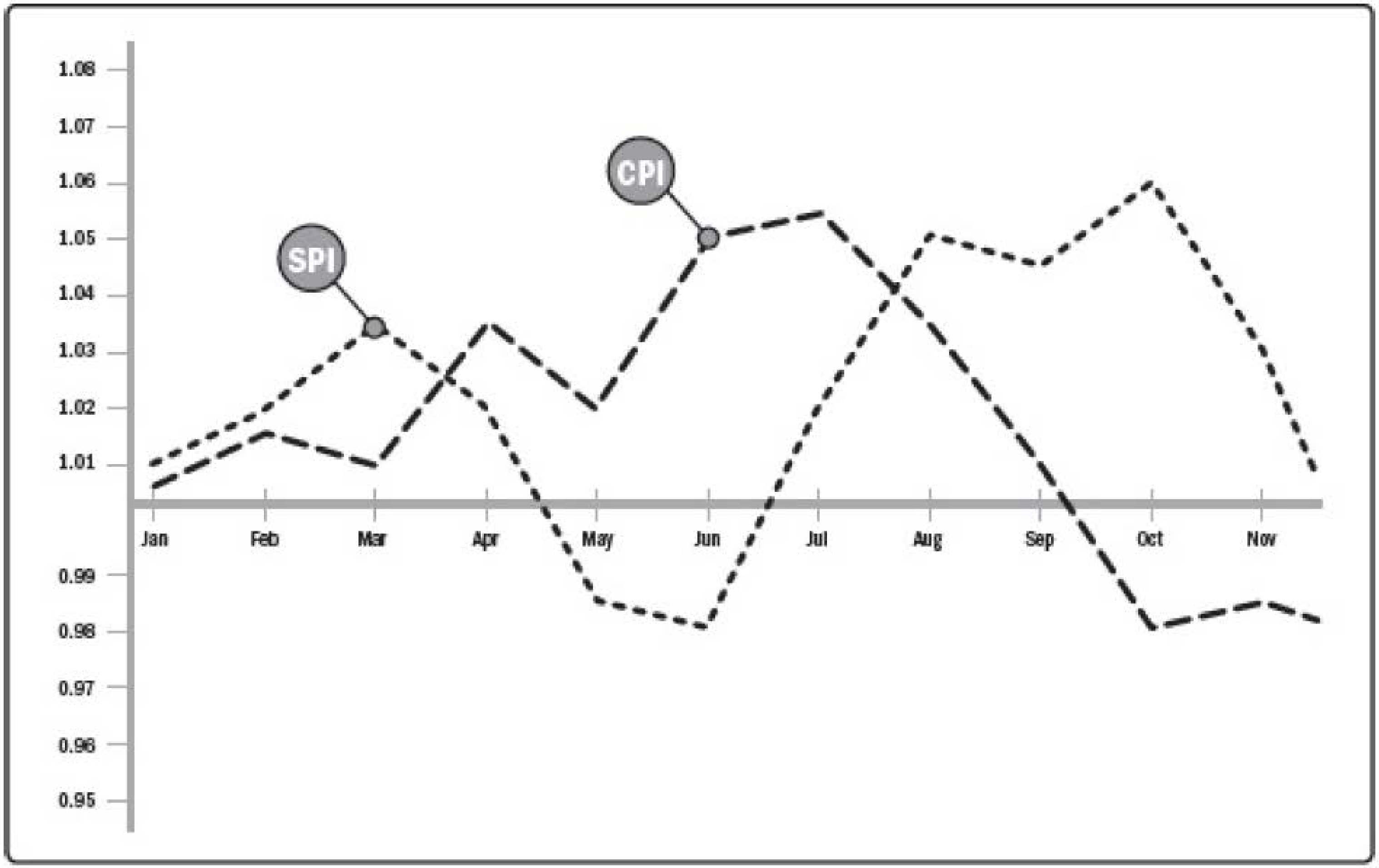
PMI

Index	Past
Cost Performance	• CPI = EV/AC
Shedule Performance	• SPI_w = EV/PV where: $AT \leq SAC$ • SPI_w = (EV/PV) x (SAC/AT) where: $AT > SAC$ • SPI_t = ES/AT

STEPS 8-11: Analyze performance – Overall program view of EVM data

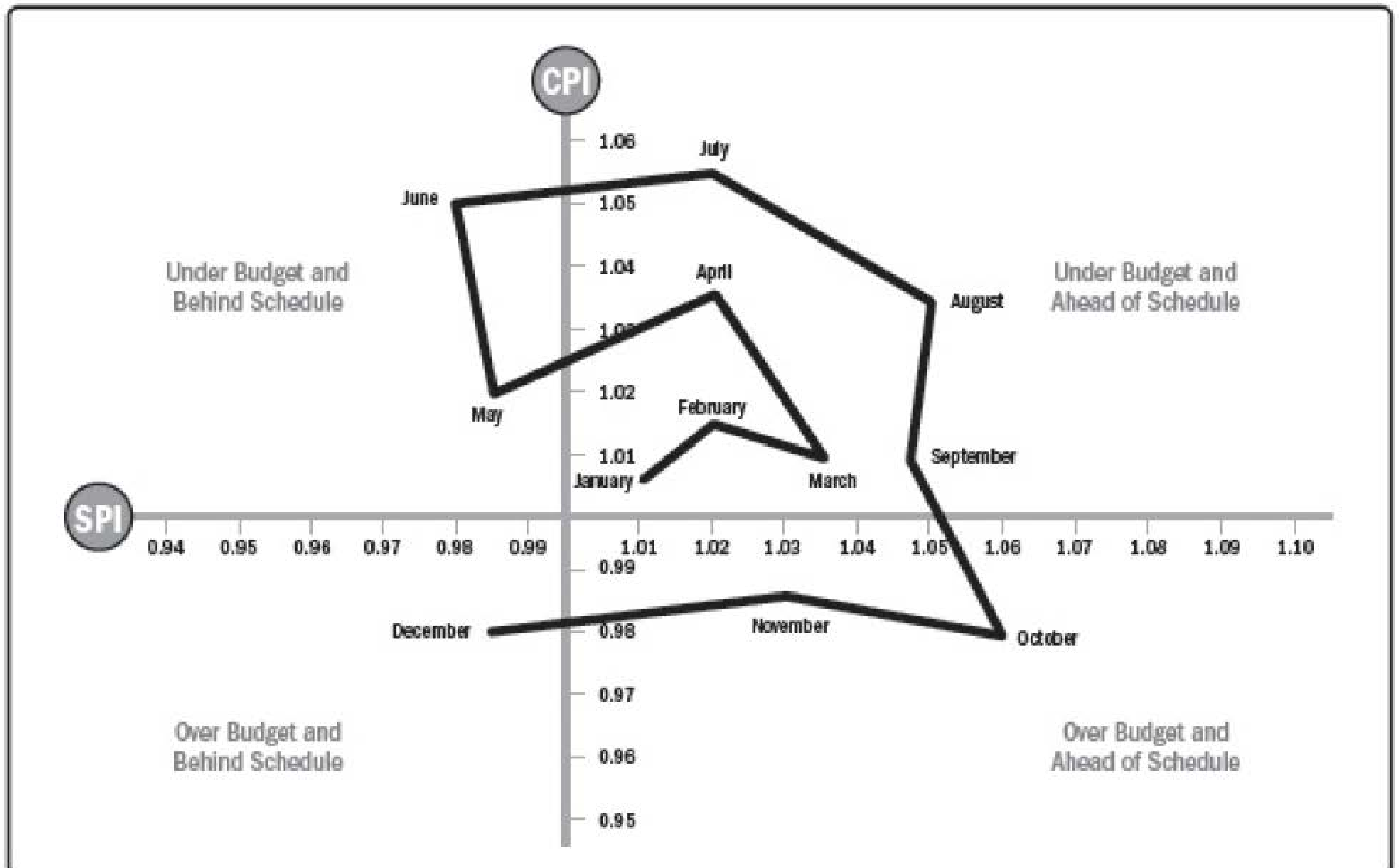


STEPS 8-11: Analyze performance – Overall program view of EVM data



Overall Project Performance (Using Linear Method)

STEPS 8-11: Analyze performance – Overall program view of EVM data



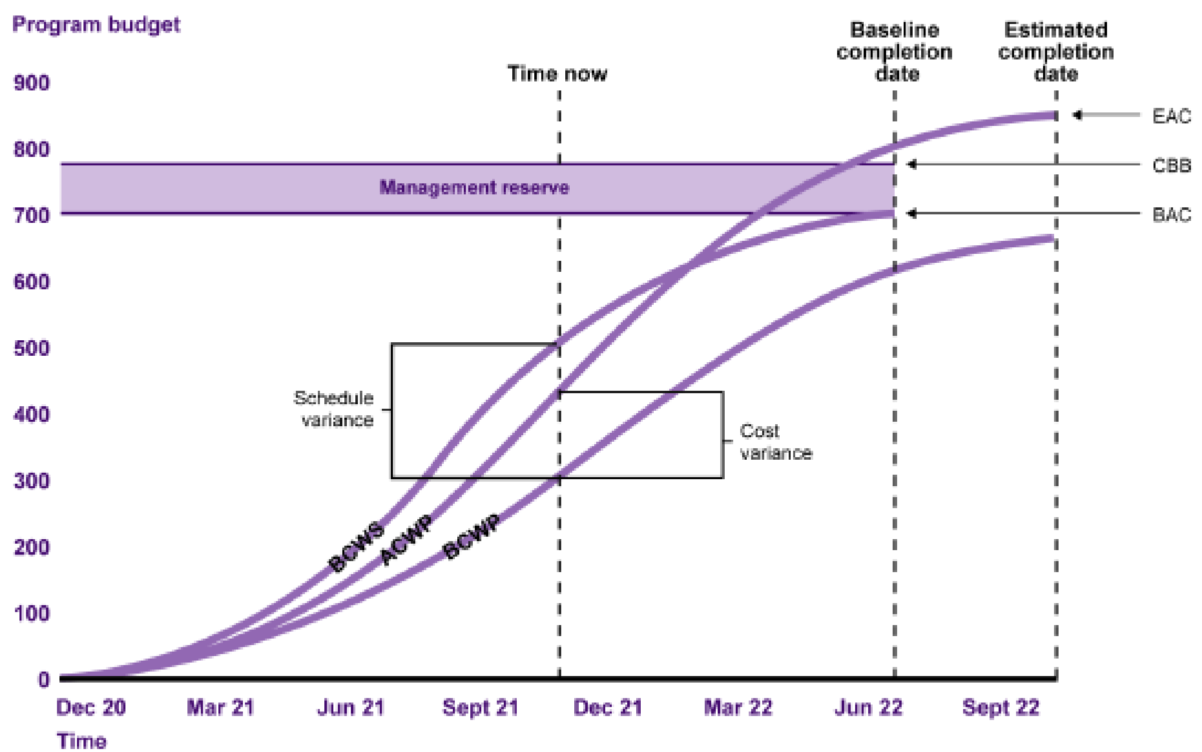
Overall Project Performance (Using Radial Method)

STEPS 8-11: Analyze performance – Overall program view of EVM data

- **Owner** may have different baseline even **on top of CBB** (due to AE, financing, etc.)
- Some **may include <u>overhead and contingency</u>** in **each line item**. This is a philosophy of management.

Management reserve should never be on PMB in any cases.

Overall Program View of Earned Value Management Data



Source: GAO. | GAO-20-195G

Note: ACWP = actual cost of work performed; BAC = budget at completion; BCWP = budgeted cost for work performed; BCWS = budgeted cost for work scheduled; CBB = contract budget baseline; EAC = estimate at completion; PMB = performance measurement baseline.

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- What are the **best target levels** for the **CPI** and the **SPI**?
  - A **high number** for either of these indices probably indicates that either the **schedule** or the **budget** was **unrealistic**.
    - For example, a **CPI of two** would indicate that the **ACWP** was **half** of the **BCWP**.
      - It is **unlikely** that the cost **savings of 50%** was solely a **result of good cost management** on the project **but instead** was a **result** of an **unrealistically high budget**.

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

❖ When **analyzing** the **CPI** and the **SPI**, management should look at **two things**:

1. The **value** of the **indices**
2. The **trend** in these **values**

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- Value of indices
  - First look at **how** the **costs** can be **calculated**:
    1. **Deterministic**
    2. **Probabilistic**

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- Value of indices

  1. **Deterministic costs**

  - Those costs that **management** can **determine** **before** they **occur**.
    - **Fixed prices** from **subcontractors**, where there is **little chance** that the cost **will change**, are considered deterministic costs.

  - Deterministic costs **include** **all committed costs**.

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- Value of indices

  2. **Probabilistic costs**

- **Cannot** be determined **before they occur** (e.g., **in-house labor**)
  - ✓ May be represented by a **statistical curve** such as the **normal** or **bell curve**.
  - ✓ **Expected value** and a **standard deviation** may be determined for **each of the costs** using **historical data**.
    - o **Expected value** is the **most likely value** and it is equal to the **average value** that expected to **fall within** the **distribution curve.**
  - ✓ The **standard deviation** represents how much the **actual costs** could vary **from** the **expected costs**.
  - ✓ By nature, **all durations** on the schedule are **probabilistic**.

$$\textit{Expected cost} - SD \leq \textit{Actual cost} \leq \textit{Expected cost} + SD$$

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- Value of indices
  - The **ideal** target range for the **CPI** and the **SPI** is within **one standard deviation** of the **expected values**.
    - **Ideal values:** ***Expected value –SD ≤ CPI, SPI ≤ Expected value + SD***

1. **If** ***Expected value – 2SD ≤ CPI, SPI ≤ Expected value + 2SD***
   - A **cause** for **concern**
2. **More than two standard deviations** from the expected values
   - **Need immediate attention** from management.

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- Value of indices
  - **General notes:**
    - If the **budget** and **schedule** used for the CPI and the SPI are **based** on the **expected values**, then the CPI and SPI should be **within one standard deviation** for both indices.
    - If the indices are based **on another value**, we **need another analysis**
    - It is **impossible** to set **a single target range for all projects**.

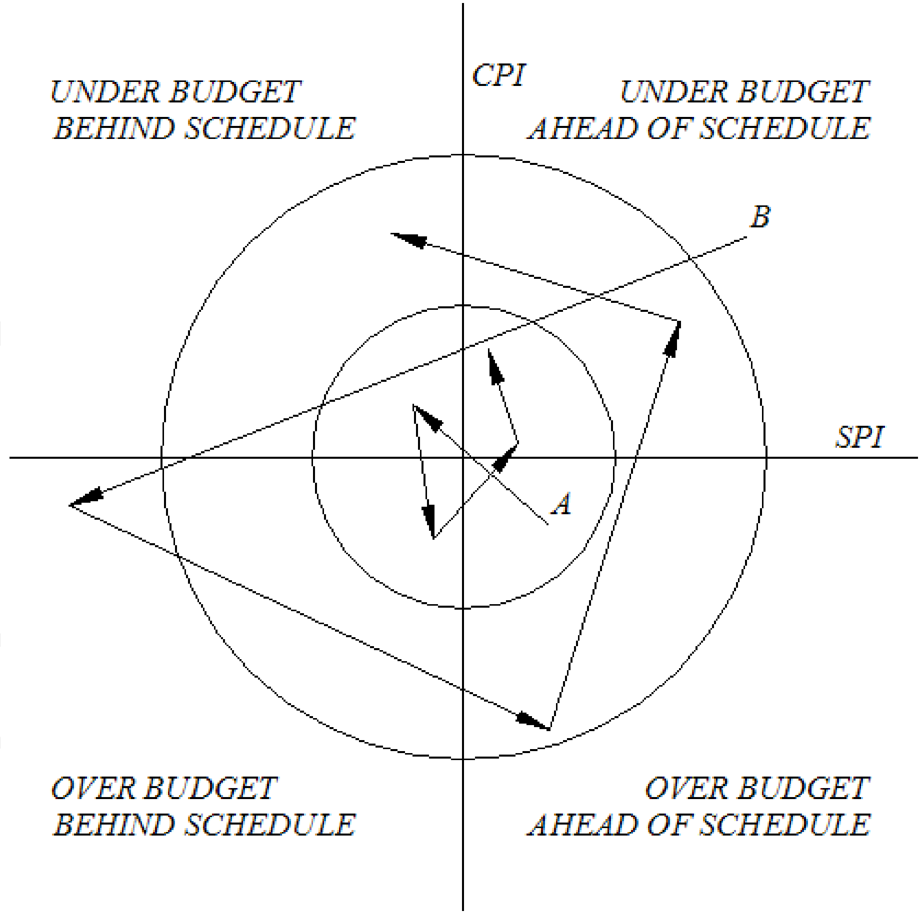
***Determining** the **standard deviation** for the CPI and the SPI is **beyond the scope of our work**.*

STEPS 8-11: Analyze performance – Target levels for CPI and SPI

1. The indices may be **graphed** with the ***x* axis** representing the **SPI** and the ***y* axis** representing the **CPI**.

2. The **inner circle** represents **one standard deviation** from the **expected values** of one for **both** the **CPI and SPI**.

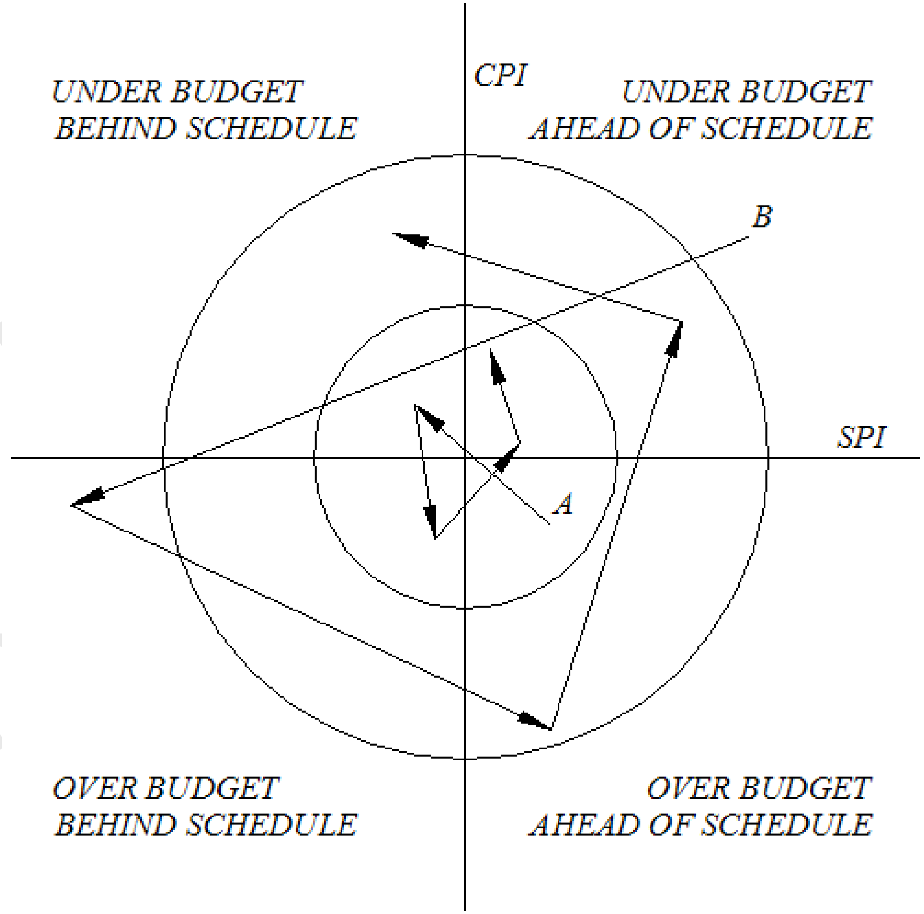
3. The **outer circle** represents **two standard deviations**.



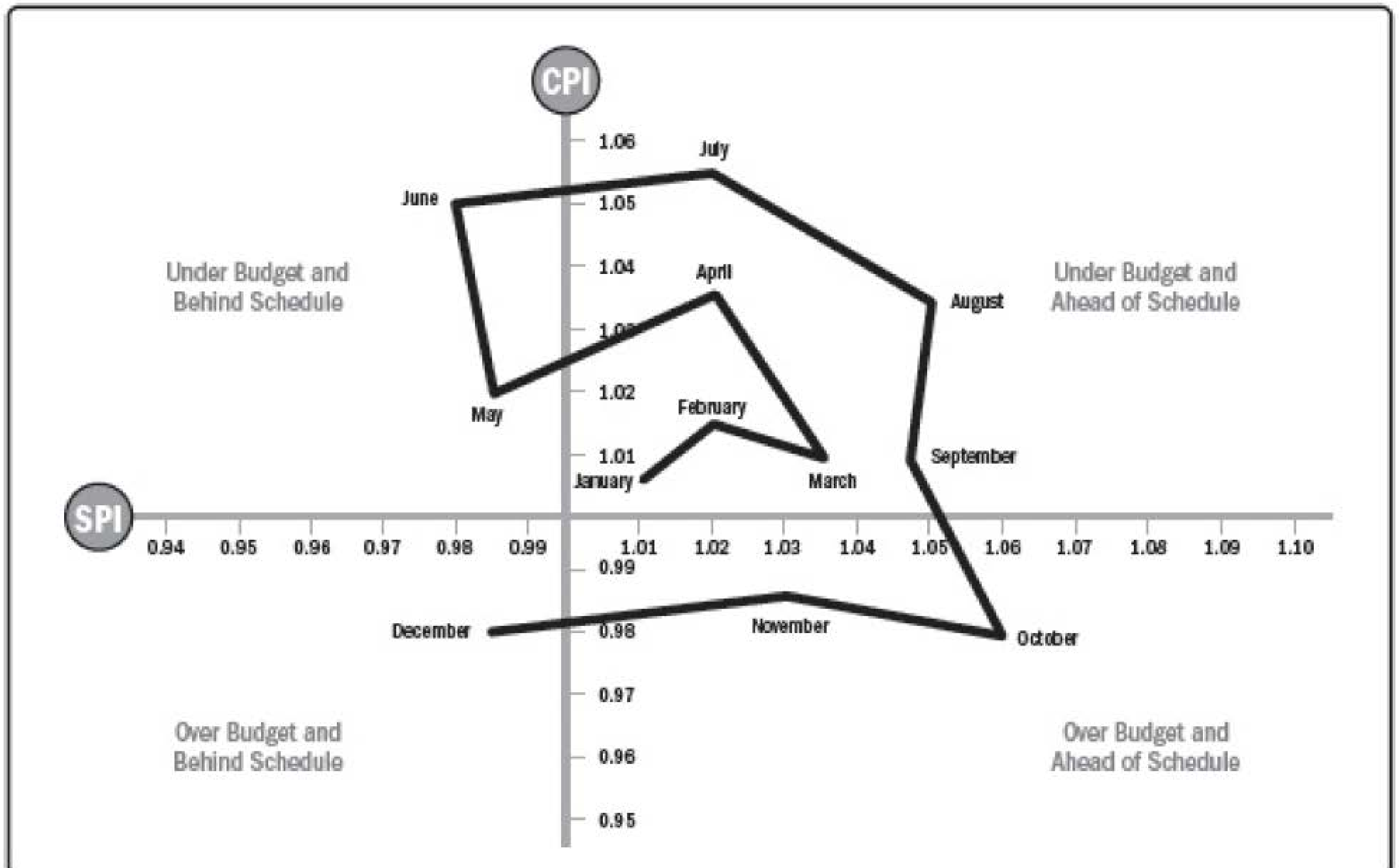
STEPS 8-11: Analyze performance – Target levels for CPI and SPI

- A project that has a **high degree of consistency** in its **schedule performance** and **cost performance** indices is being managed in a **more consistent manner**.

- Project **A is in better control** and **more likely** to **stay within the inner circle** than **Project B**, which is **all over the place**.



STEPS 8-11: Analyze performance – Target levels for CPI and SPI



Overall Project Performance (Using Radial Method)

STEPS 8-11: Analyze performance – Potential causes of variances

What potential causes may exist?

STEPS 8-11: Analyze performance – Potential causes of variances

PMI

Table 4-2. Potential Causes for Variance

	SPI < 1 (behind schedule)	SPI > 1 (ahead of schedule)
CPI < 1 (above budget)	*Underestimation?* *Unexpected scope complexity?*	*Overresourced?* *Work executed out of sequence?*
CPI > 1 (below budget)	*Underresourced?* *Value engineering?*	*Overestimated?* *Scope simpler than expected?* *Effective risk management?*

What actions management should take?

STEPS 8-11: Analyze performance – Potential management actions

PMI

Table 4-3. Examples of Possible Actions for Impact Analysis

	SPI < 1 (behind schedule)	SPI > 1 (ahead of schedule)
CPI < 1 (above budget)	*Underestimation?* *Unexpected scope complexity?* Potential actions: • Descope the project • Increase budget/schedule (when TCPI and TSPI are high)	*Overresourced?* *Work executed out of sequence?* Potential actions: • Reduce resources • Rebaseline for early completion • Control work out of sequence
CPI > 1 (below budget)	*Underresourced?* *Value engineering?* Potential actions: • Increase resources • Rebaseline to extend the schedule (if TSPI is very high)	*Overestimated?* *Scope simpler than expected?* *Effective risk management?* Potential actions: • Expand the scope and/or quality • Plan additional risk responses to reduce project risk • Rebaseline for early completion and release budget

Now, it is time to forecast the future!

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

Identify the work that remains

- Two things are needed to project future performance:
  1. The **actual costs** spent on completed work
  2. The cost of **remaining work**
  - ✓ **Actual costs** spent on completed work are easy to determine because they are captured by the ACWP.
  - ✓ The **remaining work** is determined by subtracting BCWP from BAC to derive the budgeted cost of work remaining.

However, to be accurate, the **EAC** should take into account performance to date when estimating the **cost of the remaining work**.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**

CASE 1: In this case you **assume** that the project **will continue to perform** to the end as it was performing up **until now**. Assume **CPI will not change**.

- ***Total Estimated Cost at Completion (EAC) = Budget at completion (BAC) / CPI***

Is it similar to what we taught?

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**

CASE 2: Here you say that **until now you have deviated** from your **budget estimate**; **however**, from now onwards **you can complete** the remaining work **as planned**.

- Usually this happens when due to **unforeseen conditions**, an **incident happens** and your cost elevates.
  - However in this case you are **sure** that this **will not happen again** and you **can continue** with the **planned cost** estimate.
  - $EAC = ACWP + (BAC - BCWP)$

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STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**

CASE 3: In this case, **you're over budget**, **behind schedule**, and the **client is insisting you complete the project on time**.

- Here not only the **cost** but the **schedule** also has to be taken into consideration.
  - $EAC = ACWP + (BAC - BCWP) / (CPI \times SPI)$

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**

While plenty of **EACs** can be generated from the **EVM data**, **each EAC** is calculated with a **generic index based formula**, similar to:

EAC = ACWP (cumulative) + (BAC – BCWP (cumulative)) / efficiency index

performance to date when estimating the cost of the remaining work.

But how to select efficiency index?

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**

The extensive research has been performed by DOD and the results are also mentioned in GAO

- The **findings** are based on **extensive research** that compared **efficiency factors** that appeared to **best predict program costs**.
  - The **conclusion** was that **no one** factor was **superior**.
    - ✓ Instead, the best **EAC efficiency factor** **changes** by the **stage of the program**.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

❑ Calculate range of EACs and compare to available funding

❖ Best predictive EAC efficiency factors by program completion status

Best Predictive Estimate at Completion (EAC) Efficiency Factors by Program Completion Status

EAC efficiency factor		Percent complete — Early : 0%–40%	Percent complete — Middle : 20%–80%	Percent complete — Late : 60%–100%	Comment
Cost Performance Index (CPI)	Cumulative	X	x	x	Assumes the contractor will operate at the same efficiency for remainder of program; typically forecasts the lowest possible EAC
	3-month average	X	x	x	Weights current performance more heavily than cumulative past performance
	6-month average		x	x	
	12-month average		x	x	

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**
  - The research found that **averaging performance** over a **shorter period of time—3 months**, for example—was **more accurate** for **predicting costs** than longer periods of time—such **as 6 to12 months** **especially in the middle** of a program, when costs are being spent at a greater rate.
  - Research has also shown that **once a program** is **20 percent complete**, the **cumulative CPI** does **not vary much** from its value (**less than 10 percent**) and **most often** tends to **get worse** as **completion grows** nearer.
    - ✓ Therefore, **projecting an EAC** by using the **cumulative CPI efficiency** factor tends to generate a **best case EAC**.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

❑ Calculate range of EACs and compare to available funding

❖ Best predictive EAC efficiency factors by program completion status

EAC efficiency factor		Percent complete Early: 0%–40%	 Middle: 20%–80%	 Late: 60%–100%	Comment
CPI x SPI	Cumulative	x	x		Usually produces the highest EAC
	6-month average		x	x	A variation of this formula (CPI_6 x SPI), also proven accurate[a]
SPI	Cumulative	x			Assumes schedule will affect cost also but is more accurate early in the program than later
Regression		x			Using CPI that decreases within 10% of its stable value can be a good predictor of final costs and should be studied further
Weighted		x		x	Weights cost and schedule based on .x(CPI) + .x(SPI); statistically the most accurate, especially when using 50% CPI x 50% SPI [a]

Source: Industry.

[a]According to DOD comments based on the work of David S. Christensen.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**
  - Relying on **the CPI and SPI performance** factors usually results in **higher EACs** if their **values are less than 1.0**.
  - The **theory behind** this index is that to **get back on schedule** will require **more money** because

    the contractor will either have to **hire more labor or pay for overtime**.

    As a result, the **schedule cost index** forecast is often referred to as a **worst case predictor**.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

Calculate range of EACs and compare to available funding

- The research found that assigning a **greater weight to SPI** is appropriate for **predicting costs** in the **early stage of a program** but **not appropriate later on**.
    - ✓ **SPI loses** its **predictive value** as a program progresses and **eventually returns to 1.0** when the program is complete.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Calculate range of EACs and compare to available funding**
  - A **more sophisticated EAC** method relies on using **actual costs to date** plus the **remaining work**

    with a **cost growth factor** applied plus a c**ost impact for probable schedule delays.**

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Determine if the contractor's EAC is feasible**
  - Finally, an **integrated schedule** can be used, in combination with **risk analysis data** and **Monte Carlo simulation** software, to estimate schedule risk and the EAC.

- **EACs** should be created at
  1. Program level
  2. Lower levels of the WBS

  *By doing this, areas that are performing **poorly** will **not be masked** by other areas doing well.*

  - ✓ **If** the **areas** performing **worse** represent a **large part of the BAC**, then this method will generate a **higher** and **more realistic** EAC.

STEPS 8-11: Project future performance– Estimated cost at completion (EAC)

- **Determine if the contractor's EAC is feasible**

  - Once a **range of EACs** has been developed, the results should be **analyzed** to see if **additional funding** is required.
    - **While EVM data** are useful for predicting **independent EACs**, the contractor should also **look at other information** to develop its EAC.

      In particular, the contractor should

      - evaluate its **performance** on **completed work** and compare it to the **remaining budget**,
      - assess **committed values** for material and subcontractor needed to complete **remaining work**, and
      - estimate **future conditions** to generate the **most accurate EAC**

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

- **Determine if the contractor's EAC is feasible**

❖ *EAC (K) = Committed costs (F) + Non-committed costs invoiced (H) + ETC (J)*

Committed Cost Worksheet

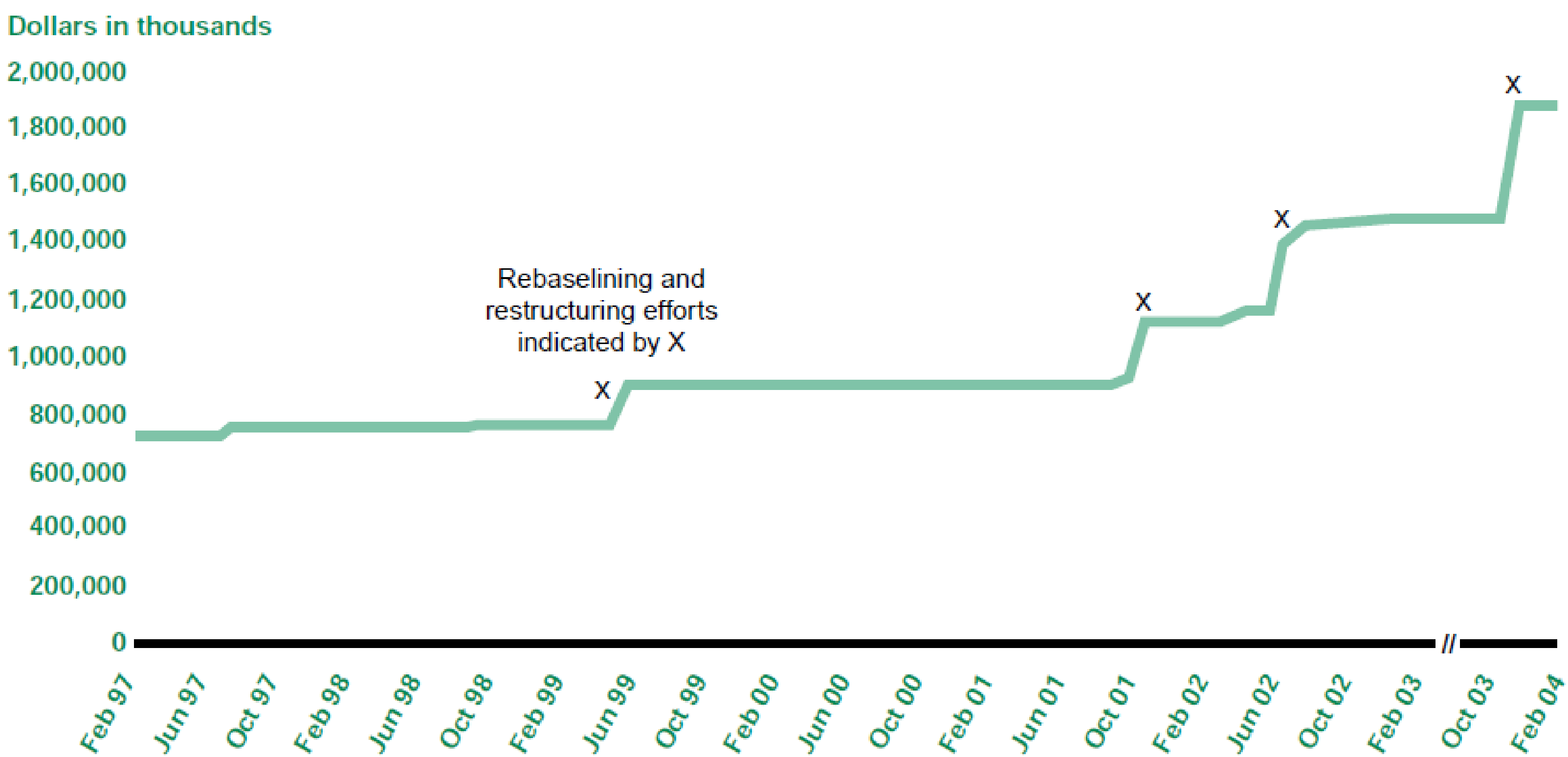
	A	B	C	D	E	F	G	H	I	J	K	L
1									Total		Total	
2									Committed		Estimated	
3								Non-	and Non-	Estimated	Cost	Variance
4					Total		Committed	Committed	Committed	Cost	at	Over /
5			Original	Change	Estimate	Committed	Costs	Costs	Costs	To	Completion	(Under)
6	Code	Description	Estimate	Orders	(C + D)	Costs	Invoiced	Invoiced	(F + H)	Complete	(I + J)	(K - E)
7					—				—		—	—
8					—				—		—	—
9			—	—	—	—	—	—	—	—	—	—

STEPS 8-11: Project future performance– Estimated cost at completion (ETC)

- **<u>Determine if the contractor’s EAC is feasible</u>**
  - ***Estimated cost to complete (ETC) =EAC – ACWP***

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

Understanding program cost growth by plotting budget at completion trends

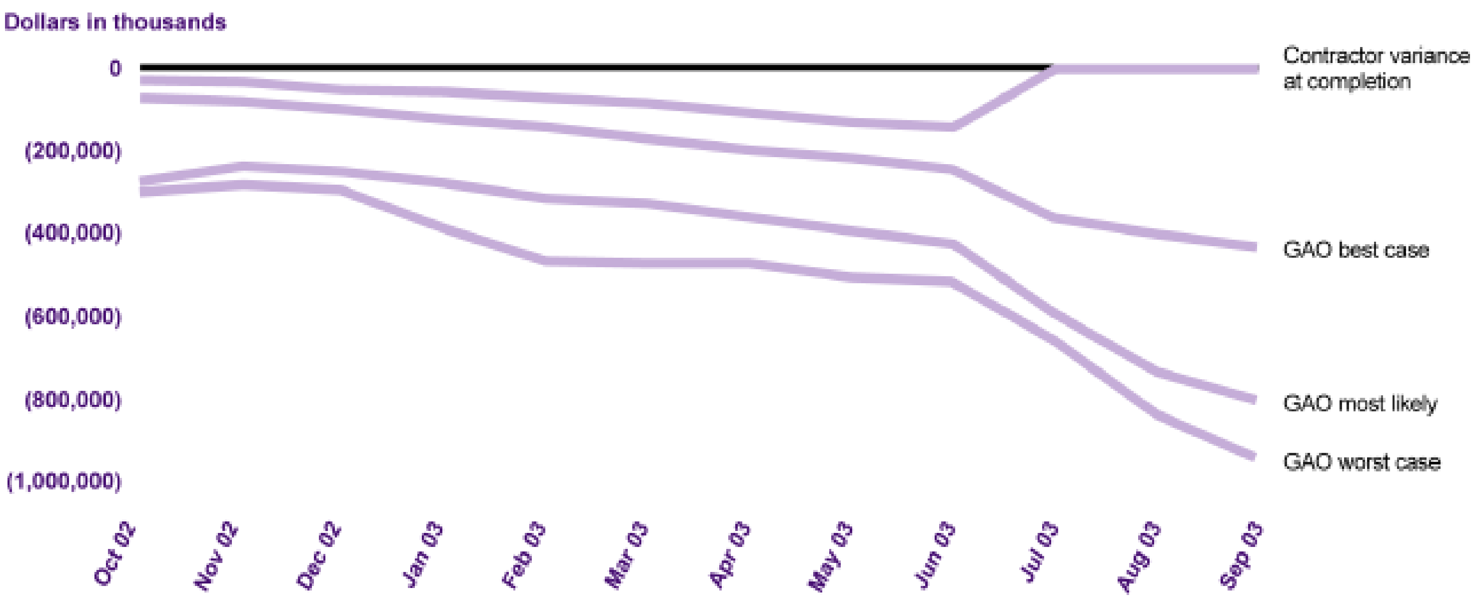


Source: GAO.

Note: The trend examples , shown for learning purposes, are drawn from GAO, *Uncertainties Remain Concerning the Airborne Laser's Cost and Military Utility*, GAO-04-643R (Washington, D.C.: May 17, 2004), pp. 17–20.

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

Understanding Expected Cost Overruns at by Plotting Estimate at Completion



Source: GAO. | GAO-20-195G

Note: The trend examples in figures 32-34, shown for learning purposes, are drawn from GAO, *Uncertainties Remain Concerning the Airborne Laser's Cost and Military Utility*, GAO-04-643R (Washington, D.C.: May 17, 2004), 17–20.

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

PMI

- **Estimate at completion (EAC).** EAC is the expected total cost or time of a control account, work package, or project when the defined scope of work will be completed.

  The equation for EAC is the current cost or time spent plus the estimate to complete (ETC):

  $EAC_c = AC + ETC_c$

  $EAC_t = AT + ETC_t$

  When the independent estimate is used for ETC, then EAC is often referred to as an independent estimate at completion (IEAC).

  Different approaches to estimate the cost and time remaining can be used.

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

PMI

- **Estimate to complete (ETC).** The ETC is the expected cost or time needed to complete all of the remaining work for a control account, work package, or project.

  There are two possible ways to develop the ETC. The most detailed method is to develop a new bottom-up estimate based on an analysis of the remaining work. This is sometimes referred to as a management ETC.

  Another alternative is to use a top-down parametric approach, applying a future efficiency to the remaining work. For cost, such an estimate is calculated as follows:

  ETC = work remaining / future expected efficiency = (BAC – EV) / CPI-future

What PMI says about CPI-future?

STEPS 8-11: Analyze performance – Estimated cost at completion (EAC)

PMI

Where CPI-future is the assumed future cost efficiency for the work remaining, for which difference scenarios can be considered:

- Independent estimate to complete (IETC) assumes no management intervention. Common alternatives for CPI-future are:
  - Future efficiency will be the same as the average observed in the past.
  - Future efficiency is the same as the average observed in the most recent control period (e.g., month, quarter).
  - Future efficiency is based on a trend of the past efficiency (statistically derived).
- Future efficiency is affected by management intervention and/or occurrences of other events foreseen by management (e.g., risks and risk responses). This results in a change from the past efficiency. If CPI-future becomes equal to TCPI, ETC will be equal to the budget remaining: BAC – AC.
- Statistical, parametric, or empirical approaches can also be used to extrapolate CPI-future from past performance indices and other factors, with some approaches using a combination of past CPI and SPI.

STEPS 8-11: Project future performance – To complete performance index (TCPI)

- The **To Complete Performance Index (TCPI)** gives you the **future cost performance index** that you must follow for the **remaining work** if you want to complete it **within the given budget**.
- **TCPI** is useful in **helping focus** project teams on the **road ahead**.

1. **CASE 1: You are under budget (original budget used (BAC))**
   - *TCPI = (BAC – BCWP)/(BAC – ACWP)*
2. **CASE 2: You are over budget (updated budget used (BAC))**
   - *TCPI = (BAC – BCWP)/(EAC – ACWP)*

- ✓ TCPI < 1 – Project has **more funds** and **less work** and **easier** to complete the project.
- ✓ TCPI = 1 – Project has just **enough funds** to complete the work.
- ✓ TCPI > 1 – Project has **less funds** and **more work**. It is **difficult** to complete the project.

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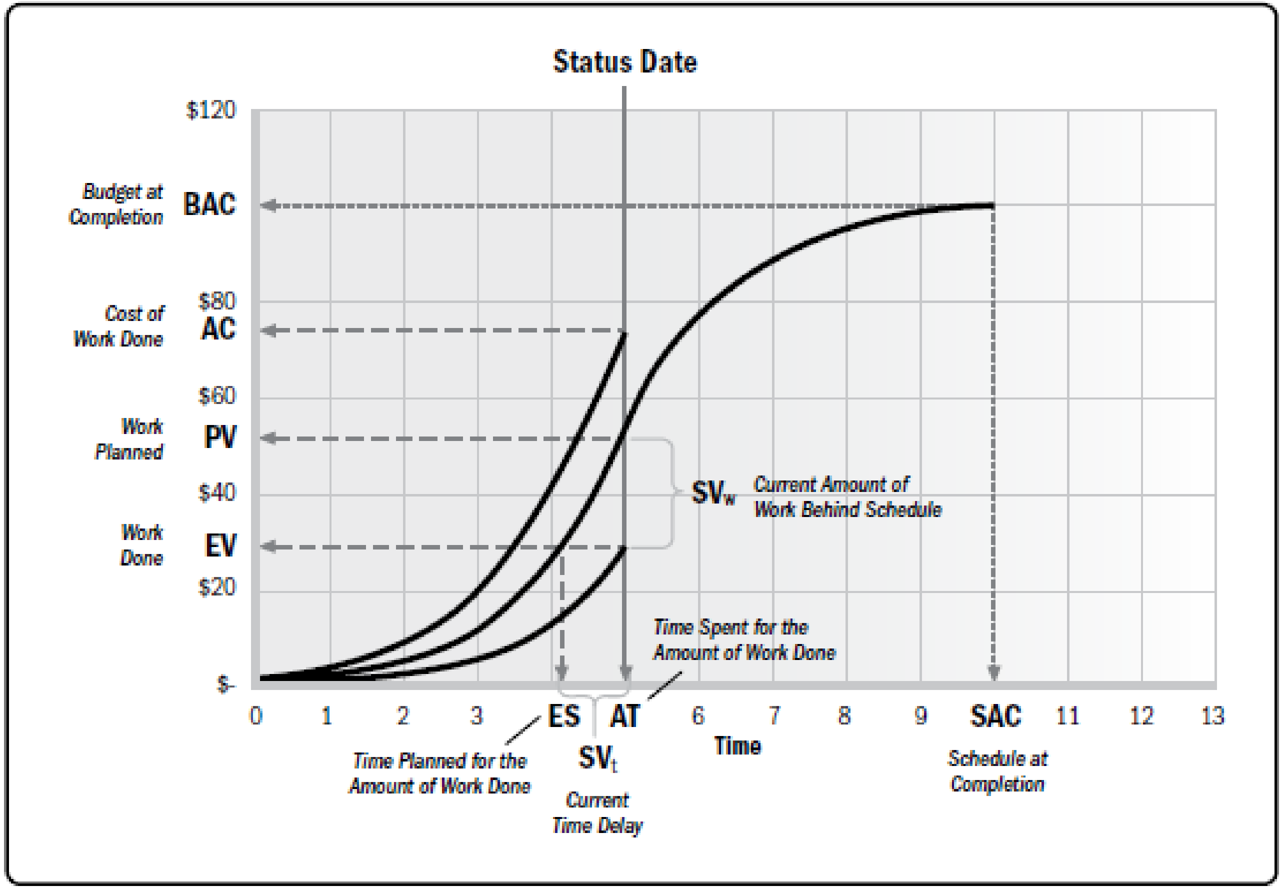
STEPS 8-11: Project future performance – To complete SPI

PMI

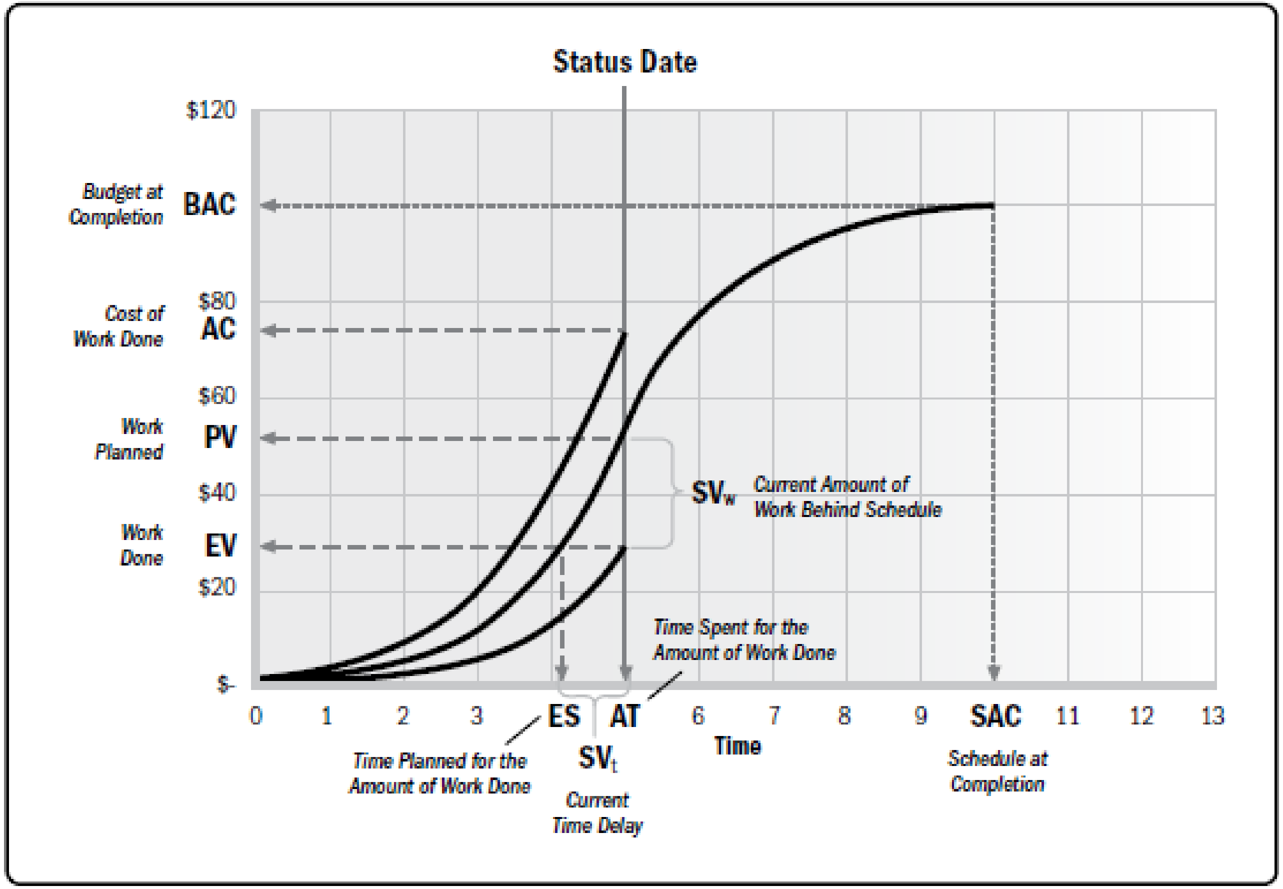


$TSPI_w$ (to-complete SPI expressed in work volume variance) = (BAC – EV) / (BAC – PV)

- TSPI equals the amount of work remaining / amount of work planned to be remaining;

STEPS 8-11: Project future performance – To complete SPI

PMI



$TSPI_t$ (to-complete SPI) = (SAC – ES) / (SAC – AT)

- TSPI equals the amount of time planned for the work remaining / amount of time actually remaining;

STEPS 8-11: Project future performance – To complete SPI

PMI

Table 4-1. Formulas of the EVM Performance Indices

Index	Past	Future
Cost Performance	• CPI = EV/AC	TCPI = (BAC – EV)/(BAC – AC) What-if analysis for BAC: TCPI = (BAC – EV)/(IEAC$_c$ – AC)
Shedule Performance	• SPI$_v$ = EV/PV where: *AT* ≤ *SAC* • SPI$_v$ = (EV/PV) x (SAC/AT) where: *AT* > *SAC* • SPI$_t$ = ES/AT	• TSPI$_v$ = (BAC – EV)/(BAC – PV) • TSPI$_t$ = (SAC – ES)/(SAC – AT) What-if analysis for BAC and SAC: • TSPI$_v$ = (BAC – EV)/(IEAC$_c$ – PV) • TSPI$_t$ = (SAC – ES)/(IEAC$_t$ – AT)

STEPS 8-11: Project future performance – Variance at completion (VAC)

PMI

- **Variance at completion (VAC).** The VAC is the variance between the forecasted trend and the baseline for cost and schedule, and it can be calculated in absolute value or as a percentage over the total:

$$VAC_c = BAC - EAC_c$$

$$VAC_c\% = VAC_c / BAC$$

$$VAC_t = SAC - EAC_t$$

$$VAC_t\% = VAC_t / SAC$$

STEPS 8-11: Project future performance – Variance at completion (VAC)

PMI

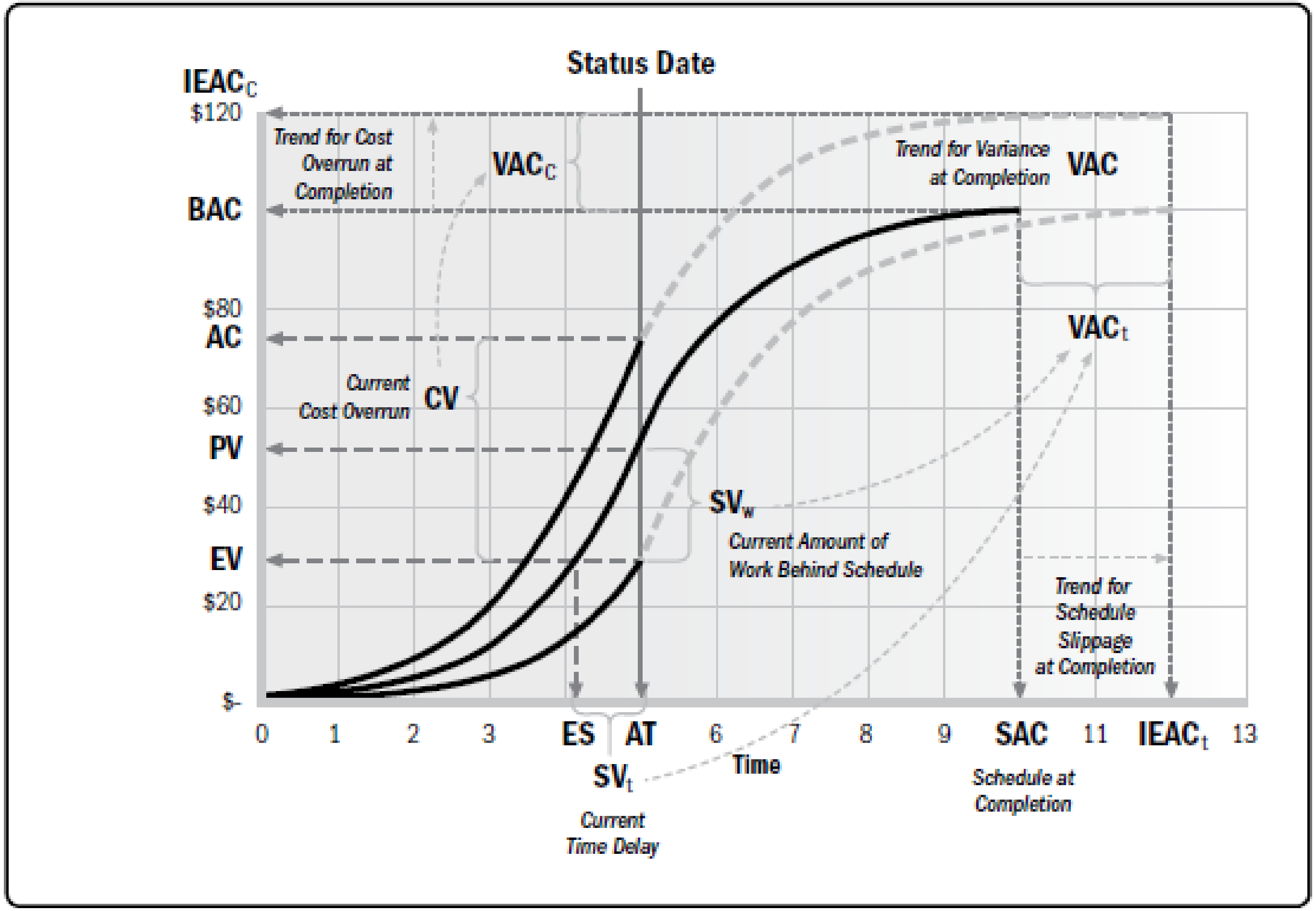


Figure 4-5. Graphical View of the EVM Trend Variances

ACEMI

STEPS 8-11: Project future performance – Reporting

PMI

Table 4-6. Consolidated Reporting for Hybrid Project

Control Account	Budget at Completion	Planned Value (to date)	Earned Value (to date)	Actual Cost (to date)	Actual Time (Weeks)	Earned Schedule (Weeks)	CPI	SPI_w	Estimate to Complete	Estimate at Completion	Cost Variance	Schedule $Variance_t$ (Weeks)
CA-001 Project Management	$336,000	$206,470	$206,470	$216,794	44	44	0.95	1.00	$136,007	$352,801	-$10,324	0
CA-002 Smart Building Planning Phase	$67,700	$67,700	$67,700	$54,057	44	44	1.25	1.00	$0	$54,057	$13,643	0
CA-003 Building Construction	$878,080	$260,283	$324,786	$324,786	44	45	1.00	1.25	$553,294	$878,080	$0	1
CA-004 Smart Buiilding Information System (Agile Team)	122 (Story Points) $61,280	17 (Story Points) $8,336	46 (Story Points) $23,316	$23,316	44	45	1.00	2.80	$37,964	$61,280	$0	1
Program Totals	**$1,343,060**	**$542,789**	**$622,272**	**$618,953**	**44**	**45**	**1.01**	**1.15**	**$727,265**	**$1,346,218**	**$3,319**	**1**

STEPS 8-11: Project future performance – Calculate an independent date for program completion

- **Dollars** can be **reallocated** to **future control accounts** by management, but **time cannot.**
  - If a **control account is 3 months ahead** and **another is 3 months behind**, time **cannot be shifted** from the one account to the other to **fix the schedule variance**.

- ***Given this dynamic,***
  1. The **schedule variance** should be examined in terms of the network schedule's **critical and near critical paths**
     to determine what specific activities are behind schedule,
  1. **Schedule risk analysis** should determine **which activities** may cause the schedule to extend in the future.

STEP 12: Project analysis to management and take management action to mitigate risk

- When **problems** are **identified**, they should be **captured** within the **program's risk management process**

  *so that someone can be **assigned responsibility** for **tracking** and **correcting** them.*

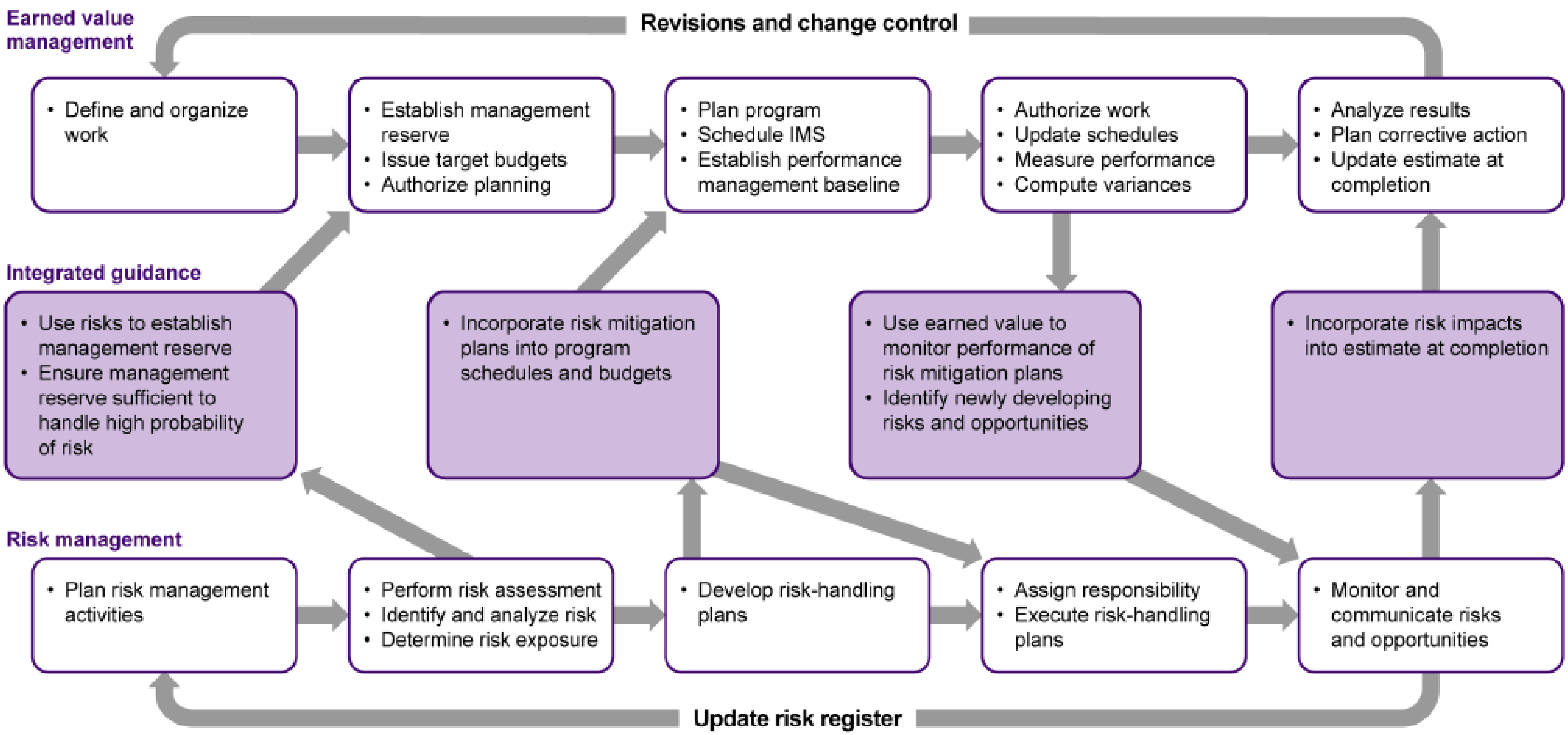
- In addition, using **information** from the **independent EACs** and the **contractor's EAC**,

  *management should decide **whether***

  1. *Additional program funding should be requested*
  2. *Contingency or management reserve used*

STEP 12: Project analysis to management and take management action to mitigate risk

Figure 23: Integrating Earned Value Management and Risk Management



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