National Defense Industrial Association
Integrated Program Management Division

A Guide to Managing Programs Using Predictive Measures

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National Defense Industrial Association (NDIA)
2101 Wilson Blvd., Suite 700
Arlington, VA 22201
(703) 522-1820
Fax (703) 522-1885
www.ndia.org

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Abbreviations and Acronyms

AC	Actual Cost
ACAT	Acquisition Category
ACWP	Actual Cost of Worked Performed (sometimes referred to as AC)
AD	Actual Duration
BAC	Budget at Completion
BCWP	Budgeted Cost for Work Performed (sometimes referred to as EV)
BCWS	Budgeted Cost for Work Scheduled (sometimes referred to as PV)
BEI	Baseline Execution Index
BL	Baseline
BOM	Bill of Materials
CAM	Control Account Manager
CBB	Contract Budget Base
CDR	Critical Design Review
CEI	Current Execution Index
CPA	Critical Path Analysis
CPI	Cost Performance Index
CPLI	Critical Path Length Index
CPR	Contract Performance Report (replaced by the IPMR in 2012)
CPTF	Critical Path Total Float
CTC	Contract Target Cost
CV	Cost Variance
DoD	Department of Defense
DPPM	Defective Parts per Million
EAC	Estimate at Completion
ED	Estimated/Forecasted Duration
EMD	Engineering and Manufacturing Development
ERP	Enterprise Resource Planning
ES	Earned Schedule
ETC	Estimate to Complete
EV	Earned Value
EVM	Earned Value Management

FTE	Full-Time Equivalent
IBR	Integrated Baseline Review
ICPM	Industry Committee on Program Management
IEAC	Independent Estimate at Completion
IECD	Independent Estimated Completion Date
$IECD_{es}$	Independent Estimated Completion Date – Earned Schedule
IMS	Integrated Master Schedule
IPMD	Integrated Program Management Division
IPMR	Integrated Program Management Report
IPMDAR	Integrated Program Management Data and Analysis Report
IPT	Integrated Product Team
K(D)	Key Member is diluted, or is not 100% dedicated to a program
KPP	Key Performance Parameter
LOB	Line of Balance
LOE	Level of Effort
LSE	Lead Systems Engineer
MR	Management Reserve
MRP	Manufacturing Resource Planning
MSA	Materiel Solution Analysis
NCC	Negotiated Contract Cost
NDIA	National Defense Industrial Association
O&S	Operations and Support
OBS	Organization Breakdown Structure
OSD	Office of the Secretary of Defense
OTB	Over Target Baseline
OTD	On-Time Delivery
OTIF	On-Time In Full
OTS	Over Target Schedule
PD	Planned Duration
PF	Planned Finish
PM	Program Manager, Project Manager, or Product Manager
PO	Purchase Order
PPM	Parts per Million

PDR	Preliminary Design Review
PDWR	Planned Duration of Work Remaining
PMB	Performance Measurement Baseline
PMWG	Program Management Working Group (part of IPMD)
PV	Planned Value
R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
R/O	Risk/Opportunity
R/Y/G	Red/Yellow/Green
SEMP	System Engineering Management Plan
SEP	System Engineering Plan
SPI	Schedule Performance Index
SPI(t)	Time-Based Schedule Performance Index
SRA	Schedule Risk Assessment
SV	Schedule Variance
SVT	Schedule Visibility Task
TBD	To Be Determined
TBR	To Be Resolved
TCPI	To Complete Performance Index
TD	Technology Development
TFCI	Total Float Consumption Index
TPM	Technical Performance Measure or Technical Performance Measurement
TSPI	To Complete Schedule Performance Index
$TSPI_{ed}$	To Complete Schedule Performance Index – Estimated Duration
UCA	Undefinitized Contract Action
WBS	Work Breakdown Structure

1 Introduction

Program management (i.e., the management of programs) can be divided into two major phases. First is the planning phase, where the baseline is established in terms of cost, schedule, and performance objectives that need to be successfully accomplished to meet client requirements. Once the baseline is established, the second phase is statusing, monitoring, and controlling the actual activities against the baseline and then making adjustments as appropriate to meet the cost, schedule, and performance objectives.

As a Program Manager (PM) performs the second phase, several metrics or measures can assist in meeting program objectives. These measures provide a comparison of current program status against the planned measures. Earned Value Management (EVM) is a project management control technique which effectively integrates actual accomplishment in terms of cost, schedule, and scope. However, EVM as a management approach should be supplemented with additional measures and metrics during the monitoring and controlling phase to attain a more comprehensive understanding of current performance and to help management make well-informed decisions. These additional measures and metrics can provide valuable predictive indicators that can be used to develop and implement effective mitigation plans.

Other measures and metrics a program manager can use during the monitoring and controlling phase to ascertain the current performance include:

- Risks and Opportunities vs. Management Reserve
- Technical Performance Measures (TPMs)
- Supplier Late Starts vs. Planned Starts
- Staffing Needs vs. Available Resources.

In 2008, the National Defense Industrial Association (NDIA) Industrial Committee for Program Management (ICPM) completed a study on Predictive Measures of Program Performance. The objectives of this study were to:

- Develop a common set of predictive measures for use by government and industry program managers to ensure program success
- Help contractors and their government counterparts predict program performance and pursue root causes and corrective actions for performance issues
    - Predictive measures that cover the program's lifecycle from pre-award through contract close-out
    - Predictive measures that can be tailored to the contract characteristics, contract type, and program phase
- Recommend an NDIA standard for predictive metrics.

This resultant documentation consisted of a set of 24 potential measures that were documented in a Microsoft PowerPoint presentation.

This Guide began with a re-assessment of the original study and its proposed measures, adding some additional measures and deleting others, and documenting the measures as a more usable Microsoft Word document in a standard format.

Each of the measures from 2008, and additional measures as they were identified, were assessed as to their suitability as predictive measures. For example, many regard EVM as a measure of current performance and mostly rearward looking; however, EVM does have a predictive nature to its measures in that it can be used as an indicator of future performance by applying current efficiencies to remaining work. Throughout this Guide, these measures are many times referred to as metrics. For the purposes of this Guide, usage of the terms “metrics” and “measures” are synonymous.

The measures identified in this Guide were documented in such a way to ensure their predictive nature. Also, it can be useful to think of measures and metrics as indicators that can be both leading indicators (predictive) and lagging indicators. For instance, actual staffing being less than planned staffing can be a leading indicator that the future planned work tasks will not be accomplished (predictive of future performance). The same indicator can be a lagging indicator that sufficient human resources could not be hired or transferred to meet the planned level of staffing.

The metrics described in this Guide follow a prescribed format as much as possible. The metric discussion is divided into several sections:

- Metric Definition – A brief discussion of the metric and how it is defined.
- Calculations – How the metric is calculated.
- Output/Threshold – What the output of the calculation provides, typically in graphical format, and any thresholds that should be noted in using the metric for analysis or management action.
- Predictive Nature – What aspect of this metric provides predictive information.
- Possible Questions – Potential questions that a PM or Line Manager might consider when performing a deeper dive into the analysis of the metric and aid in managing the program.
- Caveats/Limitations/Notes – This portion was considered optional and not all metrics may include it. This section identifies some aspects of the metric that may be of interest to the user, e.g., when a particular metric is less predictive.

One of the most critical aspects of each discussion is the Predictive Nature; this Guide is intended to provide a summary of measures that are truly predictive in nature. However, it is recognized that some of the measures included in this Guide are not truly predictive, e.g., Schedule Performance Index (SPI), Cost Performance Index (CPI), and Baseline Execution Index (BEI). Nonetheless, historical information contributes to predicting future performance. While these measures are not predictive by themselves, predictive measures can be developed by coupling them with other information; hence, they have been kept in the Guide.

The intended audiences for this Guide are organizations (government and industry) that are looking for standard approaches to manage programs. This Guide is not intended to provide a new set of standards that would be required to assess program performance, but instead provide a “menu” of typical measures that could be applied. Some metrics are better suited for certain applications than are others. Each organization should decide which measures are most appropriate for its environment and select only those measures suitable for its purposes. In this sense, this document differs from the original 2008 ICPM study that had as one of its objectives to recommend a “standard” for predictive measures.

While the document describes numerous measures or metrics, some well known and some possibly not so well known, the NDIA is not recommending a specific set of measures or metrics to be used on any particular program. There are multiple indicators described in this document that provide useful information for the (program or line) manager to examine so as to investigate root causes to revise the plan – i.e. manage. Each of these measures provide valuable indicators that should be used to develop corrective actions. As stated above, each organization needs to use the measures described as they feel appropriate. This document is a “guide.” This document does not provide a roadmap on how to develop the corrective action, but it would typically consist of identifying the root cause of the “out of bounds” measure and making adjustments in either the plan (i.e. replanning) or the execution of the plan. Each organization may have their own approach on how to manage using these metrics and the Possible Questions help in starting the management process.

While there are over 30 measures identified in this document, program managers will typically focus on the top 5 to 8 measures at any one time to assess the status of the program. These top 5 to 8 measures will vary over the life cycle of the program. It is noted that a major purpose of the predictive measures concept, as well as any measures used, are intended to promote a deeper dive into the measures reported. By themselves, the measures provide a snapshot of the program status, but only through an investigation of the cause of a measures value, through discussion, can a program manager truly understand the program status and future course.

While the intent of this document is to provide guidance for all programs, many programs that were considered in the development of this Guide, as well as some of the artifacts, are based on Department of Defense (DoD) experiences. For these programs, some of the metrics are more appropriate during one or more acquisition phases. To document this, Appendix A provides a summary table of the metrics and their applicability in one or more DoD Acquisition Phases.

This document is intended to be a living document, so it will be updated periodically (approximately every three years). If you have a comment or suggestion for improving the Guide, please contact the NDIA IPMD Chair or Vice Chairs.

2 Schedule Metrics

Section Summary

Schedule Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
SPI	Schedule Performance Index	Measure of demonstrated schedule performance, using traditional EV data, which can be used as a comparison for future projections	Similar to: BEI, SPIt	2.1
BEI	Baseline Execution Index	Measure of demonstrated schedule performance, using task counts, which can be used as a comparison for future projections	Similar to: SPI, SPIt	2.2
CPLI	Critical Path Length Index	Measure of the risk associated with meeting a downstream deadline	Similar to: TFCI	2.3
CEI	Current Execution Index	Measure of near-term schedule forecast accuracy	No close relationship	2.4
TFCI	Total Float Consumption Index	Measure of demonstrated schedule efficiency which can be used to predict a project completion date	Similar to: CPLI	2.5
SPIt	Time-Based Schedule Performance Index	Measure of demonstrated schedule performance, using traditional EV data except from a time perspective, which can be used as a comparison for future projections	Similar to: SPI, BEI	2.6.1
TSPIed	To-complete Schedule Performance Index	Measure of the future schedule efficiency that will be needed in order to not exceed the project's forecasted duration	Commonly compared to SPIt	2.6.2
IECDes	Independent Estimated Completion Date - Earned Schedule	A predicted project completion date, based on future schedule performance being consistent with past schedule performance	Based on SPIt	2.6.3

2.1 Schedule Performance Index (SPI)

Metric Definition

SPI [1], shown in Figure 1, is a summary-level snapshot measuring how well a program (or a portion of a program) has actually performed in comparison with the baseline plan. SPI is an EVM metric comparing Budgeted Cost for Work Performed (BCWP) with Budgeted Cost for Work Scheduled (BCWS) to indicate cumulative or periodic schedule performance. SPI is an early warning tool used to determine if the schedule is at risk and indicates whether the program will need to increase efficiency to complete on time.

Calculations

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

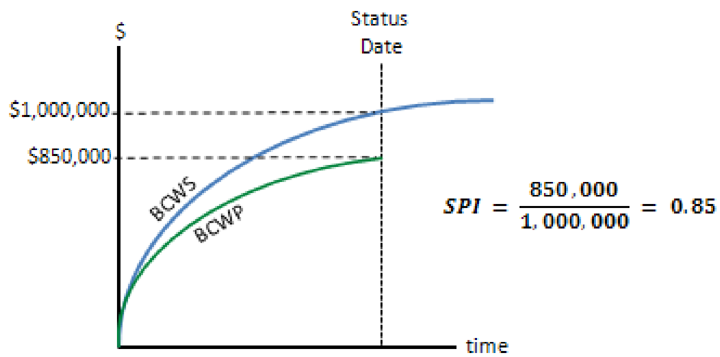


Figure 1. SPI Example

- **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 represents cumulative to date values, unless some other time period is specified.
  - Also referred to as the Earned Value (EV).
- **Budgeted Cost for Work Scheduled** (BCWS)
  - The sum of the performance budgets for all work scheduled to be accomplished in a given time period. This includes detailed (discrete) work packages, Level of Effort (LOE) packages, and apportioned effort.
  - Typically represents cumulative to date values, unless some other time period is specified.
  - Also referred to as the Planned Value (PV).

Note: SPI is typically measured from the start of a project through the current status date; however, it also can be calculated using the BCWP and BCWS over any past window of time. SPI calculated over the most-recent reporting period is commonly referred to as “current SPI”.

Output/Threshold

Similar to reading CPI or BEI, an SPI value of 1.00 indicates the effort is progressing as planned (per the baseline). Values above 1.00 denote performance better than planned, while values below 1.00 suggest poorer performance than planned.

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

Additional thresholds are commonly set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

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 on or slightly ahead of plan
0.95 - 0.99	**YELLOW** ("caution") -On average, the effort is progressing slightly behind plan
<0.95	**RED** ("warning") -indication of poor execution and/or poor planning (overly-aggressive)

Periodicity

- SPI should be calculated and analyzed after each EV status period. For most programs this is monthly, but it may be more or less frequent depending on the effort or contractual requirement.

Predictive Nature

SPI is fundamentally a rearward-looking index because it is derived entirely from historical data. As such, a program's SPI calculation is completely independent of the remaining effort in the Integrated Master Schedule (IMS). However, SPI can be used in a predictive manner as a quick and easy gauge of future project execution risk, and as a historical basis to compare forecasted schedule efficiency. SPI may appear favorable or unfavorable at a point in time, however the ability to assess a trend over time, may foreshadow future performance. It should be cautioned that no all trends in SPI are a result of project execution performance. See "Caveats/Limitations/Notes" below for more information

Risk Assessment

- For most projects, past performance *is* indicative of future results, and SPI is the most common measure of historical schedule performance.

Comparison to Forecasted Rate of Accomplishment

- Because SPI is a historical measure of schedule performance, it can be used to challenge forecasted rates of accomplishment from other sources including the To-Complete Schedule Performance Index (TSPI) , schedule rate charts (S-Curves), and other Shop Floor outputs. The IMS should be questioned if the forecasted plan suggests a rate of accomplishment that is significantly different than the program has achieved historically.

Possible Questions

- Which WBS elements have the worst performance? Why?
- Is the SPI in line with performance on the critical path? If not, why is the critical path different from the rest of the project on average?
- Are current period SPI calculations trending up or down? If so, what are the key drivers?
- Is SPI being skewed by a high percentage of LOE? What would the SPI be for discrete tasks only?
- If SPI < 1.00, is a recovery plan needed? Is it realistic given the available resources?
- Is the SPI demonstrated to date in line with other estimations of future performance? If not, what is the cause of the expected change in performance?
- Is SPI similar to BEI at the top and lower levels? If not, why?

Caveats/Limitations/Notes

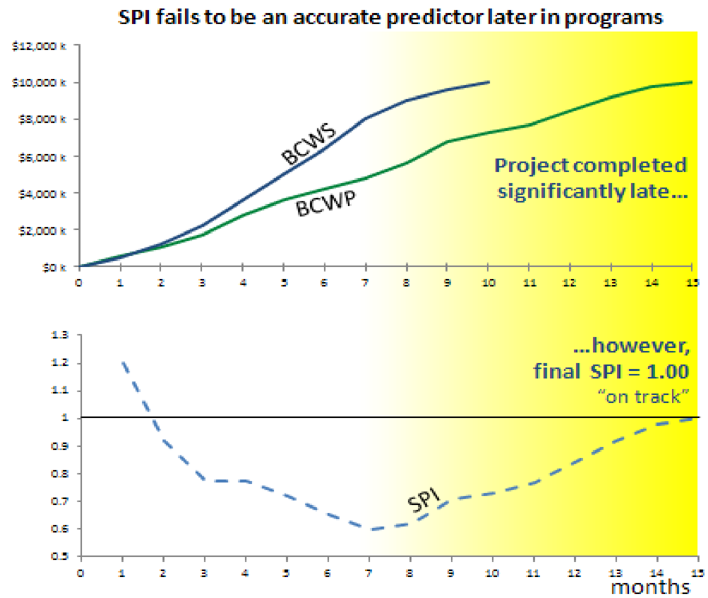


Figure 2. SPI Limitations

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.

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.

SPI should be used in conjunction with sound critical path analysis and schedule risk assessments, and never as a stand-alone indicator of the health of a program.

SPI can only be calculated as often as EV is processed on a project. 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.

Advantage of SPI over BEI

Sensitivity

- SPI is more sensitive than BEI. BEI places equal weight on all activities, while SPI weights activities by their planned resource loading. Therefore, activities that require more effort will have a greater effect on the SPI calculation.

Advantages of BEI over SPI

Objectivity

- BEI is a more objective metric than SPI
  - Programs consider BEI an objective assessment since it is based on the planned and actual completion of activities.
  - SPI has at least some degree of embedded subjectivity due to the earned value assessments made on in-progress effort.

Potency

- SPI may be a more “watered down” index than BEI. LOE tasks skew BEI and SPI calculations toward 1.00, and thus can mask the true state of the program.
    - LOE is generally *included* in the calculation of a program’s SPI.
    - LOE is typically *excluded* from BEI calculations.

2.2 Baseline Execution Index (BEI)

Metric Definition

The BEI [1], shown in Figure 3, reveals the "execution pace" for a program and provides an early warning of increased risk to on-time completion. BEI is a summary-level snapshot measuring how well the program (or a portion of the program) has actually performed compared with the baseline plan. BEI is simply a ratio of completed (or started) tasks to tasks planned to be completed (or started). Management can use this metric to evaluate schedule progress towards the baseline plan. BEI is similar in function to SPI.

Calculations

$$BEI = \frac{\#\,Tasks\ Actually\ Completed}{\#\,Tasks\ Planned\ to\ Be\ Completed}$$

- **# Tasks Actually Completed**
  - Count of activities with an Actual Finish date on or before the status date of the IMS.
- **# Tasks Planned to Be Completed**
  - Count of activities with a Baseline Finish date on or before the status date of the IMS.

Note: While there may be exceptions under certain circumstances, programs typically exclude the following activity categories from BEI counts and calculations:

- Summary Tasks
- Level of Effort (LOE) Tasks
- Milestones (zero duration tasks)

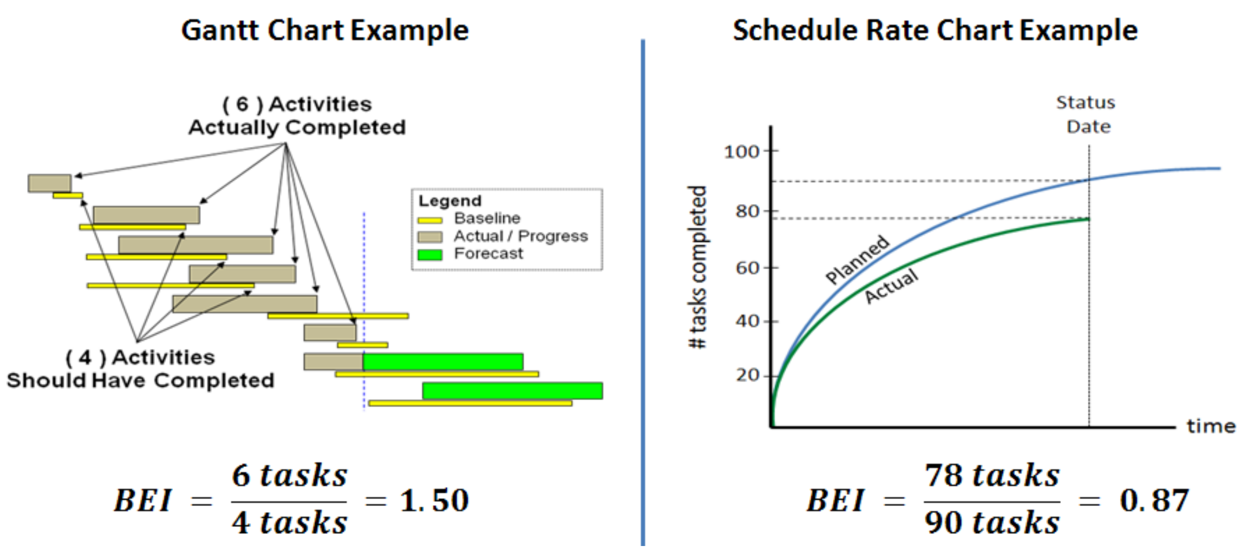


Figure 3. BEI Examples

BEI Companion

While standard BEI is based on task completions, a complementary metric can be calculated based on task starts.

$$BEI(starts) = \frac{\#\ Tasks\ Actually\ Started}{\#\ Tasks\ Planned\ to\ Have\ Started}$$

Note: BEI is typically measured from the start of the project through the current status date; however, it can also be calculated using the count of actual and planned task completions over any past window of time. BEI calculated over the most-recent reporting period is commonly referred to as “current BEI.”

Output/Threshold

Similar to reading SPI or CPI, a BEI value of 1.00 indicates the effort is progressing as planned (per the baseline). Values above 1.00 denote better performance than planned, while values below 1.00 suggest poorer performance than planned.

BEI 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

Additional thresholds are commonly set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

BEI 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** ("well behind") -indication of poor execution and/or poor planning (overly-aggressive)

The above thresholds can also be applied at lower levels. Programs can filter down BEI analysis to specific IMS sections (i.e., Control Account, Work Breakdown Structure [WBS], Organization Breakdown Structure [OBS], Event, or IPT) to facilitate refined analysis. This will allow for a BEI metric to be assessed at any level in an IMS, and Program Management can hold Integrated Product Team leads and/or Control Account Managers accountable for a BEI metric.

BEI vs. BEI(starts)

- When BEI(starts)—calculated using the equation as previously shown—is higher than BEI:
  - The effort may be more complex than planned as tasks are being started at a higher rate than they are being completed (an indication of increasing task durations).
  - Performance on the effort may be improving. Since tasks are started before they are finished, BEI(starts) tends to react to fluctuations in performance before BEI.
- When BEI(starts) is lower than BEI:
  - The effort may be less complex than planned (an indication of decreasing task durations).
  - Performance on the effort may be declining. BEI(starts) tends to lead BEI.

Periodicity

- BEI should be calculated and analyzed as often as the IMS is statused. This is weekly for many programs, but may be more or less frequent depending on the effort or contractual requirement.

Predictive Nature

Like SPI, BEI is fundamentally a rearward-looking index. Because it is derived entirely from historical data, a program's BEI calculation is completely independent of the remaining effort in the IMS. However, BEI can be used in a predictive manner as a quick and easy gauge of future project execution risk and as a historical basis to compare forecasted schedule efficiency. BEI may appear favorable or unfavorable at a point in time, however the ability to assess a trend over time, may foreshadow future performance. It should be cautioned that no all trends in BEI are a result of project execution performance. See "Caveats/Limitations/Notes" below for more information.

Risk Assessment

- For most projects past performance *is* indicative of future results, and BEI is one of the simplest methods of measuring past performance.

Comparison to Forecasted Rate of Accomplishment

- Because BEI is a historical measure of schedule performance, it can be used to challenge forecasted rates of accomplishment from other sources including TSPI, schedule rate charts (S-Curves), and other Shop Floor outputs. The IMS should be questioned if the forecasted plan suggests a rate of accomplishment that is significantly different than the program has achieved historically.

Potential Questions

- Is the BEI in line with performance on the critical path? If not, why is the critical path different from the rest of the project on average?

- Are current period BEI calculations trending up or down? If so, what are the key drivers?
- If BEI < 1.00, is a recovery plan needed? Is it realistic given the available resources?
- Is the BEI demonstrated to date in line with other estimations of future performance? If not, what is the cause of the expected change in performance?
- Is BEI being inflated by "cherry picking" easier downstream tasks? Were they completed out of sequence? And if so, why?

Caveats/Limitations/Notes

- No matter how early or late a program completes, BEI calculations will eventually equal 1.00. This is because BEI formula breaks down over the final third of the project. During this time, BEI trends will always skew toward 1.0 regardless of how the project is actually progressing, rendering the metric less effective as the project nears completion.
- BEI is based on average schedule performance across all, or a specified subset, of the project to date. This can create a misleading perception of project performance. For example, running ahead of schedule in non-critical areas can mask the fact the other, more critical areas are falling behind. Cherry picking future non-critical tasks also can skew BEI upward, hindering the metric from fully conveying the magnitude of the schedule performance deficiencies.
- BEI should be used in conjunction with sound critical path analysis, and never as a stand-alone indicator of the health of a program.
- If un-baselined tasks are included in the BEI calculation, it will inflate the result as there will be more actual finishes than baseline finishes. Because of this, it may be more appropriate to only count tasks with a baseline finish.
- Like most EV metrics, BEI can be affected by changes to the baseline such as an Over Target Baseline (OTB)/Over Target Schedule (OTS).
- To counteract the effect of "cherry-picking" on program performance, other variants of the BEI calculation include:
    - Not counting activities completed out of sequence (tasks with incomplete predecessors) in the BEI numerator, or
    - Not counting activities completed early to their baseline plan in the BEI numerator.
- Be aware of the effect of efforts to adjust or reset schedule variances such as single point adjustments (SPA) or an OTB/OTS.

Advantages of BEI over SPI

Objectivity

- BEI is a more objective metric than SPI

  - Programs consider BEI an objective assessment since it is based on the planned and actual completion of activities.
  - SPI has at least some degree of embedded subjectivity due to the earned value assessments made on in-progress effort.

Potency

- SPI may be a more “watered down” index than BEI. LOE tasks skew BEI and SPI calculations toward 1.00, and thus can mask the true state of the program.
  - LOE is generally *included* in the calculation of a program’s SPI.
  - LOE is typically *excluded* from BEI calculations.

Advantage of SPI over BEI

Sensitivity

- SPI is more sensitive than BEI because BEI places equal weight on all activities while SPI weights activities by their planned resource loading. Therefore, activities that require more effort will have a greater effect on the SPI calculation.

2.3 Critical Path Length Index (CPLI)

Metric Definition

Negative total float is never a desirable condition; however, in different projects the exact same negative float value can represent significantly different risk conditions. For example, if you have -10 days of total float on a project that is not planned to complete for two more years, there are multiple ways to mitigate the issues and recover to an on-time position (authorize overtime, bring on additional resources, etc.). However, if you have -10 days of total float on a project that is forecasted to complete next month, the mitigation options are likely to be very limited, and recovery is less likely if not impossible.

Critical Path Length Index (CPLI) [1] is a ratio that uses the remaining duration of a project and the critical path total float to help quantify the likelihood of meeting program completion requirements. Figure 4 shows an example.

Calculations

$$CPLI = \frac{Critical\ Path\ Length\ +\ Critical\ Path\ Total\ Float}{Critical\ Path\ Length}$$

- **Critical Path Length**
  - The remaining duration of the project. It is the number of working days from the current status date to the end of the project critical path.
- **Critical Path Total Float**
  - The calculated total float on the final activity along the project's critical path.

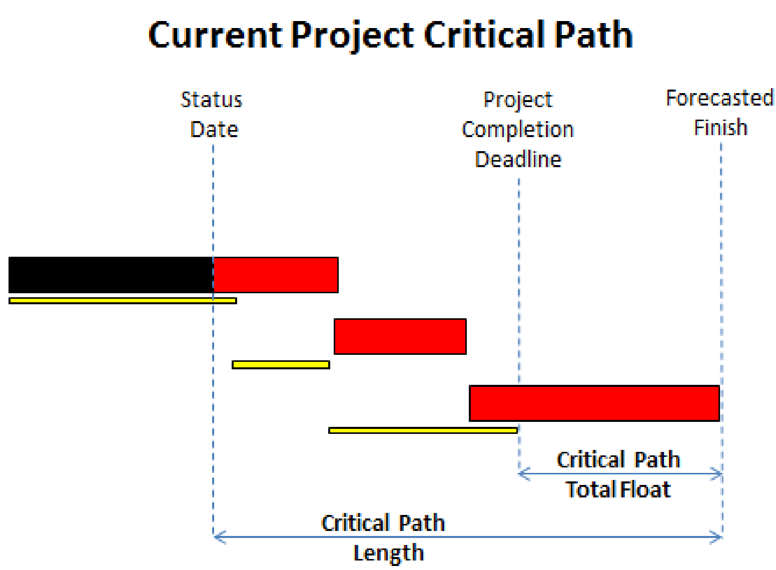


Figure 4. Critical Path Example

Note: In order to calculate the total float on a critical path, the final task/milestone will need have a constraint or deadline to indicate the due date for the project completion.

Output/Threshold

Similar to reading SPI or BEI, a CPLI value of 1.00 indicates that the effort is forecasted to progress as planned. A value above 1.00 denotes a forecasted project completion earlier than required, while a value below 1.00 indicates a forecasted completion that does not support project deadlines.

CPLI Value	Implication
> 1.00	**LOWER RISK** - The project can absorb a certain amount of schedule slippage and still complete on plan
= 1.00	**MODERATE RISK** - The project is currently forecasted to complete on plan
< 1.00	**HIGHER RISK** - Future opportunities must be realized in order to offset past schedule slippage

Additional thresholds can also be set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

CPLI Value	Implication
>1.05	**BLUE** ("too good?") - High likelihood of meeting project completion target
1.00 - 1.05	**GREEN** ("on track") -The project is forecasted to complete on or slightly ahead of plan
0.95 - 0.99	**YELLOW** ("caution") -The project is forecasted to complete slightly behind the plan. Increased risk to on-time completion
<0.95	**RED** ("well behind") -The project is forecasted to be significantly late, greatly lowering the chance of completing on plan

Predictive Nature

CPLI measures the sufficiency of the total float available relative to the remaining duration of the critical path. For example, 20 days of float on a critical path that has 80 days remaining would result in a CPLI of 1.25, indicating a low risk of not completing on time. However, if the critical path has 800 days remaining, a total float of 20 days would result in a CPLI of 1.03. Although this is still above the target of 1.0, it indicates there is much less room for error.

CPLI is a forward-looking metric that is only affected by the activities on the project's critical path. SPI is a rearward-looking metric that is calculated across all activities in a project. Looking at both CPLI and SPI can provide additional insight into the health of a project's schedule.

CPLI vs SPI	*Implication*
CPLI ≥ 1.00 **SPI ≥ 1.00**	**GOOD** ("ahead of schedule") - On or ahead of schedule in most areas, including the project's critical path
CPLI ≥ 1.00 **SPI < 1.00**	**CAUTION** ("future problems") - Critial path remains on track, but falling behind in the majority of other areas
CPLI < 1.00 **SPI ≥ 1.00**	**CAUTION** ("poor prioritization") - On or ahead of schedule in most areas, but behind on the activities on the project's critical path
CPLI < 1.00 **SPI < 1.00**	**WARNING** ("behind schedule") - Behind schedule in most ares, including activities on the project's critical path

Note: BEI or SPI(t) (particularly later in programs) may also be substituted as a comparison to CPLI.

Possible Questions

- Is the current critical path reasonable?
  - Do schedule metrics such as Incomplete Logic and Constraints suggest that the IMS is in sound enough shape to be able to create a valid critical path?
  - Do metrics such as the Current Execution Index indicate that the IMS is being well maintained?
  - Do metrics such as SPI(t) vs. TSPI indicate that demonstrated past performance is being taken into consideration when forecasting future performance?
  - Are known schedule risks and opportunities being incorporated into the IMS?
- Is CPLI trending up or down? If so, what are the key drivers?
- If CPLI < 1.0, what is the recovery plan? Is it realistic given the available resources?

Caveats/Limitations/Notes

- CPLI does not assess the risk of achieving the current forecasted completion of a project. Instead, it provides an assessment of the risk in achieving the planned/required completion of a project.
- CPLI is based on subjective forecasts and, as such, can be manipulated. If a project has a poor SPI, there is nothing that can immediately be done about it other than to start performing better so that future SPI is increased. CPLI, on the other hand, can be directly (and immediately) changed simply by modifying the forecasted completion of the critical path (thus altering both the critical path length and total float). In short, a poor CPLI can be improved without actually improving schedule performance.
- The inclusion of schedule buffer/margin in the IMS can complicate the calculation of CPLI because changes to total float cannot be suppressed for the metric to function properly. Buffer/margin tasks can be temporarily set to zero duration prior to metric calculation to avoid this problem.

- Depending on how the IMS is modeled, the critical path total float may not ever be greater than zero, even if the project is forecasted to complete earlier than planned. If this is the case, CPLI will never be greater than 1.00.
- The treatment of schedule margin (inclusion or exclusion) in determining critical path length should be consistent, in order to help insure the integrity of trend analysis

2.4 Current Execution Index (CEI)

Metric Definition

CEI [1] (sometimes referred to as Forecast Efficiency) is a schedule execution metric that measures how accurately the program is forecasting and executing to that forecast from one period to the next. Its design is to encourage a forward-looking perspective to the IMS and program management. The real benefit of implementing CEI is increased program emphasis on ensuring the accuracy of the forecast schedule. This results in a more accurate predictive model and increases the program's ability to meet its contractual obligations on schedule.

The goal of this metric is to communicate the accuracy of near-term forecasting in the IMS. The index maximum is 1.00, but a sound forecast schedule will consistently trend in the range higher than 75th percentile. There is a direct correlation between the lower probability (less than 75% probability of completion) and the program's ability to manage the projected near-term tasks. This indicates that work is slipping and possibly adding to the "bow wave" of unachievable work.

Note: Terms like "period," "window," and "near-term" are used to describe the period over which CEI is calculated. The duration of the timeframe that these terms typically refer to is the same as the status cycle for the IMS, but can be longer depending on the nature and criticality of the project.

Calculations

$$CEI = \frac{\#\ Tasks\ Actually\ Completed\ During\ the\ Window\ (of\ the\ Denominator\ Tasks)}{\#\ of\ Tasks\ Previously\ Forecasted\ to\ Complete\ During\ a\ Defined\ Window}$$

Use of the CEI metric drives ownership and accountability behaviors that are necessary for program success when consistently used by program management. CEI is derived by comparing the number of tasks forecasted to finish within the status period to the number of those tasks that actually did finish within the status period.

The process for collecting the data necessary to calculate CEI is as follows:

1. At the beginning of the status period, create a "snapshot" of the status period (capturing Forecast Finishes).
2. Execute through the status period.
3. Retrieve initial snapshot.
4. Compare actual finish dates to the initial snapshot.

Figure 5 illustrates the forward-looking snapshot of seven items Forecasted to finish in the future window.

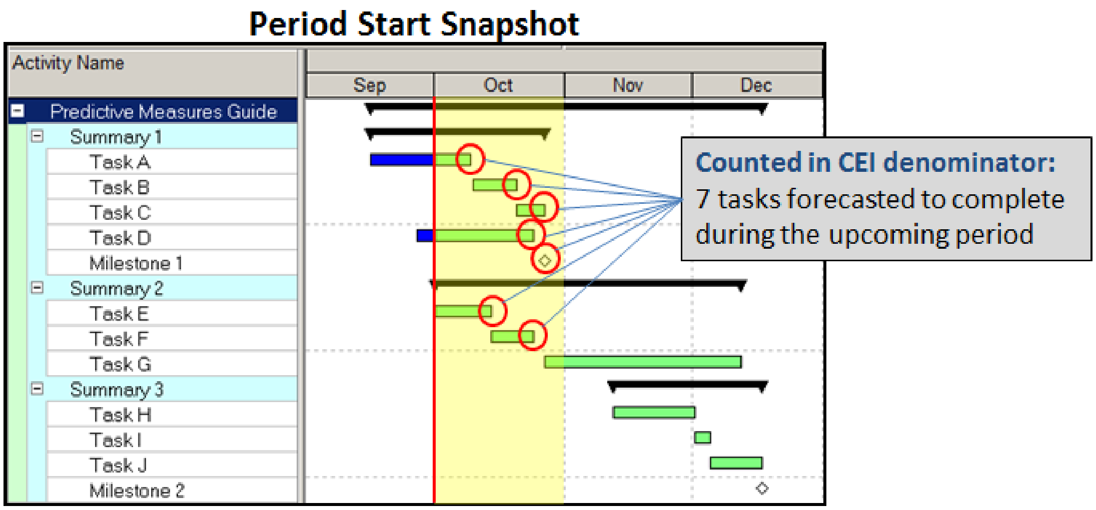


Figure 5. CEI Example – Period Start

At the end of the period, as shown in Figure 6, the schedule will be revisited to determine how many of those seven tasks are now actually complete.

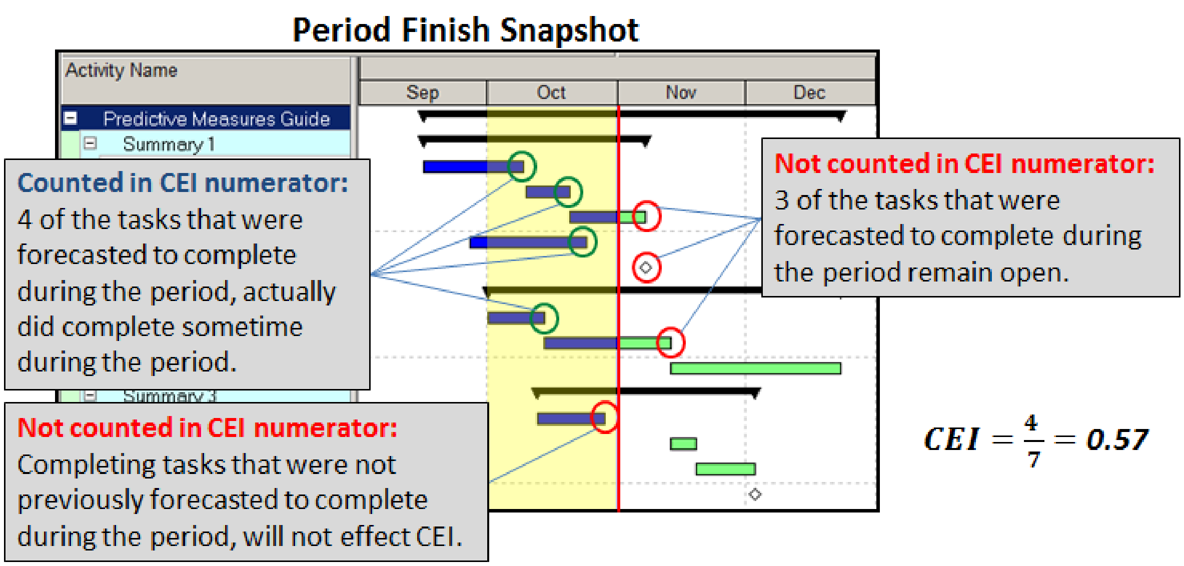


Figure 6. CEI Example – Period Finish

Note: Tasks in this formula include "Discrete," "Milestones," and "LOE" (if LOE is in the schedule) and exclude Summary lines. Be careful when establishing the parameters of this metric that, unlike BEI, the numerator contains only tasks that were previously forecasted to finish and then actually did finish in the defined window. An optional technique involves measuring "start CEI" by using the start dates vs. the finish dates.

Output/Threshold

Figure 7 is a red/yellow/green (R/Y/G) graphic illustration of the CEI, with thresholds of green for equal to or greater than 75% of tasks completing as forecasted, yellow less than 75% and greater than or equal to 70% of tasks completing as forecasted, and red at less than 70% of the tasks completing as forecasted. The specific threshold values can be tailored depending on the nature and criticality of the effort.

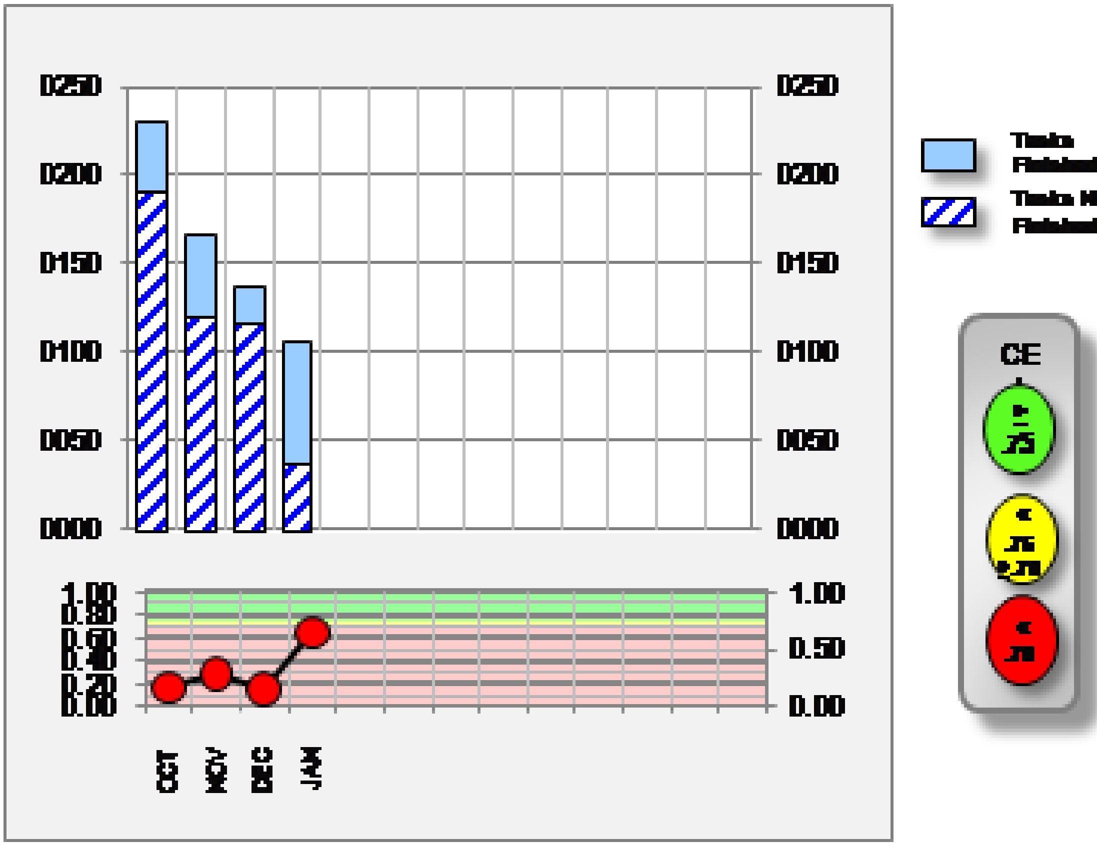


Figure 7. Example of CEI Criticality Measure

Predictive Nature

An IMS provides much more forecasting accuracy with near-term tasks. Because of this, if an IMS is failing to accurately predict the easier, near-term tasks), how much confidence should be placed in the ability of the IMS to forecast major downstream milestones (that is, the harder tasks)? Program teams that can effectively manage the road ahead have a higher probability of long-term success.

Good program management is good people management. The intent of this metric is to drive behavior by motivating and influencing the program team to focus on the accuracy and execution of the forecast schedule. By influencing the "soft" or "people" side of program management, the program team increases its chance of success. With leadership attention, this measure creates an increased program emphasis on ensuring the accuracy of the forecast schedule and influences behavior to plan the work and execute to the plan. Thus, the IMS becomes a more accurate predictive model and increases the program's ability to meet its contractual obligations on schedule by instilling ownership and accountability.

Possible Questions

- What biases are the performing organizations under that contribute to poor forecasting?
- Is there significant management pressure to keep estimates "looking good?"
- Are the estimates being anchored to the original plan that we now know to be overly optimistic?
- Is the Control Account Manager (CAM) optimistic by nature and underestimating the amount of effort required to complete the task?
- Is it possible to quantitatively demonstrate that individual task durations are underestimated?
- What will happen to key program milestones if this continues? If near-term effort cannot be effectively forecasted, how does this affect confidence in the long-term forecasts?
- What is the program manager doing to improve the estimating of these tasks?

Note: People will adapt their behaviors to succeed if they perceive that success is measured. Changing people's behavior creates new experiences that in turn create new attitudes. Over time, the new attitudes fuse into a new culture.

Caveats/Limitations/Notes

- While LOE tasks are commonly included in CEI calculations, their presence can inflate or mask true schedule accuracy. For a project with a higher LOE percentage, consider calculating CEI using discrete tasks only.
- Schedule Visibility Tasks (SVT's) are typically included in CEI measurement. Even though SVTs do not contain budget and are not associated with the PMB, they may contain very important effort that's being executed during the month.
- Milestones are typically included in CEI measurement. While some milestones represent the "accomplishment" of other effort in the IMS and could therefore result in double counting, other milestones may be a "touch point" that represents a very important handoff from a subcontractor (not otherwise represented in the IMS in the form of activities with duration) and would therefore need to be included in the CEI metric.
- If CEI is being used as an Award Fee or other "incentive type" metric, then it may be more appropriate to exclude SVTs and accomplishment milestones. This will ensure the metric is only focused on PMB-related effort. The contractor and Government Schedule Analyst should work together to identify and code in the IMS the SVT's and the accomplishment milestones so that they can be excluded from the Award Fee CEI metric.

2.5 Total Float Consumption Index (TFCI)

Metric Definition:

TFCI [1] [10], shown in Figure 8, is a duration-based performance index that uses historical total float trending to calculate a schedule efficiency factor, which can then be used to estimate future schedule execution. TFCI is a prospective tool to assist in the analysis of delinquent schedules in any state: improving, non-fluctuating/constant, or deteriorating. TFCI is in turn used to calculate the following:

- **Predicted Critical Path Total Float (CPTF)**
  - The estimated value of critical path total float at the time of the project's completion.
- **IECD(tfci)**
  - The predicted Independent Estimated Completion Date (IECD) of the project based on current TFCI

Calculations

$$TFCI = \frac{Actual\ Duration + Critical\ Path\ Total\ Float}{Actual\ Duration}$$

- **Actual Duration (AD)**
  - The number of working days from the actual start of the program through the current status date of the IMS, and
- **Critical Path Total Float (CPTF)**
  - The calculated total float on the final activity along the project's critical path.

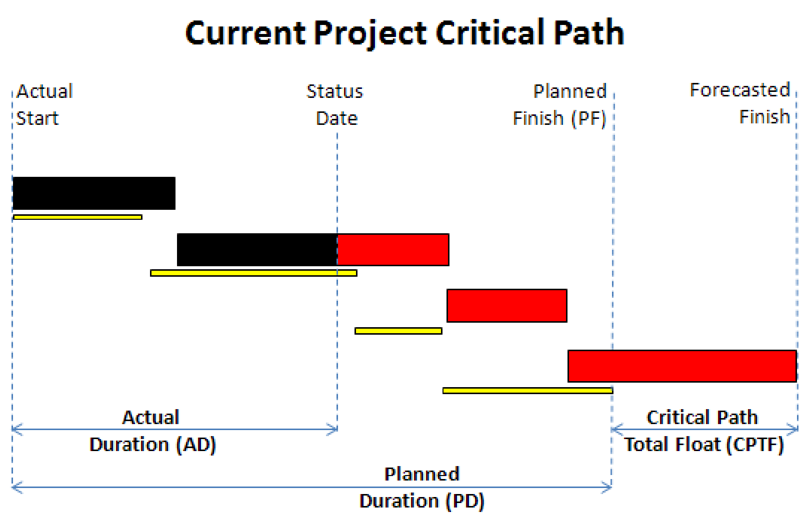


Figure 8. Components of TFCI

Once the current TFCI has been established, predictions about the future state of the project, as shown in Figure 9, can now be calculated.

$$Predicted\ CPTF = PD\ (TFCI - 1)$$

$$IECD(tfci) = PF - Predicted\ CPTF$$

- **Planned Duration (PD)**
  - The baseline duration of the project.
- **Planned Finish (PF)**
  - The baseline finish date of the project.

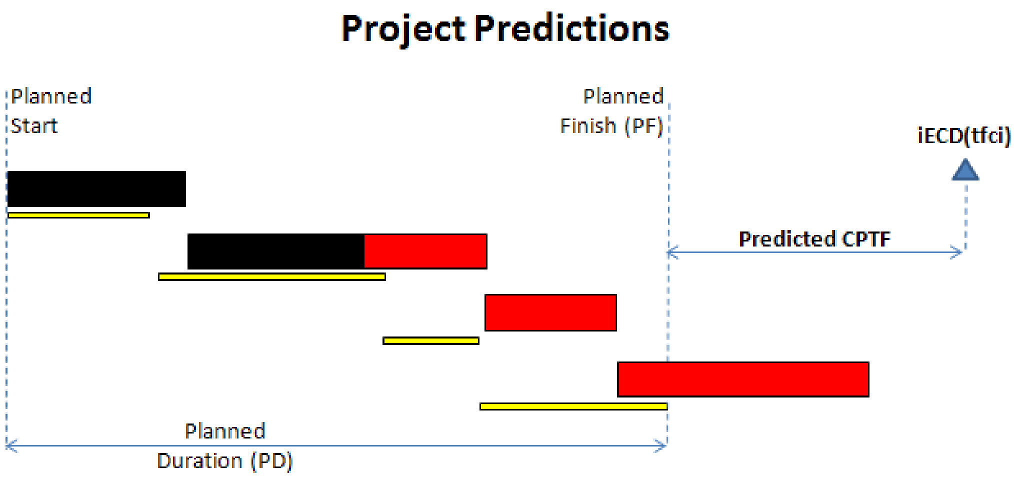


Figure 9. Predicted Project Completion Based on TFCI

Note: The durations for the elements of TFCI (such as predicted CPTF or planned duration) should be measured in working days, using the predominant calendar for the project.

Output/Threshold

TFCI

Similar to reading SPI or BEI, a TFCI value of 1.00 indicates the effort is forecasted to progress as planned (per the baseline). Values above 1.00 denote better performance than planned, while values below 1.00 suggest poorer performance than planned.

TFCI Value	*Implication*
> 1.00	**FAVORABLE** - The effort is being forecasted to be completed at a faster rate than planned
= 1.00	**ON TRACK** - The effort is forecasted to complete on plan
< 1.00	**UNFAVORABLE** - The effort is being forecasted to be completed at a slower rate than planned

Additional thresholds can also be set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

TFCI 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") -The effort is forecasted to be accomplished on or slightly ahead of plan
0.95 - 0.99	**YELLOW** ("caution") -The effort is forecasted to be accomplished slightly behind the plan
<0.95	**RED** ("warning") -indication of poor execution and/or poor planning (overly-aggressive)

Predicted CPTF

There are no prescribed thresholds for Predicted CPTF because its practical application will differ greatly from project to project. Although the prospect of finishing a project late is never desirable, completing 1 month late on some projects may have minimal impact while finishing just 1 day late on other projects can have severe consequences. In this metric, as Predicted CPTF decreases (becomes more negative), the risk to completing the project on time increases.

IECD(tfci) ≈ IMS Forecast

- When the IECD(tfci) is close to the completion date that is forecasted in the project's IMS, downstream schedule performance is in line with the total float trending that has been observed to date. While this does not guarantee the forecast accuracy of future deliverables, it does increase confidence in the IMS.

IECD(tfci) > IMS Forecast

- When IECD(tfci) predicts a date that is significantly later than what is forecasted in the IMS, it may indicate an overly optimistic IMS; that is, in this case, the calculated estimate implies an expected increase in schedule performance over the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

IECD(tfci) < IMS Forecast

- When IECD(tfci) predicts a date that is significantly earlier than what is forecasted in the IMS, it may indicate an overly pessimistic IMS that implies an expected decrease in schedule performance for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

Predictive Nature

While Schedule Risk Assessments (SRAs) are vital components of sound project management, performing a thorough analysis can be a time-consuming effort typically requiring the acquisition of an additional software application. The intent of TFCI is to complement SRAs by providing a quick and easy method of assessing the magnitude of schedule risk existing on a project.

Even though TFCI and SPI are both schedule performance ratios, they are fundamentally different in two areas:

- **All Activities vs. Critical Path Tasks Only**
  - SPI is calculated based on the performance on all activities in the IMS, while TFCI is only affected by the activities along the project's critical path.
- **Past vs. Future**
  - SPI is based solely on past performance, while the TFCI calculation is primarily determined by the change in total float on the last future activity in the project.

Possible Questions

- Is the current critical path reasonable?
  - Do schedule metrics such as Incomplete Logic and Constraints suggest that the IMS is in sound enough shape to be able to create a valid critical path?
  - Do metrics such as the Current Execution Index indicate that the IMS is being well maintained?
  - Do metrics such as SPI(t) vs. TSPI indicate that demonstrated past performance is being taken into consideration when forecasting future performance?
  - Are known schedule risks and opportunities being incorporated into the IMS?
- Is TFCI trending up or down? If so, what are the key drivers?
- If TFCI < 1.0, what is the recovery plan? Is it realistic given the available resources?

Caveats/Limitations/Notes

- TFCI is based in part on subjective forecasts and, as such, can be manipulated. If a project has a poor SPI, there is nothing that can immediately be done about it other than to start performing better so that future SPI is increased. TFCI, on the other hand, can be directly (and immediately) changed simply by modifying the forecasted completion of the critical path. In short, a poor TFCI can be improved without actually improving schedule performance. Because of this, significant changes in TFCI should warrant a review of the critical path forecast changes.
- The inclusion of schedule buffer/margin in the IMS can complicate the calculation of TFCI because changes to total float cannot be suppressed for the metric to function properly.
- If the initial critical path for a project was early to its baseline plan (so that some amount of slippage could be absorbed without missing the end deadline), then TFCI would be misleading. TFCI assumes that the IMS baseline was set to an "as soon as possible" condition.

- TFCI can exaggerate predicted impact. TFCI functions on the premise that downstream forecasts are not adjusted based on past performance. If proper attention is given to accurate forecasting, TFCI can "double dip" the projected impact and predict a slip larger than past performance would suggest.
- Depending on how the IMS is modeled, the CPTF may not ever be greater than zero, even if the project is forecasted to complete earlier than planned. Because of this, TFCI is intended to be used to analyze delinquent projects only.
- An inherent property of the TFCI formula is early project instability. When a project is newly underway, its Actual Duration (AD) will be small. Since AD is the denominator of the TFCI equation, any change in CPTF in the numerator will have a magnified effect on the outcome of the metric. Because of this, less emphasis should be place on TFCI during the first few months of a project.
- TFCI should not be used as a stand-alone assessment of projected project performance, but in conjunction with other tools such as schedule risk assessments.

2.6 Earned Schedule (ES)

If you were behind schedule to meet some friends for dinner, would you call and tell them you were running about $10 late? Well, that is the way Earned Value Management (EVM) measures schedule performance.

EVM is a respected management tool for analyzing cost, schedule, and technical performance. While the fundamental components of EVM (BCWS, BCWP, and Actual Cost of Work Performed [ACWP]) are all plotted in dollars (y-axis) spread over time (x-axis), the perspective of EVM is skewed almost exclusively toward cost. As would be expected, all of the "cost" indices such as Cost Performance Index (CPI) and Cost Variance (CV) are most commonly derived from inputs measured in dollars (or other currency). What is not so intuitive is that "schedule" indices such as SPI and SV are also measure in terms of dollars, too, rather than time.

Earned Schedule (ES) [5] is an analytical technique that uses the exact same data as EVM, except that it uses the x-axis (time) values to derive its schedule metrics. By doing this, not only are the results more intuitive (time-based rather than dollar-based, i.e. "I am running about 15 minutes late to dinner"), but ES also provides a more consistently accurate measure of true schedule performance.

ES offers many tools and indices to a management team. This Guide will focus on three of the most common and predictive measures:

- **Time-Based Schedule Performance Index (SPI[t])**
    - The schedule efficiency at which the project has performed to date.
- **SPI(t) vs. TSPI**
    - A comparison of past and future schedule efficiency.
- **Independent Estimated Completion Date from Earned Schedule (IECD[es])**
    - A mathematical calculation of project completion based on SPI(t).

2.6.1 Time-Based Schedule Performance Index (SPI_t)

Metric Definition

SPI(t) [5] is the Schedule Performance Index derived from Earned Schedule principles. The fundamental goal of SPI(t) is no different than traditional SPI, which is to provide a measure of the schedule efficiency to which the IMS has been performed to date. The difference with SPI(t) is that it overcomes the two fundamental obstacles inherent with traditional measures of SPI and Schedule Variance (SV):

1) SPI returns to 1.0 and SV returns to $0 at the completion of every project, regardless of whether planned commitment dates were met or not.
    - Causes SPI to be an ineffective measure of true project performance over the final 1/3 of the project.
2) Instead of measuring deviation from the IMS in units of time, traditional EV indices measure schedule variance in terms of dollars.
    - Results in an unintuitive method of assessing a deviation from the planned schedule.

Both SPI and SPI(t) use the exact same BCWS and BCWP plots, as shown in Figure 10, except from different perspectives. Traditional SPI uses the y-axis ($) values of BCWS and BCWP, while SPI(t) uses the x-axis (time). At project completion, the y-axis ($) values of BCWP and BCWS will be exactly the same, while the final x-axis (time) values can be considerably different depending on how early or late the project completed. By shifting the focus to time, SPI(t) avoids both of the above problems, yielding accurate, intuitive, and actionable results through the entire life of the project.

Calculations

$$SPI(t) = \frac{\textbf{Earned Schedule } (ES)}{\textbf{Actual Duration } (AD)}$$

- **Earned Schedule (ES)**
    - The amount of time that was originally planned to take (from the BCWS plot) to reach the current level of BCWP.
    - *ES = ED Date – BL Start*
- **Actual Duration (AD)**
    - The amount of time that has elapsed on the project to date.
    - *AD = Status Date – BL Start*

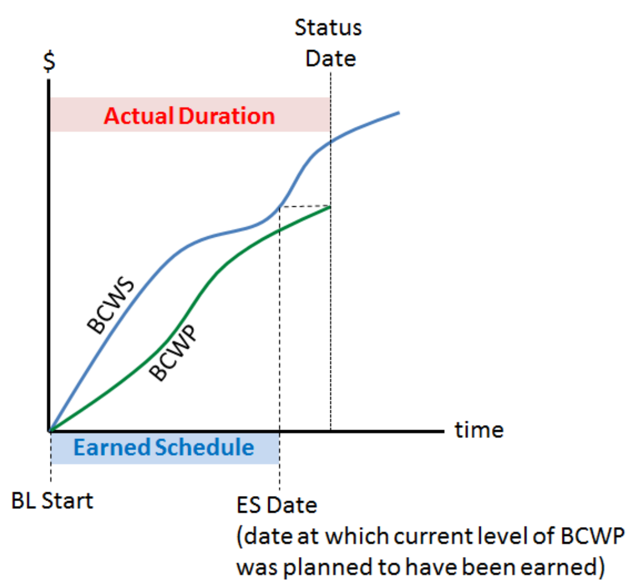


Figure 10.
Example BCWS and BCWP EV Plots

Output/Threshold

An SPI(t) of 0.85 means that it is taking a full day to accomplish what was planned to only take 0.85 days. Similarly, an SPI(t) of 1.1 indicates that it is only taking 1 day to accomplish effort that was planned to take 1.1 days.

Similar to reading SPI or BEI, an SPI(t) value of 1.00 indicates that the effort is progressing as planned (per the baseline). Values above 1.00 denote better performance than planned, while values below 1.00 suggest poorer performance than planned.

SPI(t) 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

Additional thresholds are commonly set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

SPI(t) 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)

Periodicity

- SPI(t) should be calculated and analyzed after each EV status period. For most programs this is monthly, but may be more or less frequent depending on the effort or contractual requirement.

Predictive Nature

Traditional SPI is a staple of EVM. It strives to provide an actionable gauge of project schedule performance. While initially SPI accomplishes this goal, the formula breaks down over the final third of the project. During this time, SPI trends will always skew toward 1.0 regardless of how the project is actually progressing, as shown in Figure 11.

The SPI(t) formula, on the other hand, retains its mathematical integrity over the entire project duration.

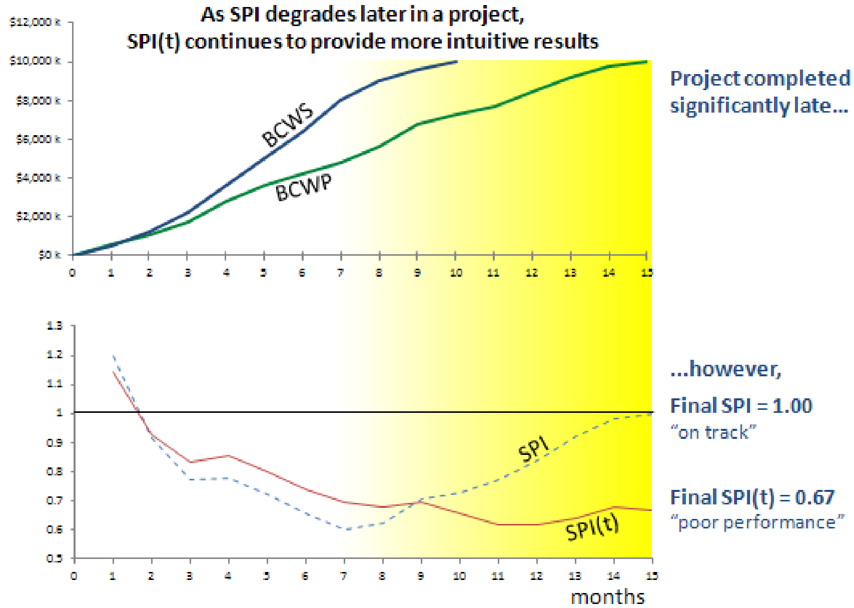


Figure 11. SPI vs. SPI(t) Differences

SPI(t) is fundamentally a rearward looking index, as it is derived entirely from historical data. As such, a program's SPI(t) calculation is completely independent of the remaining effort in the IMS. However, SPI(t) can be used in a predictive manner as a quick and easy gauge of future project execution risk, and as a historical basis to compare forecasted schedule efficiency.

Risk Assessment

- For most projects, past performance *is* indicative of future results, and SPI(t) is the most common measure of historical schedule performance.

Comparison to Forecasted Rate of Accomplishment

- Since SPI(t) is a historical measure of schedule performance, it can be used to challenge forecasted rates of accomplishment from other sources including TSPI, schedule rate charts (S-Curves), and other Shop Floor outputs. The IMS should be questioned if the forecasted plan suggests a rate of accomplishment that is significantly different than the program has achieved historically.

Possible Questions

- Is the SPI(t) in line with performance on the critical path? If not, why is the critical path different from the rest of the project on average?
- Is SPI(t) trending up or down? If so, what are the key drivers?
- Is the efficiency being skewed by a high percentage of LOE? What would the SPI(t) be for discrete tasks only?
- If SPI(t) < 1.0, what is the recovery plan? Is it realistic given the available resources?

- Is the SPI(t) demonstrated to date in line with the predicted performance as measured by TSPI? If not, what is the cause of the expected change in performance?

Caveats

- Like traditional SPI, SPI(t) 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 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(t) will be skewed upward and thus may not fully convey the magnitude of the schedule performance deficiencies.
- Traditional SPI and SPI(t) are both susceptible to being dampened by LOE. As the percentage of LOE on a project increases, both metrics' results are pushed toward 1.0. To mitigate this issue, SPI(t) can be calculated using BCWS and BCWP for discrete effort only.

2.6.2 SPI_t vs. $TSPI_{ed}$

Metric Definition

TCPI is a well-known measure of the future cost efficiency needed to meet program downstream goals. TCPI(bac) is the future cost efficiency that must be maintained in order to keep from over-running the project's Budget at Completion (BAC) target, while TCPI(eac) is the future cost efficiency that will be needed in order to achieve the current Estimate at Completion (EAC).

TSPI [5] is the scheduling counterpart to TCPI, as it is a measure of future schedule efficiency. TSPI(pd) is the future schedule efficiency that will be needed in order to not exceed the project's Planned/Baseline Duration (PD), while TSPI(ed) is the future schedule efficiency that will need to be maintained in order to achieve the current Estimated/Forecasted Duration (ED). This guide will focus on TSPI(ed) (see Figure 12).

Just as you expect the future cost efficiency of TCPI(eac) to be similar to the CPI that has been demonstrated to date, the forecasted schedule efficiency of TSPI(ed) is generally expected to be in line with the SPI(t) pace that has been demonstrated thus far in the project.

Calculations

$$SPI(t) = \frac{\text{Time planned to arrive at the current BCWP level}}{\text{Time it has actually taken}} = \frac{ES}{AD}$$

$$TSPI(ed) = \frac{\text{Time planned to go from current BCWP to BAC}}{\text{Time we are now forecasting to do it in}} = \frac{PDWR}{RD}$$

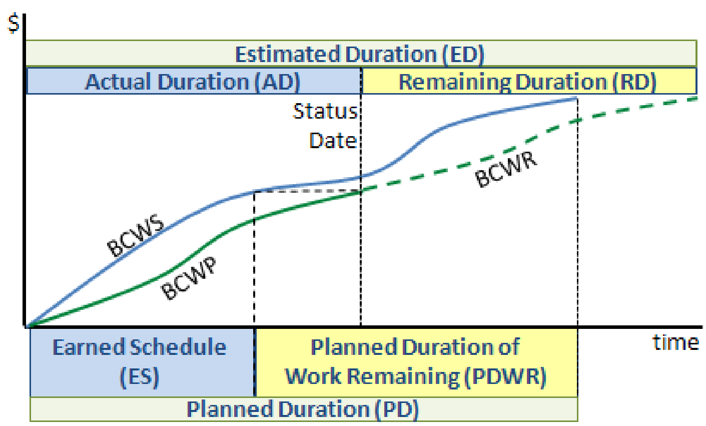


Figure 12. TSPI is the scheduling counterpart to TCPI

Output/Threshold

This metric differs from many others as it does not return a clear "pass/fail" result. Instead, it either increases or decreases the confidence in the forecasting accuracy of the IMS based on how close TSPI(ed) is to SPI(t).

This metric can be calculated at the control account or total program level. The threshold is set at 0.10 (10%) for this example, but can be adjusted to meet surveillance requirements.

|SPI(t) – TSPI(ed)| < 0.10

- When TSPI(ed) is close to SPI(t), downstream schedule performance is in line with the efficiency that has been demonstrated to date. While this does not guarantee the forecast accuracy of future deliverables, it does increase confidence in the IMS.

SPI(t) – TSPI(ed) > 0.10

- An SPI(t) – TSPI(ed) > 0.10 (10%) may indicate an overly pessimistic forecast; that is, in this case, the estimate implies an expected drop in schedule performance by 0.10 (10%) or more for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

SPI(t) – TSPI(ed) < -0.10

- An SPI(t) – TSPI(ed) < 0.10 (10%) may indicate an overly optimistic forecast that implies an expected increase in schedule performance by 0.10 (10%) or more for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

Predictive Nature

If a driver averages 40 mph over the first half of his road trip from L.A. to New York, could he average 65 mph for the entire trip? Based on the performance demonstrated so far, the answer would be "No." SPI(t) and TSPI(ed) function the same way; SPI(t) is your average speed so far, and TSPI(ed) is the speed you claim to be able to maintain the rest of the trip. The more your future speed (TSPI(ed) differs from your current average speed (SPI[t]), the more questions you should ask about the accuracy of your forecasts.

However, SPI(t) – TSPI(ed) is just a guide. On your cross-country road trip, what if your car overheated in the Arizona desert, or you took the scenic route through the Rockies? If those are events you do not reasonably believe will occur over the remainder of your trip, maybe averaging 65 mph is not as far-fetched as it might have first seemed. A project should behave the same way. If the IMS forecasts a pace significantly different than what has been executed to date, then specific, identifiable events must be driving that change in performance (i.e., hired additional staff, moved to new facility, solved nagging fatigue test deficiencies, etc.).If a specific event cannot be identified, the credibility of the IMS decreases.

Possible Questions

- What factors might be causing future schedule efficiency to differ from what has been demonstrated to date? Change in resources/staffing? Change in facilities/capacity? Change in technology? Change in plan (OTB/OTS)? Change in complexity?

- Is the efficiency calculated by TSPI(ed) similar to the efficiency that has been executed along the project's critical path? If not, why?
- Has SPI(t) been trending up or down? If so, does TSPI(ed) more closely resemble recent SPI(t)?
- Is TSPI(ed) very close to 1.00? If so, do we believe it is an accurate representation of the future effort, or are downstream tasks simply being ignored?
- If SPI(t) < 1.0 and TSPI(ed) > 1.00, are we simply shrinking future tasks to artificially hold delivery deadlines? Is it possible to make the improvement necessary to achieve the efficiency needed?

Caveats/Limitations/Notes

Not all discrepancies between SPI(t) and TSPI(ed) indicate an unreliable forecast, because there can be reasons to believe that past performance is *not* indicative of future results:

- Changes in staffing levels or proficiency
- Changes in facility capacity
- Changes in suppliers
- Changes in technology
- Performing an OTB/OTS.

2.6.3 Independent Estimated Completion Date – Earned Schedule ($IECD_{es}$)

Metric Definition

If you have been averaging 50 mph so far on your road trip and are 200 miles from your destination, when will you arrive? One way to answer that question is to assume the speed on the remainder of your trip will be the same as what you have averaged so far. So if it is currently noon, then it should take you 4 hours to cover the remaining distance, which would have you arriving at 4:00 PM.

Similar to the way we calculated the arrival time on our road trip, IECD(es) [5] is a calculated estimate of a project's eventual completion date. The calculation takes the current average pace of schedule execution as measured by SPI(t) and projects that same pace over the remainder of the unexecuted portion of the plan. Components of an IECD are shown in Figure 13.

NOTE: While the acronym IECD(es) is used here for consistency with other nomenclature within this Guide, other symbology such as "IEAC(t)" (time-based Independent Estimate at Completion [IEAC]) is an equivalent method to provide an estimate of project duration.

Calculations

$$IECD(es) = SD + \frac{PDWR}{SPI(t)}$$

or (equivalently),

$$IECD(es) = PS + \frac{PD}{SPI(t)}$$

where,

$$PDWR = PD - ES$$

$$SPI(t) = \frac{ES}{AD}$$

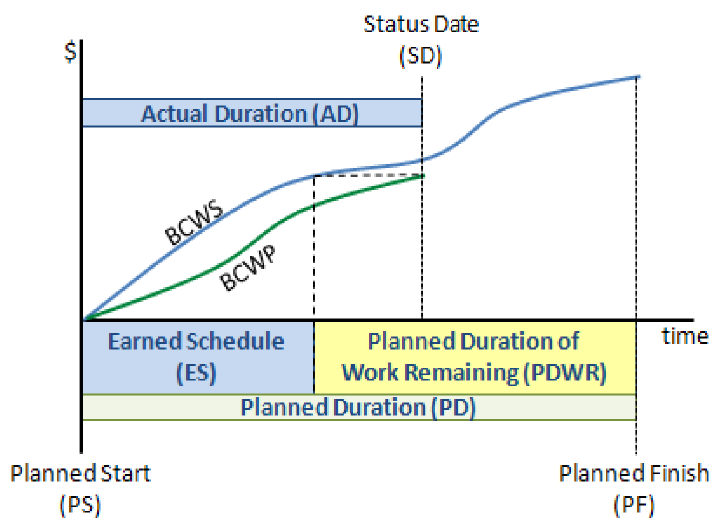


Figure 13. Components of an IECD

Note: The durations components such as PDWR, PD and ES should be measured in working days, using the predominant calendar for the project.

Output/Threshold

Similar to the SPI(t) – TSPI(ed) metric, IECD(es) does not return a clear "pass/fail" result. Instead, it either increases or decreases the confidence in the forecasting accuracy of the IMS based on how close the calculated IECD(es) is to the forecast derived from the IMS.

Under certain circumstances this metric can be calculated for individual control accounts, but it is typically applied at the total program level.

IECD(es) ≈ IMS Forecast

- When the IECD(es) is close to the completion date that is forecasted in the project's IMS SPI(t), downstream schedule performance is in line with the efficiency that has been demonstrated to date. While this does not guarantee the forecast accuracy of future deliverables, it does increase confidence in the IMS.

IECD(es) > IMS Forecast

- When IECD(es) is predicting a date that is significantly later than is forecasted in the IMS, it may indicate an overly optimistic IMS; that is, in this case, the calculated estimate implies an expected increase in schedule performance over the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

IECD(es) < IMS Forecast

- When IECD(es) is predicting a date that is significantly earlier than is forecasted in the IMS, it may indicate an overly pessimistic IMS. This implies an expected decrease in schedule performance for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast.

Predictive Nature

Most schedule metrics yield some sort of ratio. While these can be very informative, the magnitude of the discrepancy may not be completely intuitive. For example, an SPI(t) of 0.85 is not ideal, but what will that mean in terms of project completion? While the calculations involved in producing an IECD(es) may be slightly more complex, the beauty of this metric is in the simplicity of its output. If an IMS is forecasting a project completion in July, but the IECD is predicting that the project will not end until November, a 4-month risk is being signaled.

Possible Questions

- What factors might be causing the calculated IECD(es) to be significantly different than the IMS forecast? Change in resources/staffing? Change in facilities/capacity? Change in technology? Change in plan (OTB/OTS)?
- Is progress along the critical path similar to the schedule performance for the entire project?
- Has recent schedule performance been significantly better or worse than overall performance?
- Does the project have a favorable Current Execution Index? If not, more attention should be given to the IECD(es), since the poor CEI calls the credibility of the IMS forecasts into question.
- Is the calculated IECD(es) in line with SRA results? If not, why?

Caveats/Limitations/Notes

Not all discrepancies between the IMS and the calculated IECD(es) indicate an unreliable forecast, as there are inherent differences in their calculations:

All vs. Critical Path

- The IECD(es) is based on average schedule performance (as measured by SPI[t]) across the entire project to date, while the IMS completion forecast is driven only by the tasks currently forming the project's critical path. So, for example, if performance along the critical path has been significantly worse than schedule progress on the whole, it would not be unusual for the IECD(es) to predict a project completion date much earlier than the IMS.

Past vs. Future

- The IECD(es) uses past schedule performance as the sole gauge for predicted downstream effectiveness, while the IMS forecast is based solely on estimates of future performance. Therefore, if there are specific reasons to believe that past performance is *not* indicative of future results, less emphasis should be placed in IECD(es) results. For example, if an erratic major supplier has recently been replaced by another more reliable one, future schedule performance is likely to improve. Because of this, the IECD(es) may yield a prediction that is much later than forecasted in the IMS.

Want a second (or third) opinion? SPI(t) is the performance factor that is used to calculate IECD(es). Other schedule-based performance factors can also be used to help provide additional perspectives. Just remember, any weakness/shortcoming associated with the performance factor will then also apply to the resulting IECD. For example, since SPI skews toward 1.00 as a project nears completion, an IECD calculated using SPI in the equation will also become more and more diluted over time. Other IECD examples include:

$$\boldsymbol{IECD(bei) = SD + \frac{PDWR}{BEI}} \quad (using\ the\ Baseline\ Execution\ Index)$$

$$\boldsymbol{IECD(tfci) = SD + \frac{PDWR}{TFCI}} \quad (using\ the\ Total\ Float\ Consumption\ Index)$$

$$\boldsymbol{IECD(spi) = SD + \frac{PDWR}{SPI}} \quad (using\ traditional\ SPI)$$

$$\boldsymbol{IECD}(?) = \boldsymbol{SD} + \frac{\boldsymbol{PDWR}}{?} \quad (using\ other\ schedule\ performance\ indices)$$

3 Cost Metrics

Section Summary

Cost Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
CPI	Cost Performance Index	A measure of the cost efficiency relative to the performance of tasks and completion of those tasks.		3.1
BCWP	Budgeted Cost for Work Performed	The value of completed work expressed as the value of the performance budget assigned to that work.		3.1
ACWP	Actual Cost of Work Performed	The sum of the actual costs incurred for all work performed within a given time period.		3.1
TCPIeac	TCPIeac	TCPI(eac) is the average future cost efficiency that must be maintained going forward in order to achieve a project's EAC.		3.2
ETC	Estimate to Complete	The estimated cost to complete the remaining scope on a project.		3.2
EAC	Estimate at Completion	The projected total cost of a project.		3.2
BCWR	Budgeted Cost for Work Remaining	The value of completed work expressed as the value of the performance budget assigned to that work.		3.2
BAC	Budget at Complete	The total planned value of a project.		3.2
IEAC	Independent Estimates at Completion	IEAC is a metric that projects historical efficiency forward to mathematically calculate the total projected cost of a project without influence from other subjective variables.		3.3

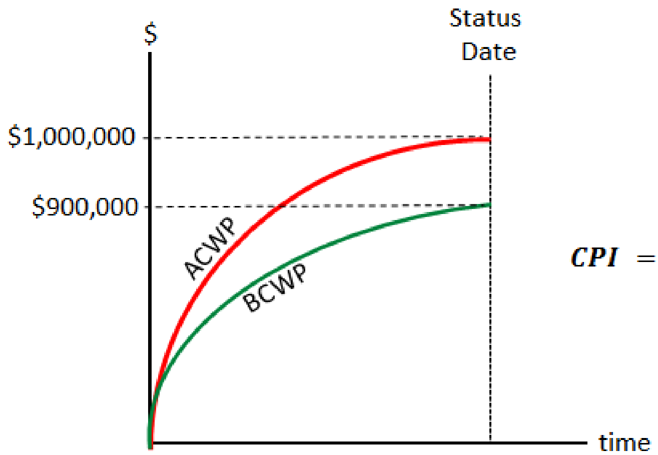
3.1 Cost Performance Index (CPI)

Metric Definition

CPI, shown in Figure 14, is a measure of the cost efficiency relative to the performance of tasks and completion of those tasks. It is derived from the project's Cost Accounting System and used to provide an early warning that course corrections are required in order to meet the objectives of the project and minimize the impact of risk.

Calculations

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



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

Figure 14. CPI Example

- **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, represents cumulative to-date values unless some other time period is specified.
  - Also referred to as the Earned Value (EV).
- **Actual Cost of Work Performed (ACWP)**
  - The sum of the actual costs incurred for all work performed within 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, represents cumulative to-date values unless some other time period is specified.
  - Also referred to as the Actual Cost (AC).

Output/Threshold

Similar to reading Schedule Performance Index (SPI), a value of 1.00 indicates the effort is being accomplished at the planned efficiency (per the baseline). Values above 1.00 denote efficiency better than planned, while values below 1.00 suggest poorer efficiency than planned.

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

Additional thresholds are commonly set to further categorize (color-code) performance. The specific value thresholds can be tailored depending on the nature and criticality of the effort.

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 planned
<0.95	**RED** ("warning") -indication of poor efficiency and/or poor planning (overly "challenged" budgets)

Periodicity

- CPI should be calculated and analyzed after each EV status period. For most programs, this is monthly, but may be more or less frequent depending on the effort or contractual requirement.

Predictive Nature

CPI is fundamentally a rearward-looking index, as it is derived entirely from historical data. As such, the CPI calculation is completely independent of a program's Estimate to Complete (ETC). However, CPI can be used in a predictive manner as a quick and easy gauge of future project cost risk, as a historical basis to compare forecasted cost efficiency, and to make projections based on observed trends. CPI may appear favorable or unfavorable at a point in time, however the ability to assess a trend over time, may foreshadow future performance.

Risk Assessment

- A CPI less than 1.00 indicates that the work accomplished to date was, on average, over budget. The further below 1.00 the CPI drops, the higher the risk of failing to complete the project on budget is. An estimate of this risk can be calculated by projecting the efficiency demonstrated to date over the remaining effort on the project. See Range of IEACs (Independent Estimates at Completion).

Comparison to Forecasted Rate of Efficiency

- Because CPI is a historical measure of cost efficiency, it can be used to challenge the forecasted efficiency rate, or To Complete Cost Performance Index (TCPI). The project's EAC should be questioned if the TCPI suggests a rate of efficiency that is significantly different than that which the project has achieved historically.

Trend Analysis

- *CPI (or Cumulative CPI):* The most common indicator used to analyze cost performance data. It represents the average efficiency at which work has been performed to date. CPI stabilizes largely because it is a cumulative index. As the project progresses, monthly BCWP and ACWP have decreasing influence on the cumulative CPI. The capability of future performance to significantly alter the cumulative record of past performance decreases as the contract progresses.
- *Current CPI:* Another indicator used to analyze cost performance data. It represents the average efficiency that work has been performed for the current (i.e. most recent) reporting period. Unlike cumulative CPI, there is no dampening effect on the current CPI trend as a project progresses. This is because there is no mounting backlog of historical data to overpower the most recent cost performance.
- As seen in Figure 15, looking at any single point in a vacuum can be misleading. Simply knowing that a project is running a CPI of 1.01 could result in a false sense of security. In Figure 15, the steady deterioration of cumulative CPI over the past year, combined with the fact that the current CPI has been below 1.00 each of the last 9 months, paints a very different picture of the state of the project.

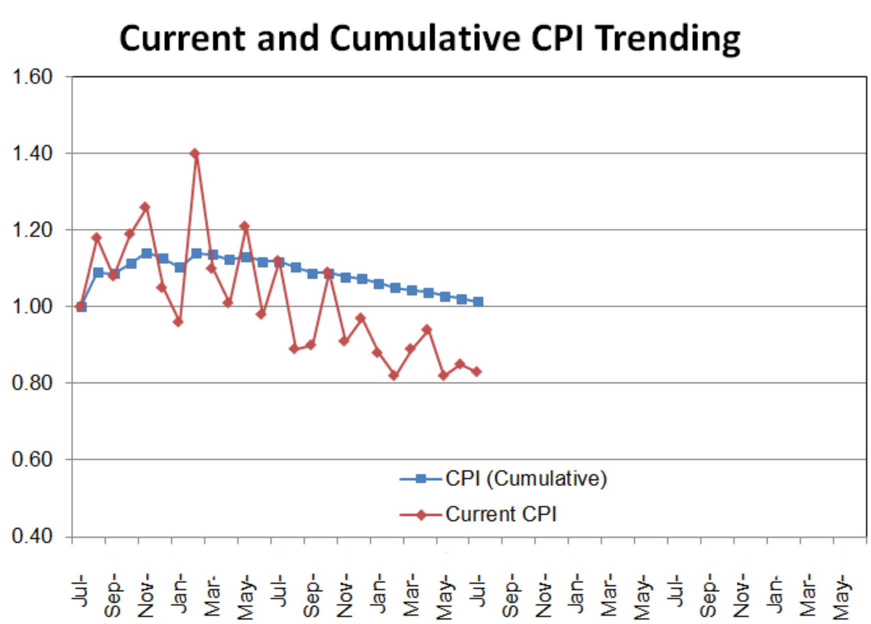


Figure 15. CPI Trending

Potential Questions

- Are current period CPI calculations trending up or down? If so, what are the key drivers?
- What will the program manager do to recover?
- If CPI < 1.00, is a recovery plan needed? Is it realistic?
- Is the CPI demonstrated to date within .10 of TCPI? If not, what is the cause of the expected change in efficiency?

3.2 Cost Performance Index vs. To Complete Cost Performance Index Estimate at Completion (CPI vs. TCPIeac)

Metric Definition

CPI is the cost efficiency a project has demonstrated to date. TCPI(eac) is the average future cost efficiency that must be maintained going forward in order to achieve a project's EAC. Unless effective corrective actions are being implemented, for a typical project, future efficiency will likely be similar to past efficiency if the same conditions exist (e.g. same resources, level of technical difficulty, etc. By comparing CPI and TCPI(eac), assessments can be made about the risk associated with achieving a project's EAC.

A CPI of 0.91 indicates that, to date, $0.91 of work was done for every dollar spent on the project. Similarly, a TCPI(eac) of 1.11 indicates that $1.11 worth of work must be done for every dollar spent to meet the current EAC.

Note: TCPI(bac) is another calculation of future cost efficiency, except it is the efficiency needed to achieve a project's BAC. Unlike TCPI(eac), TCPI(bac) is not expected to trend in a similar fashion to CPI.

Calculations

$$CPI = \frac{BCWP}{ACWP} \qquad TCPI(eac) = \frac{BAC - BCWP}{EAC - ACWP} = \frac{BCWR}{ETC}$$

- **Actual Cost of Work Performed (ACWP)**
  - The sum of the actual costs incurred for all work performed within 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, represents cumulative to-date values unless some other time period is specified.
  - Also referred to as the AC.
- **Estimate to Complete (ETC)**
  - The estimated cost to complete the remaining scope on a project. This includes the projected cost of completing in-progress work packages, as well as an estimate of the cost to complete all future work packages and planning packages.
- **Estimate at Completion (EAC)**
  - The projected total cost of a project. This is equal to the sum of all costs incurred to date and estimated costs going forward.
  - EAC = ACWP + ETC.

- **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, represents cumulative to-date values unless some other time period is specified.
  - Also referred to as the EV.
- **Budgeted Cost for Work Remaining (BCWR)**
  - The budget value of all work yet to be performed. This includes the unearned budget for in-progress work packages, as well as the budget for all future work packages and planning packages.
- **Budget at Complete (BAC)**
  - The total planned value of a project. This is equal to the sum of the budgets for completed work packages, in-progress work packages, and future work and planning packages.
  - Represents the value of BCWS at a project's completion (not cumulative to date).
  - BAC = BCWP + BCWR.

Output/Threshold

This metric differs from many others as it does not return a clear "pass/fail" result. Instead, it either increases or decreases the confidence in the projected accuracy of the project's EAC based on how close TCPI(eac) is to CPI.

This metric can be calculated at the control account level or total program level. The threshold is set at 0.10 for this example, but can be adjusted to meet surveillance requirements.

|CPI – TCPI(eac)| < 0.10

"In-Range"

Downstream cost efficiency is in line with the efficiency that has been demonstrated to date. While this does not guarantee the accuracy of the project EAC, it does increase confidence.

CPI – TCPI(eac) > 0.10

"Pessimistic"

May indicate an overly pessimistic estimate; that is, in this case, the estimate implies an expected drop in cost efficiency by 0.10 or more for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the estimate. Indicates an increased likelihood that the project's EAC may be too high or that the remaining work is expected to be more difficult/less efficient.

CPI – TCPI(eac) < -0.10

"Optimistic"

May indicate an overly optimistic forecast that implies an expected increase in cost efficiency by 0.10 or more for the remainder of the effort. It should be used as a flag for further investigation into the reasonableness of the forecast. Indicates an increased likelihood that the project's EAC is too low.

As TCPI diverges from CPI, as shown in Figure 16, the likelihood of achieving that cost target decreases because the gap between demonstrated efficiency and the efficiency needed to reach the estimate widens.

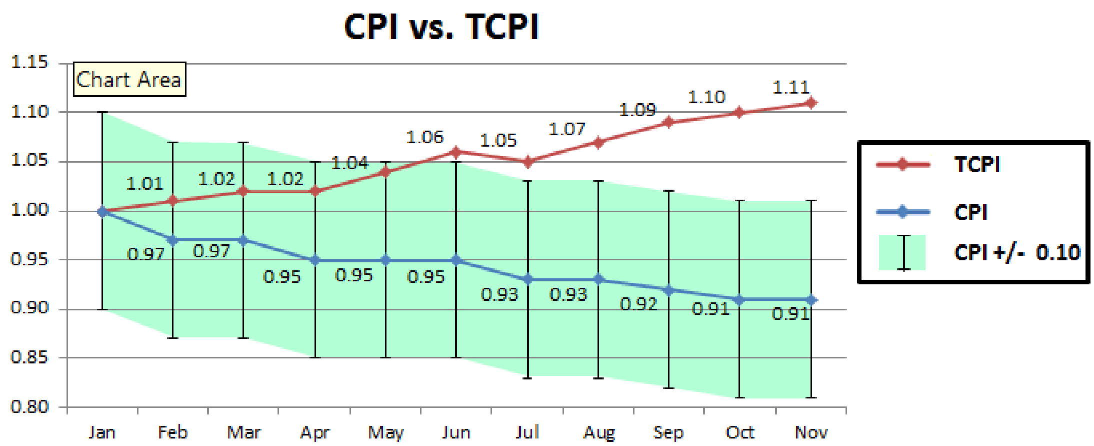


Figure 16. CPI vs. TCPI

Predictive Nature

If a project ran at a CPI of 0.90 over the first half of the contract, a TCPI(eac) of 1.10 for the remainder of the contract is not necessarily credible. CPI – TCPI(eac), however, is just a guide. For example, if a substantial one-time expedite fee had been paid to a vendor (unplanned) or process improvements have now been put in place that are expected to dramatically reduce costs, it might be reasonable to believe that efficiency going forward can improve significantly. Under normal circumstances, CPI and TCPI(eac) should be expected to be similar, but when they are not, there should be specific, identifiable causes to help explain the change in future performance.

Potential Questions

- Are CPI and TCPI(eac) diverging (indicating an unrealistic EAC)?
- If so, what factors might be causing future cost efficiency to differ from what has been demonstrated to date? Change in resources/staffing? Change in facilities/capacity? Change in technology? Change in plan (OTB/OTS)?
- Has CPI been trending up or down? If so, does TCPI(eac) more closely resemble current period CPI values?

- Is TCPI(eac) very close to 1.00 (regardless of CPI value)? If so, is it an accurate representation of the future effort, or are downstream tasks simply being ignored?
- If CPI < 1.00 and TCPI(eac) > 1.00, are future ETCs being reduced to artificially project meeting the BAC target?
- If the CPI is being calculated at the CA or higher, the amount of LOE can skew the CPI since BCWP is earned as a passage of time.

3.3 Range of IEACs (Independent Estimates at Completion)

Metric Definition

IEACs are metrics that projects historical efficiency forward to mathematically calculate the total projected cost of a project without influence from other subjective variables. IEACs can then be used as a “sanity check” for the project’s EAC.

Note: Although the IEACs described in this section are in reference to the total project, they can also be applied to a subset of a project such as a Control Account or a grouping of similar control accounts.

Calculations

Because there are multiple ways to measure historical performance, there are multiple methods of calculating an IEAC. Four common IEAC formulas are described in Table 1.

Table 1. Four Common Ways of Calculating IEAC

IEAC	Formula	Assumption	Comments
IEAC1	$= \boldsymbol{ACWP} + \dfrac{\boldsymbol{BAC - BCWPcum}}{\boldsymbol{CPI}}$	Future cost performance will be the same as all past cost performance.	“Best Case” when CPI is less than 1.0 and “Worst Case” when CPI is greater than 1.0.
IEAC2	$= \boldsymbol{ACWP} + \dfrac{\boldsymbol{BAC - BCWPcum}}{\boldsymbol{SPI}}$	Future cost performance will be influence by past schedule performance.	Use with caution as SPI is diluted by LOE and loses accuracy over the last third of the project.
IEAC3	$= \boldsymbol{ACWP} + \dfrac{\boldsymbol{BAC - BCWPcum}}{\boldsymbol{SPI \times CPI}}$	Future cost performance will be influence by past schedule and cost performance.	In contrast to IEAC1, this calculation typically yields the “Worst Case” when SPI and CPI are less than 1.0.
IEAC4	$= \boldsymbol{ACWP} + \dfrac{\boldsymbol{BAC - BCWPcum}}{\boldsymbol{(0.2 \times SPI) + (0.8 \times CPI)}}$	Similar to IEAC3, except increased weight is placed on CPI.	More reliable than IEAC3 late in a project since less weight is given to SPI.

Note: “Best Case” is also referred to as “$IEAC_{min}$”, while “Worst Case” is also known as “$IEAC_{max}$”

Output/Threshold

Once a set of IEACs are calculated, they create a confidence band that spans between the lowest and highest IEAC values. This is not a “pass/fail” metric; however, it can be used as a sanity check of the project EAC. Generalizations can then be made depending on where the project’s EAC falls in comparison to the IEACs (see Figure 17).

Lowest IEAC ≤ Project EAC ≤ Highest IEAC

"In-Range"

The EAC for the project is consistent with historical performance. While this does not guarantee an accurate EAC, it does increase confidence.

Project EAC < Lowest IEAC

"Optimistic"

The EAC for the project is lower than historical performance would indicate. While this does not guarantee an inaccurate EAC, it does reduce confidence unless specific changes can be cited that are reasonably expected to improve the lower past cost efficiency.

Project EAC > Highest IEAC

"Pessimistic"

The EAC for the project is higher than historical performance would indicate. While this does not guarantee an inaccurate EAC, it does reduce confidence unless specific changes can be cited that are reasonably expected to degrade the higher past cost efficiency.

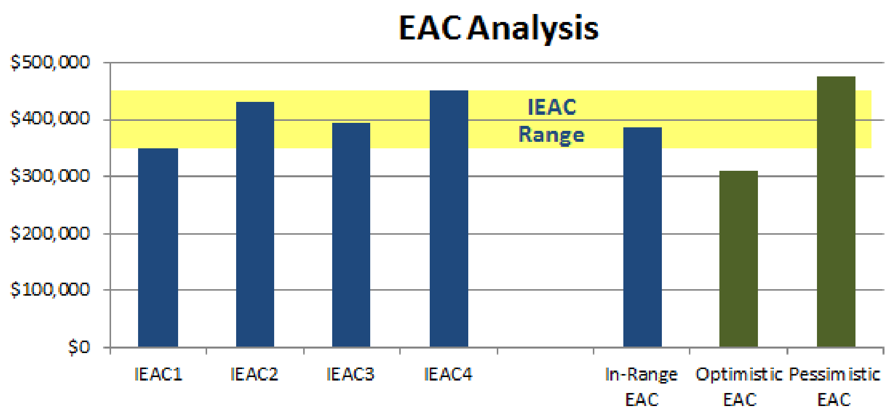


Figure 17. Range of IEACs

Predictive Nature

A PM's assessment of EAC should be the most accurate information available. The PM will be able to incorporate high potential risks and opportunities that did not materialize in the past. However, that same human element that allows for improvements over the purely mechanical computations of an IEAC can also be a detriment. Optimism and pessimism do not support sound judgments about a team's ability to execute and overcome obstacles.

IEACs provide a purely objective sounding board for a PM to analyze the subjective elements of the project EAC. IEACs near the project EAC help validate those judgments. However, when the IEACs consistently differ from the project EAC with no significant rationale to account for the expected change in cost efficiency, the project EAC should be re-evaluated.

Possible Questions

- What factors might be causing the calculated IEACs to be significantly different than the project EAC?

  - Upcoming high probability risk or opportunity?
  - Change in resources/staffing?
  - Change in facilities/capacity?
  - Change in technology?
  - Change in plan (OTB/OTS)?
- Has recent cost efficiency been significantly better or worse than overall performance? Would IEACs calculated with recent CPI be more in line with the project EAC?
- Have the CAMs been given an unrealistic challenge?

Caveats/Limitations/Notes

- Like an SRA measures the risk associated with meeting schedule deadlines, a Cost Risk Analysis (CRA) can be used to add insight into the probability of achieving a project's EAC.

4 Staffing Metrics

Section Summary

Staffing Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
Critical Skills Metric	Critical Skills Key Personnel Churn	The Critical Skills metric is a staffing metric that tracks turnover of critical skilled project team members within the program organizational or Integrated Product Team (IPT) structure.		4.2
Resource Multiplexing Metric	Critical Resource Multiplexing Metric	The Resource Multiplexing Metric is intended to measure the percent of personnel dedicated to the program vs. the percent that is spread across multiple programs.		4.3

4.1 Staffing Profile

Identifying and obtaining the right team members at the right times is critical to a program's success. The team leaders should not start executing a program without commitments from the Staffing/Resource Managers. The earlier in the lifecycle of the program that the staffing requirements are identified and conveyed, the better the program will be able to ensure that the correct staffing profile is established to successfully execute the program.

Metric Definition

A time-phased, 12-month rolling full-time equivalent (FTE) headcount by product, organizational, or functional area of individuals required on the program comprises the staffing profile that has been developed as part of the time phased baseline and forecast/estimate to complete (ETC) plan. It includes a program-determined number of actual months and forecasted (demand) months (i.e., 3 months of actuals and 9 months of forecast/ETC). The staffing profile is an indicator of future staffing trends on the program.

Output/Threshold

Comparison staffing projections vs. staffing actual by month.

Predictive Nature

Figure 18 is an effective project management tool that provides the following predictive information:

1. Forecasted data indicate the program's staffing needs. Analysis of data and interacting with staffing/resource managers is essential to ensure staffing availability.

2. Significant changes to the forecasted staffing needs require active management to ensure that either insufficient staffing conditions or excessive staffing conditions are resolved in a timely manner.

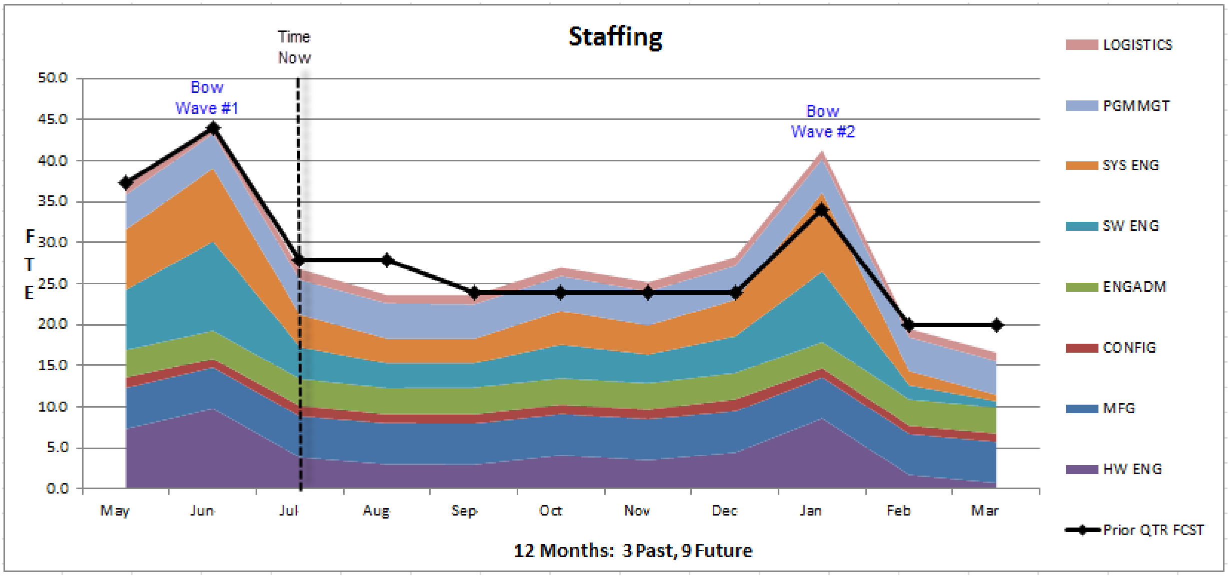


Figure 18. Staffing Profile Chart

Bow Wave Effect Root Causes

- Results from improper planning or expiration of ETC
- Incorrect finish date of task and therefore improper phasing of resources.
- ETC is not removed when the task is complete.
- ETC being "hoarded"
    - Poor Behavior: Keeping all ETC hours when full ETC no longer needed—attempting to preserve EAC at current level (holding MR at the Task Level).
    - Good Behavior: Using ETC as a metric analysis for remaining work—results in more realistic ETC.
    - Signs of hoarding: CPI = 1.20; TCPI= 0.80
        - Based on past favorable cost performance of 1.20, remaining effort can be completed less efficiently.
        - Rule of Thumb: Keep difference between CPI and TCPI < 0.10.
- Human Nature – Optimism can lead to the attitude that activities that did not get completed yesterday will get completed tomorrow (including all the new tasks for tomorrow). A more realistic approach places the task and, therefore, the resources in the appropriate periods.

Possible Questions

- What is being done to correct staffing shortages or excesses? What is the recovery plan and what mitigation actions is the program taking?
- Has the program filled all of the Key/Critical positions? The team may want a way to isolate the Key/Critical positions to understand if there are gaps that need to be addressed as a high priority.
- Do the recovery plan and mitigation actions make sense? For example, is the plan to use staffing from other programs that are winding down?
- Has the program finalized its external resourcing decisions yet? Are supplier agreements in place yet? Is there a chance that planned work may require internal staffing that is not part of the current staffing plan?
- Has the program considered external resources such as contract labor in their forecast? Has the program considered outsourcing scope to a subcontractor to assist with staffing demand peaks?
- Are Key/Critical Subcontractors meeting deliverable schedule? If not is there a get well plan and/or are alternate sources being considered? Is there a chance that subcontractor issues will require additional staffing that is not part of the forecast to resolve issues?
- Does the recovery plan include the appropriate critical or key skills for the program experiencing the staffing shortages?
- Is the team able to explain any staffing peaks or drop-offs?
- How does the staffing plan compare to the work remaining of the PMB?

Caution

- Metrics should be collected and analyzed, at a minimum, on a monthly basis for signs and trends of improper planning and/or expiration or hoarding of ETC (Bow Wave Effect).
- Pay attention to the trends in staffing forecast versus functional area forecast. In addition to analyzing overall program level staffing forecast, review functional area staffing forecast to ensure reasonableness.
- Establish a staffing plan for the resources that the program is guaranteed to receive and consider documenting a formal risk item to the Project's Risk Register if it is believed that the project is at risk as pertains to securing staff or critical/key staff.

4.2 Critical Skills Key Personnel "Churn"/Dilution Metric

Critical Skills are key individuals that have a deeper-than-average knowledge or unique expertise in one or more of the following areas important to the project:

- Program interface and customer business portfolio.
- Program leadership of critical aspects of the project.
- Technical knowledge of critical aspects and emerging technology of the project.

Examples of individuals critical to successful program planning and execution include the PM, Technical Project Manager (TPM), or Lead Systems Engineer (LSE).

Often, program or resource managers have limited or no visibility into the number of concurrent project assignments that a given critical resource may have. Critical skilled resources are often multiplexed across several projects (dilution) or moved entirely to another project ("churn"/turnover). As a result, staffing the project with the right critical resources at the right time and the evaluation of staffing criticality is essential to a project's success.

Metric Definition

The Critical Skills metric is a staffing metric that tracks turnover of critical skilled project team members within the program organizational or Integrated Product Team (IPT) structure. Project team members are considered a Critical Skill if the loss of those individuals would directly or indirectly impact program technical requirements, compliance, cost or schedule performance, customer commitments, or program deliverables.

It is important that the program team identify critical skilled personnel early in the project timeline. Having a staffing plan that identifies critical skilled personnel is essential at contract award or authorization to proceed. The program team should not begin executing the program without a commitment from the Staffing/Resource Manager. The earlier the program team conveys the needs and critical skills required on the program, the more likely it is that the program will be staffed appropriately and that the program will succeed.

Figure 19 below includes an example of how the data is collected. It identifies each of the Key Members on the team and is updated monthly to represent turnover/churn ("C") or dilution ("K(D)").

For example, if a Key Member has been replaced entirely on the program, a "C", representing the "Churn" of the Key Member being replaced is inserted in the spreadsheet over the timeframe defined by the program. Therefore, in Figure19, a "C" was added in the months ranging from March through June to account for the learning curve of this particular Key Member being replaced.

If a Key Member is diluted, or is not 100% dedicated to the program, a "K(D)" representing "Key Dilution" is inserted in the spreadsheet over the timeframe of dilution. Therefore, in Figure 19, a "K(D)" was added to the months ranging from September through December to represent this dilution.

ACTUALS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Key Member (Name)	K	K	K	K	K	K						
Key Member (Name)	K	K	K	K	K	K	K	K	K(D)	K(D)	K(D)	K(D)
Key Member (Name)	K	K	K	K	K	K	K	K	K	K	K	K(D)
Key Member (Name)	K	K	K	K	K	K	K	K	K	K	K	K
Key Member (Name)	K	K	C	C	C	C						
Replacement (Name)			K	K	C	C	C	C				
Replacement (Name)					K	K	K	K	K	K	K	K
Key Member (Name)							K	K	K	K	K	K
Key Member (Name)							K	K	K	C	C	C
Replacement (Name)										K	K	K
Total Key: (K) + K(D)	5	5	5	5	5	5	6	6	6	6	6	6
Total Churn (C) + Key Dilution K(D)	0	0	1	1	2	2	1	1	1	2	2	3

Figure 19. Example spreadsheet input for Key Team Churn/Dilution Metric

Output/Threshold

Figure 20 below graphs the Critical Skills or Key Personnel Churn/Dilution metrics obtained from the data gathered in the spreadsheet in Figure 19. It is recommended, that these metrics be collected and analyzed at a minimum, on a monthly basis, for signs and trends of churn or dilution on the program. Graphing of the historical data will highlight possible trends in increasing churn and dilution of critical or key personnel as well as trends that do not change or diminish over time.

Specific critical skills personnel required on the project will likely change during the project lifecycle. The LSE, for example, is a critical skill early in the project lifecycle. The LSE is responsible for integrating the customer’s technical approach, as defined in the System Engineering Plan (SEP) or System Engineering Management Plan (SEMP),with the program team’s technical strategy/approach and ensuring that all operational and performance requirements are captured and balanced with program cost, schedule, and risk constraints. As the program transitions from design and development into production, the manufacturing program specialist would be added to the program critical skill personnel list. If these critical skills are identified early in the program phase, then the risk of incurring cost overruns, schedule delays, and/or impacts to end customer deliverables is minimized or entirely mitigated.

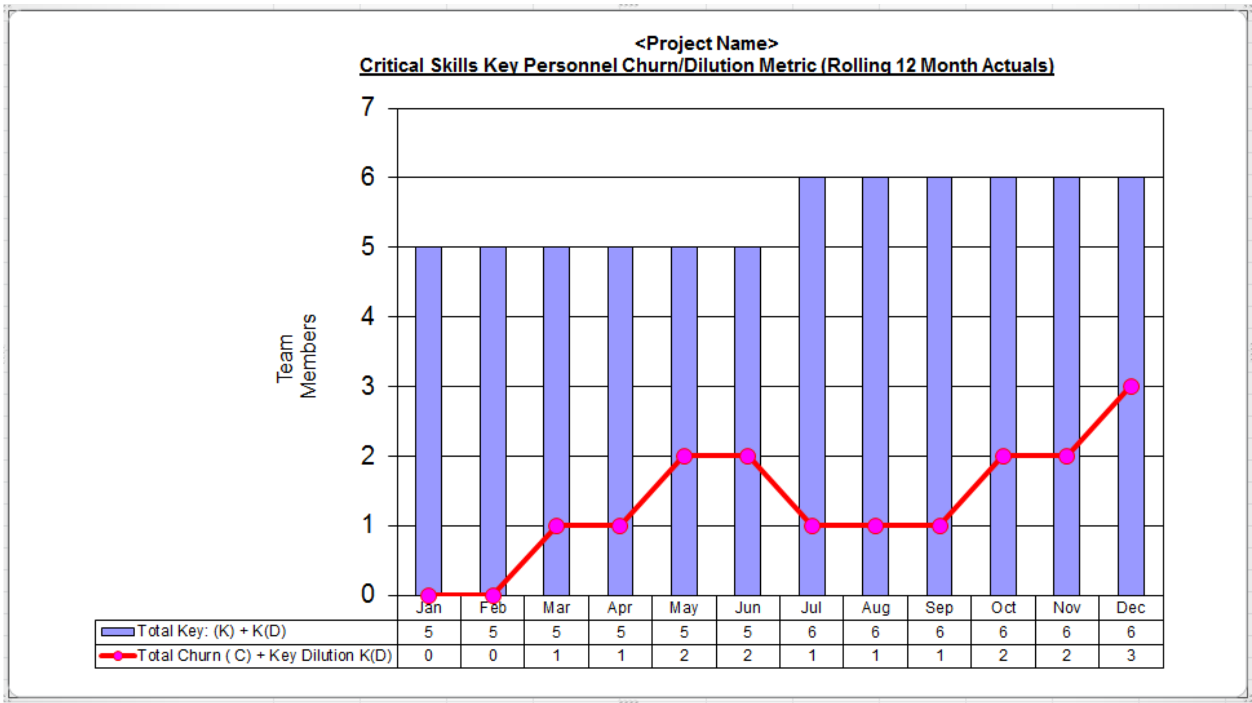


Figure 20. Example spreadsheet input for Key Team Churn/Dilution Metric

Possible Questions

- Will critical or key resources be available or replaced on the timeframe in which the project requires them?
- Are key/critical resources matrixed within the organization or fully dedicated to the program? Is there a risk that their availability could be impacted based on other commitment's future demand?
- What is the internal talent pool for any particular key/critical resource look like? Are the skills required for a particular skill specialized and additional training will be required to backfill open positions?
- What is the external talent pool for any particular key/critical resource look like? Is the industry market in high demand?
- Does the company have strategies or programs for recruiting, developing, and retaining critical skill workforces?
- What types of formal or on-the-job training is offered for employees being mentored or prepared for performing essential or critical operations?
- In addition to succession planning typically conducted at management or leadership areas within the enterprise, is succession planning performed in critical skill areas as well?
- Is physical preservation or recording of critical information and knowledge maintained within the enterprise?

Caution

- Agree early-on what is meant by “critical”, the tendency will be to make everyone critical.
- Metrics should be collected and analyzed at a minimum on a monthly basis for signs and trends of churn or dilution.
- Pay attention to the quantity of churn and dilution compared to the total number of critical or key personnel.
- Pay attention to the trends in increasing churn and dilution of critical or key personnel as well as trends that do not change or diminish over time.
- Establish a training plan for the resources that the program is guaranteed to receive and consider documenting a formal risk item to the Project’s Risk Register if it is believed that the project is at risk in securing critical or key personnel.
- Be sure to ask the question (of Resource Managers) whether the critical or key resources will be available or replaced during the timeframe in which the project requires them.

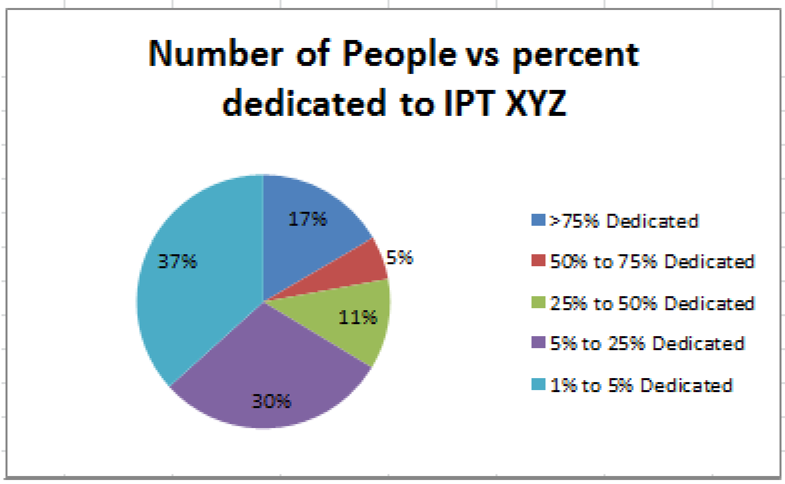
4.3 Critical Resource Multiplexing Metric

Metric Definition

One challenge facing program teams is the ability to balance the stability and continuity of dedicated personnel on the program. The Resource Multiplexing Metric is intended to measure the percent of personnel dedicated to the program vs. the percent that is spread across multiple programs. Performance inefficiencies, learning curve, and accountability issues can be expected when a large percentage of team members work on the program in a part time capacity. The key difference between the Critical Skills metric and this metric is that, while the Critical Skills metric tracks the team members by name with specialized critical skills needed on the program, this metric measures the level of multiplexing of the program team membership.

Output/Threshold

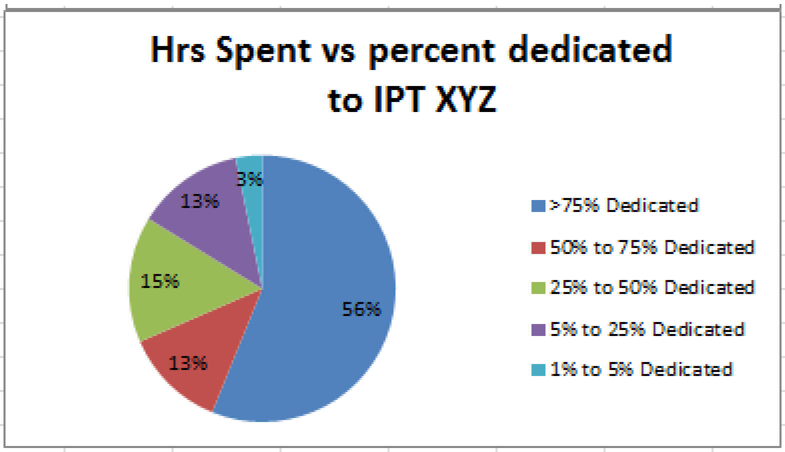
Figure 21 illustrates the number of people on a program vs. the percent dedication to the program. On the larger programs, a goal can be set as to the number desired to be >75% dedicated to the program, hence minimizing multiple program priority inefficiencies.



People	
>75% Dedicated	34
50% to 75% Dedicate	11
25% to 50% Dedicate	20
5% to 25% Dedicated	63
1% to 5% Dedicated	66
Total	194

Figure 21. Number of Personnel vs. Percent Dedicated to a Program

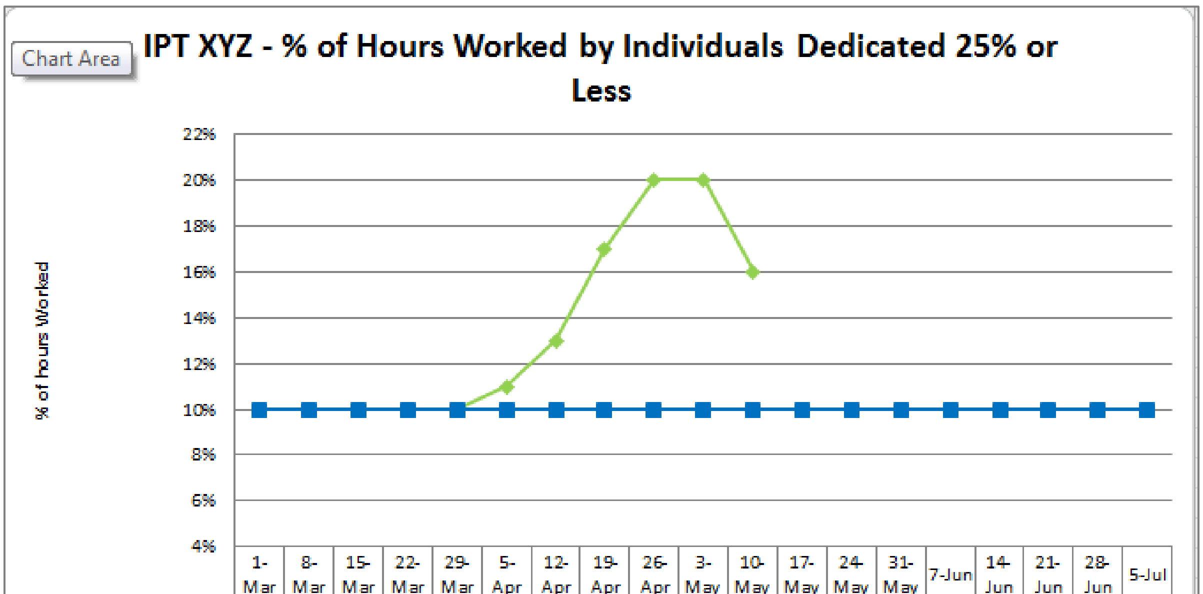
Figure 22 illustrates hours spent by individuals dedicated to the program at different percentage dedication levels. In Figure 22, 56% of the hours spent were from personnel dedicated to the program >75% of the time. The goal would be that the majority of the hours spent on the program are by personnel that are dedicated to the program.



Hrs spent by people	
>75% Dedicated	6972
50% to 75% Dedicate	1420
25% to 50% Dedicate	1640
5% to 25% Dedicated	1599
1% to 5% Dedicated	357
Total	11988

Figure 22. Hours Spent vs Percent Dedicated to a Program

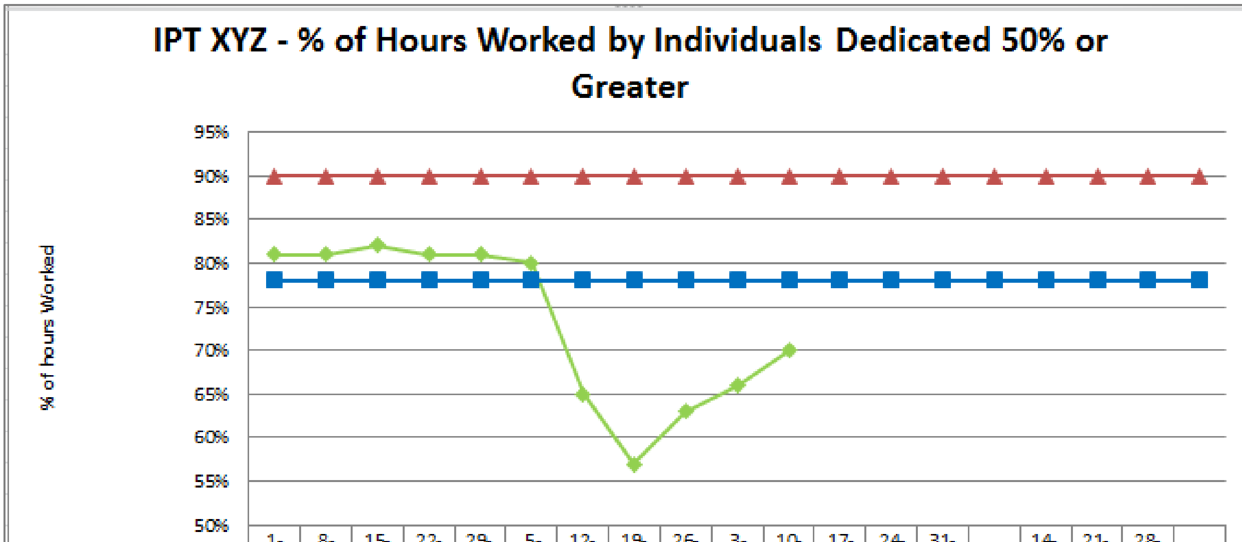
Figure 23 illustrates the number of hours worked by individuals on the program that had less then 25% of their time dedicated to the program.



	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	14-Jun	21-Jun	28-Jun	5-Jul
IPT XYZ	10%	10%	10%	10%	10%	11%	13%	17%	20%	20%	16%								
Trigger Threshold	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

Figure 23. Percent of Hours Worked by Individuals Dedicated 25% or Less to a Program

Figure 24 represents the number of hours worked by individuals on the program that had greater than 50% of their time dedicated to the program with a lower bound of 78% and an upper bound of 90%. For example, if the percentage falls below the lower bound threshold, this can indicate low levels of dedication and may indicate concerns or inefficiencies within the program or IPT. If the percentage falls above the upper bound threshold, this can indicate dedication levels that are above what is expected or budgeted.



	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	14-Jun	21-Jun	28-Jun	5-Jul
IPT XYZ	81%	81%	82%	81%	81%	80%	65%	57%	63%	66%	70%								
Trigger Threshold	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%
Upper Threshold	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%

Figure 24. Percent of Hours Worked by Individuals Dedicated 50% or Greater to IPT XYZ

Predictive Nature

Minimizing churn and multiplexing of key personnel on a project is important to long-term success – monitoring the churn/dilution metric allows the leadership team to monitor key personnel changes and take corrective actions as necessary.

The multiplexing metric should be done at specific levels of the program and not at the total program level. It is recommended that this be done at a critical WBS or IPT level. This is because measuring the multiplexing level of all members of the program team may not be a good predicative indicator (e.g., drafting and configuration management may only be needed part time on the program). Additionally, the WBS and/or IPT being monitored may change over the lifecycle of the program.

Both critical skills metrics predict potential future inefficiencies that should be acted upon to mitigate program impacts.

Possible Questions

- What are the reasons for program personnel being multiplexed?
- Are the multiplexed program personnel critical or key resources?
- If the dedicated resources are above the upper limit, can the overall budget afford their efforts and/or should the ETC be adjusted to account for their level of effort?
- If the dedicated resources are below the lower limit, is the performance output or schedule impacted? Should the team take action to realign a resource's commitments?

- What phase(s) of the program are considered critical? Are program personnel multiplexed during these critical program phases, thereby increasing the risk to the program?
- Which WBS/IPTs on the program require a particular focus? Are program personnel multiplexed across these WBS/IPTs, thereby increasing the risk to the program?

Caution

- Metrics should be collected and analyzed, at a minimum, on a monthly basis for signs and trends of resource multiplexing.
- Pay attention to the level of multiplexing of program team personnel and trends associated with decreasing program dedication of personnel.
- Pay attention to the WBS/IPT percent dedication less than planned percent dedication.

5 Risk and Opportunity Metrics

Section Summary

Risk and Opportunity Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
R&O Summary	Risk & Opportunity Summary	The summary provides a listing of a project's most significant risks and opportunities, as well as a summarization of their likely effect on the project.		5.1
Total Project Risk	Total Project Risk	The sum of the factored values for all risks tracked in the project's risk register.		5.1
Total Project Opportunity	Total Project Opportunity	The sum of the factored values for all opportunities tracked in the project's opportunity register.		5.1
MR	Total Project Management Reserve (MR)	The remaining MR on the project.		5.1
Exposure Cost	Exposure Cost	The estimated cost of the impact if the risk is not mitigated.		5.1
Factored Value	Factored Value	Exposure Cost x Probability		5.1
R/O vs. MR Plot	Risk/Opportunity (R/O) $ vs. Management Reserve (MR) $	An R/O vs. MR plot is a graphical comparison of the level of MR against the outstanding R/O over time. The plot provides a visual gauge of the rate at which MR is being expended against the estimated risk exposure on a project.		5.2
SRA	Schedule Risk Assessment (SRA)	SRAs use a Monte Carlo simulation to predict the probability of meeting a project's completion target or the finish of any key event.		5.3
Schedule Margin	Schedule Margin	Schedule margin is a duration buffer prior to an end-item deliverable or any contract event.		5.3.1
Tornado Graphs	SRA Sensitivity (Tornado) Graphs	Sensitivity graphs are used to help identify the tasks that are most likely to be the true drivers of project completion or provide the greatest opportunity to reduce the project duration.		5.3.2

5.1 Risk & Opportunity Summary

Metric Definition

The Risk and Opportunity Summary provides a concise view of how a program is tracking to risk mitigation and opportunity pursuit plans. The summary provides a listing of a project's most significant risks and opportunities, as well as a summarization of their likely effect on the project.

Note: The Risk and Opportunity Summary will only be as accurate and useful as its supporting data. A disciplined and rigorous risk and opportunity management process is critical to the success of a program. Active management of risk mitigation and opportunity pursuit plans should be driven into organization's culture at every level.

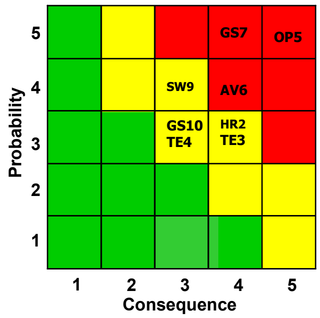
Calculations

The Risk & Opportunity Summary is not an independent metric/measure, but is instead a summarization of other metrics and measures. As such, it does not typically require any new calculations that are not already performed elsewhere within a project's R&O system.

Output/Threshold

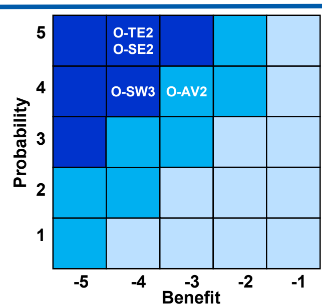
The example output displayed in Figure 25 is not intended to be prescriptive in nature. It is merely one way in which risks and opportunities can be summarized. Format and content should be standard across the company and thresholds should be tailored to best meet the needs of the management team.

Risk & Opportunity



Risk Register (Level 1, Over 60% Probability)							
Risk No	Risk Description	Risk Mitigation	Exposure Cost ($K)	Prob (%)	Factored Value ($K)	Mitig Status	Retirement Date
OP5	Fuselage Assembly Rate	Install new robotic production line	2,500	90	2,250		10/15/2014
GS7	Gear Assembly Supplier	Identify Alternate Supplier	1,806	90	1,625		11/11/2013
AV6	Sensor Integration & Test	SE study on schedule acceleration	1,500	80	1,200		8/21/2013
SW9	Ground Segment Infrastructure S/W Schedule	Alternate source code and reuse	1,000	80	800		9/7/2014
HR2	Critical Skills Retention	Incentive program revision	929	70	644		1/7/2014
TE3	Range Availability	Customer schedule review board	804	70	563		10/15/2014
GS10	Mission Planning Software Delivery	Supplier schedule incentive	710	60	426		12/15/2014
TE4	Implementation of SILs	Facilities Plan update	700	60	420		6/27/2013

Total Level 1 Cost $9.9M, Factored Value $7.9M → Total Level 2 Cost $4.1M, Factored Value $1.6M → Total Level 3 Cost $2.2M, Factored Value $.4M → Total Level 1&2 Cost $14.0M, Factored Value $9.5M → **Total Program Risk Cost $16.2M, Factored Value $9.9M**



Opportunity Register (Level 1, Over 60% Probability)							
Opp No	Opp Description	Opportunity Pursuit Plan	Savings ($K)	Prob (%)	Factored Value ($K)	Pursuit Status	Capture Date
O-TE2	Less Test Flights Req'd	Meet spec, customer concurs	(2,500)	90	(2,250)		12/25/2015
O-SE2	Fewer Drawings	New drawing tool	(2,000)	90	(1,800)		4/21/2014
O-SW3	S/W Make vs. Buy	Mission Planning S/W in-house	(1,243)	70	(870)		11/17/2013
O-AV2	NRE Efficiencies	Consolidate IPTs, fewer changes	(500)	70	(350)		9/7/2014

Total Opportunity $6.2M, Factored Value $5.2M

Total Program MR $151M,
Total Program Risk (Factored) $9.9M, Total Program Opportunity (Factored) $5.2M

Figure 25. Elements of Risk and Opportunity

The individual elements of Figure 25 include:

Total Project Risk and Opportunity Summary

Total Project Risk

- The sum of the factored values for all risks tracked in the project's risk register.

Total Project Opportunity

- The sum of the factored values for all opportunities tracked in the project's opportunity register.

Total Project Management Reserve (MR)

- The remaining MR on the project.

Risk Elements

Risk Register – A listing of the most significant risks as determined by criteria established by the management team.

- Risk No. – The unique risk number from the project's risk register.

- Risk Description – An executive summary description of the risk.
- Risk Mitigation – A succinct statement of the mitigation strategy.
- Exposure Cost ($K) – The estimated cost of the impact if the risk is not mitigated.
- Probability (%) – The likelihood the risk could become an issue if not mitigated.
- Factored Value ($) – Exposure Cost x Probability
- Mitigation Status – R/Y/G indicator of Mitigation Plan progress to plan: on track (green), behind schedule (yellow), or unachievable (red). Yellow and red status require a “Return to Green” plan.
- Retirement Date – The planned date that mitigation steps will be completed such that the risk is reduced to an acceptable level and can be retired.

Risk Matrix

- A graphical display of the risk numbers listed on the Risk and Opportunity Summary, plotted on a standard risk matrix. The criteria for categorizing risks as high (red), medium (yellow), and low (green) should be consistent with the corporate/program policy on determining levels of consequence and the probabilities of occurrence.

Total Project Risk Summary

- Top-level risk summary – Display of the total cost values and factored values summed from the risks listed on the Risk and Opportunity Summary.
- Lower-level risk summaries – Display of the total cost values and factored values summed from risks that are tracked in the project’s risk register, but *not* listed on the Risk and Opportunity Summary.
- Total project risk summary – Display of the total cost values and factored values from all risks tracked in the project’s risk register.

Opportunity Elements

Opportunity Register (Level 1, Over 60% Probability)

- Opportunity No. – The unique opportunity number from the project’s opportunity register.
- Opp Description – An executive summary description of the opportunity.
- Opportunity Pursuit Plan – A succinct statement of the pursuit strategy.
- Savings ($K) – The cost of the benefit if the opportunity is captured. This will be a negative number since it reflects a reduction in cost.
- Probability (%) – The likelihood the opportunity will be realized.
- Factored Value ($) – Savings x Probability

- Pursuit Status – Indicator of Pursuit Plan progress to plan: on track (green), late to schedule (yellow), or unachievable with current resources (red). Yellow and red status require a "Return to Green" plan.
- Capture Date – The planned date that pursuit steps will be completed and the opportunity is realized.

Opportunity Matrix

- A graphical display of the opportunity numbers listed on the Risk and Opportunity Summary, plotted on a standard opportunity matrix. The criteria for categorizing opportunities as high (dark blue), medium (medium blue), and low (light blue) should be consistent with the corporate/program policy on determining levels of benefit and the probabilities of occurrence.

Total Project Opportunity Summary

- Top-level opportunity summary – Display of the total opportunity values and factored values summed from the opportunities listed on the Risk and Opportunity Summary.
- Lower-level opportunity summaries – Display of the total opportunity values and factored values summed from opportunities that are tracked in the project's opportunity register, but *not* listed on the Risk and Opportunity Summary.
- Total project opportunity summary – Display of the total opportunity values and factored values from all opportunities tracked in the project's opportunity register.

Predictive Nature:

By consolidating the most pertinent risk data, the management team has a single, high-level source of information on a project's significant risks and opportunities. While the Risk and Opportunity Summary is not intended to provide a detailed analysis of any one item, it does serve as a dashboard to help identify areas in need of management action.

The overall dollar value of risks minus opportunities can be compared to the Management Reserve Burn-down to ensure reserves are adequate through the end of the contract. This can be depicted as text on the Summary sheet or in a line graph as shown in Section 5.2 (Figure 26).

Possible Questions

- Are there mitigation plans for each high and medium risk?
- Are the mitigation plans included in the project schedule and logically linked to associated scope?
- Does the mitigation plan address the root cause of the risk (source) or just minimize the impact (symptom)?
- Are there any risks or opportunities trending down (i.e., yellow to red)? If so, why are the mitigation steps ineffective?

- Are the high and medium risk mitigation tasks defined within the program schedule?
- Are any mitigation plans behind schedule? If so, why?
- Are opportunities being pursued as vigorously as risks are being avoided?
- Are opportunity enhancement tasks defined within the program schedule?

5.2 Risk/Opportunity (R/O) $ vs. Management Reserve (MR) $

Metric Definition

An R/O vs. MR plot is a graphical comparison of the level of MR against the outstanding R/O over time. The plot provides a visual gauge of the rate at which MR is being expended against the estimated risk exposure on a project. This allows management to examine the trends and implement mitigation steps as needed before MR depletion becomes irrecoverable.

Calculations

R/O vs. MR dollars [11] (or other currency) is plotted on a timeline beginning at the start of the project and running through the forecasted project completion. There are three basic values plotted:

Management Reserve

- Actual MR over time from the initiation of the contract to time now. Always start the graph with the original MR that was established at project inception.

Net Risks

- Each month, calculate the risk exposure minus the opportunity potential. Plot the net value.

Projected MR Consumption

- An assessment by the project manager of the future distribution of MR in order to mitigate projected risks and execute unplanned scope (in-scope to the contract, but out-of-scope to the CAMs)

  OR
- Based on past MR consumption, insert an MR depletion trend line.

Note: Additional information can also be plotted if available, such as MR as a percentage of ETC. Also, if mitigation plans are well maintained, forecasted net risk exposure can be plotted.

Output/Threshold

By plotting historic and forecasted MR, as shown in Figure 26, an estimation of the MR at project closeout can be made. Also, if the actual MR burn down rate has been too steep, the date at which MR is completely depleted can be estimated. Adding a plot of the net risk exposure to date provides additional insight into the adequacy of MR to cover known risks.

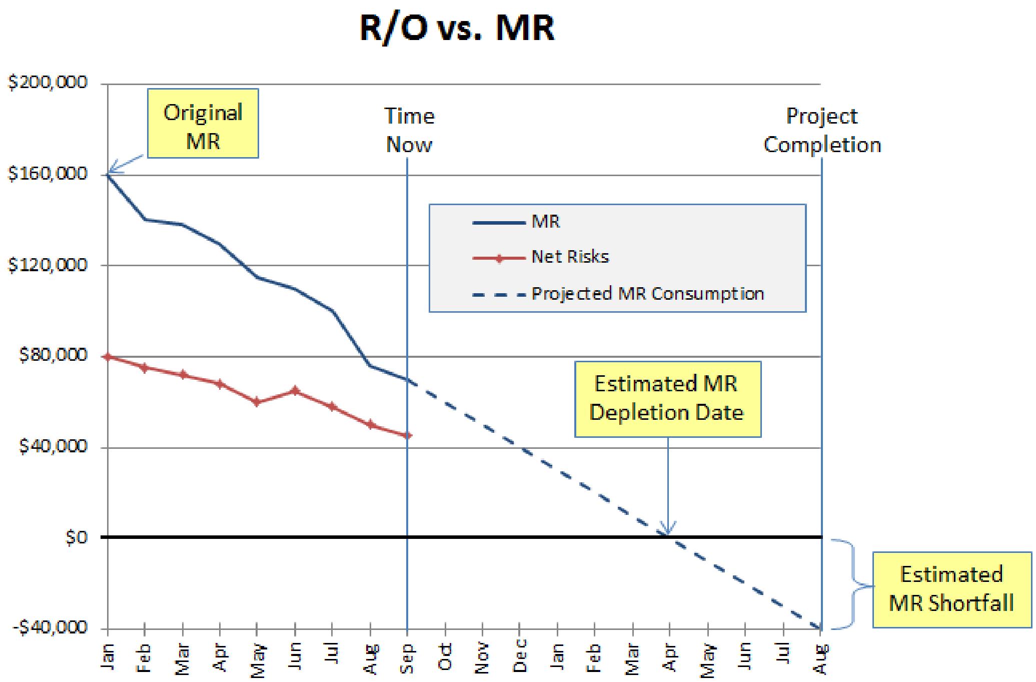


Figure 26. R/O vs. MR

Predictive Nature

Monitoring the trends of MR consumption and net risk exposure can provide valuable insight into the future state of a project.

MR Adequacy

- The value of the MR Forecast plot at the time of project completion will provide an estimate of MR adequacy. If management knows of a risk to MR coverage earlier, then more time is available to implement mitigation plans.

Estimated MR Depletion Date

- In the event of a projected MR shortfall (negative MR value at project completion), an estimate of the date at which MR is depleted can be made. This is the “drop dead” date for implementing measures to extend MR coverage.

Risks > MR

- Initially, MR should be set to cover the specific items identified in the project’s risk register plus an allowance for unidentified (non-specific) future risks. Over time, the available MR should ideally be more than the net risk exposure. In the event that the net risk exposure is more than the MR (or expected to be in the future), management must expedite risk reduction measures and/or explore additional opportunities to offset the risks.

Possible Questions

- Are all significant risks being tracked and mitigated?

- Do we expect the current rate of MR consumption to continue? Why or why not?
- What other opportunities are we currently not pursuing?
- Is MR as a percentage of the project ETC trending up or down?
- Is future MR expected to be sufficient to cover net risks?

5.3 Schedule Risk Assessment (SRA)

SRAs use a Monte Carlo simulation to predict the probability of meeting a project's completion target or the finish of any key event. The process is dependent on the estimated variability of the activities that make up the remainder of the project.

To conduct an SRA, probability distributions are applied to activity durations using three-point estimates (Maximum, Most Likely, and Minimum), with reference to historical data if it exists. This should include any discrete tasks identified, quantified, but not yet mitigated in the project's risk register. The integrity of the IMS, including all logical relationships, durations, etc., is essential and should be validated prior to conducting the simulation. When it is impossible or impractical to apply three-point estimates to every activity in the project, the focus should be put on the activities that comprise the critical (driving) and near critical paths, increasing the number of near critical paths considered with the amount of risk perceived. The results could be used to identify specific mitigation actions and/or help determine the amount of buffer or reserve needed to ensure a desired outcome.

Conducting an SRA in this manner helps account for the inherent variability that is always present. Project leaders should also have a robust risk management process to account for unplanned risk events that have some probability (but less than 100% probability) of occurring.

While there are many different reports and metrics that can be generated by the various SRA software tools, there are two that are widely used regardless of project or toolset:

- Histograms (frequency distribution graphs)
    - Calculates the probability of achieving a specific schedule completion date.
- Sensitivity (tornado) Graphs
    - Used to identify the activities most likely to drive the outcomes.

Note: While the most common use of an SRA is to perform schedule analysis, it can be used to assess the probability of achieving cost targets as well.

5.3.1 SRA Histogram (Frequency Distribution Graph)

Metric Definition

Schedule margin is a duration buffer prior to an end-item deliverable or any contract event.

The original duration of this buffer task is determined by considering the risk and uncertainty associated with a particular effort. This is commonly accomplished by running an SRA and calculating the number of working days between the forecasted completion of the event from the IMS (with no schedule margin tasks applied) and an acceptable risk adjusted date (such as the P80 date – the date supported by 80% of the SRA simulation runs).

As a project progresses, the duration of the schedule margin task is re-evaluated and adjusted as needed to protect the deliverable from risks that arise from natural variances in duration. A Schedule Margin Burn Down is a graphical display of schedule margin over time.

Note: The use of schedule margin is an optional project management technique. In lieu of plotting a burn down of schedule margin, other values such as total float or baseline finish variance can be substituted to track project completion trends over time.

Calculations

Determining the Original Schedule Margin Duration

The original duration of a Schedule Margin task is determined by considering the risk and uncertainty associated with a particular effort. Ideally, this is determined by performing a Schedule Risk Assessment (SRA) and calculating the number of working days between the forecasted completion of the event from the IMS (with no schedule margin tasks applied) and an acceptable risk adjusted date (such as the P80 date – the date supported by 80% of the SRA simulation runs).

Maintaining the Schedule Margin Duration

There are two basic methods of determining the duration of a Schedule Margin task as a project progresses:

1) **Risk-based approach**
    - Assess the current risk and uncertainty associated with the effort.
    - This is similar to the original method of determining the Schedule Margin duration, except a program manager’s assessment of risk/uncertainty is commonly used when it is impractical to run monthly SRA’s.
    - Results:
        - Attempts to maximize the accuracy of the forecasted completion of the subsequent program event based on the project’s tolerance for risk.

   - The event is forecasted independently of its planned completion data – the forecast may be earlier, later, or on its baseline finish date (positive, negative or zero total float).
   - This results in a fluid forecast that may fluctuate from one status period to the next.
- Burn-down analysis
   - Since the duration of the margin task is determined by the amount of risk and uncertainty associated with that event, a rapidly shrinking margin task is desirable. This is an indication that the risk and uncertainty in that area is also rapidly diminishing.

2) Float-consumption approach

- Task duration is set to consume any time between the forecasted completion in the IMS and the required deadline for the event – which consumes any positive total float.
- If the event is forecasted to miss its deadline, the duration of the Schedule Margin task is set to zero.
- Results:
   - Increases the likelihood of achieving the completion of the subsequent event on or before the forecasted date.
   - The forecasted completion of the event is driven by the planned completion date – forecast is equal to the plan until the schedule margin task is completely consumed and logic pushes the forecast beyond the baseline finish (only zero or negative total float).
   - Until the schedule margin consumed, this method will result in a static forecast equal to the planned completion of the event.
- Burn-down analysis
   - Since the duration of the margin task represents the amount of time between the forecasted completion of the event (without a margin task) and the planned completion of the event, a rapidly shrinking margin task is a cause for alarm. This would be an indication that the project is being executed in a slower than expected rate.

The Risk-based approach (Method 1) is the preferred means of maintaining a Schedule Margin task. This is because it results in a forecast that is free to move left and right based on past execution, expected downstream performance, and the remaining risk and uncertainty in that area. In contrast the float-consumption approach (Method 2), essentially constrains the forecast to the planned completion of the event, minimizing the effect of past execution, future performance, and risk/uncertainty.

Note: The remainder of this section is based on the usage of the risk-based approach for maintaining the duration of a Schedule Margin task.

Creating the Burn-Down Plot

Schedule Margin duration is re-evaluated by project management each reporting period and then plotted along a timeline that runs from the start of the project through the current status date.

In addition to graphing the actual value of schedule margin over time, a depiction of the planned consumption of schedule margin is plotted for comparison. Unless some other consumption pattern is known, this planned schedule margin plot can be as simple as a straight line drawn from the original schedule margin value at the project start to zero at the planned completion of the deliverable milestone.

Calculations

Histogram Bars

- Each iteration performed during the Monte Carlo simulation produces an estimated completion date for the selected major milestone. A bar is drawn on each day that the major milestone was forecasted to occur. The height of the bar is determined by the number of iterations that yielded that particular date (the taller the bar, the more often that day was calculated as the likely completion date for the major milestone).
    - X-Axis – Timeline ranging from the earliest simulated completion to the latest.
    - Y-Axis - Number of simulation iterations yielding that particular completion date.

Cumulative Probability Curve

- A frequency graph representing the cumulative completions over time. In essence, it is the sum of all of the histogram bar values through that point in time.
    - X-Axis – Timeline ranging from the earliest simulated completion to the latest.
    - Y-Axis – Percent of iterations completing on or before that particular date.

Output/Thresholds

Minimum

- The earliest simulated completion (out of all iterations performed).

Maximum

- The latest simulated completion (out of all iterations performed).

Mean

- The average simulated completion (out of all iterations performed).

Highlighter (available with most SRA software)

- The date associated with a specified confidence level. For example, if 80% is selected as a Highlighter, the histogram report will display the date at which 80%

of all of the simulated iterations completed on or before. In other words, according to the SRA results, this is the date that management can be 80% confident in achieving. This and other outputs are shown in Figure 27.

Deterministic Probability

- Represents the percentage of simulated iterations that completed on or before the date forecasted by the IMS.

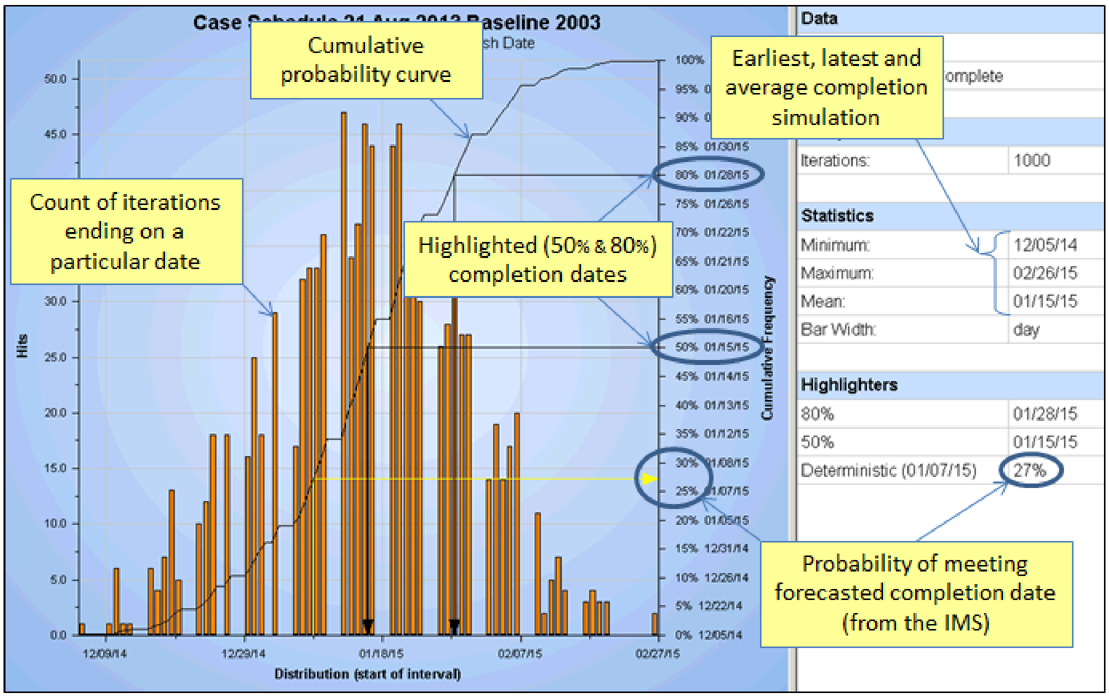


Figure 27. SRA Histogram

Predictive Nature

An SRA Histogram is a tool specifically designed to be predictive. The primary function of an SRA Histogram is to display the likely range of completion dates for a project and to determine the probability of achieving a completion target. In the event that there is an unacceptable risk level in achieving the desired project completion target, other Sensitivity reports described in the next section can be used to identify the tasks with the greatest impact on project completion.

Possible Questions

- Do the histogram bars resemble a standard “bell” shape? If not, why?
  - Is the IMS overly constrained?
  - Is the IMS properly linked?
  - Are duration estimates overly optimistic (or pessimistic)?
  - Is the non-bell shape due to the presence of known risks or other skewing inputs?

- Is there an acceptable risk level in achieving the deterministic date? If not:
  - Can additional risk mitigation steps be implemented?
  - Are there additional opportunities that can be pursued?
  - Would additional resources reduce schedule duration on key tasks?

Caveats

- To produce meaningful results with an SRA, starting with a sound IMS is a must. An incomplete, immature or neglected IMS will produce inaccurate and misleading results. Characteristics of an IMS that should increase the confidence in SRA results include:
  - Complete and accurate predecessor/successor logic
  - Limited and justifiable use of constraints
    - particularly "hard" constraints that can prevent a task from slipping to the right (later)
  - Relatively stable
    - no excessive use of baseline changes
  - Well maintained forecast
    - as evidenced by favorable results from metrics such as CEI

5.3.2 SRA Sensitivity (Tornado) Graphs

Metric Definition

A critical path is not static over the life of a project. Often tasks that are not currently on the critical path will actually end up driving the completion of the project. Sensitivity graphs are used to help identify the tasks that are most likely to be the true drivers of project completion or provide the greatest opportunity to reduce the project duration. Sensitivity is a measure of how a change to an attribute on a specific task will affect the completion of the entire project (or the completion date of some other specified major milestone). For example, changes to tasks with the highest Duration Sensitivity are more likely to effect the ultimate duration of the project.

Note: There are several methods of performing Sensitivity Analysis. Depending on the tool used to conduct the SRA, reports such as Duration Sensitivity, Criticality Index, Cruciality, and Schedule Sensitivity can be produced. Refer to the help documents in the SRA tool for more information on how these reports can be used. In addition, while the discussions in this section are centered on the correlation between a task's duration and the duration of the project, sensitivity analysis can also be performed on the correlation between the expected cost of a single task and the total cost of the total project.

Calculations

Sensitivity calculations are automatically performed within the SRA tool. Through each iteration of the Monte Carlo simulation, as the duration increases or decreases on a specific task, the completion of the project (or other specified major milestone) is evaluated. High sensitivity values are the result of a high correlation between the duration of the task and the duration of the project.

Output/Thresholds

Sensitivity analysis graphs list, in descending order, the activities with the greatest correlation to the duration of the project. Greater correlation between the task and project durations means that a longer the bar is graphically displayed for that task. Because of this, the bars at the top of the list are the longest and the tasks at the bottom of the list are the shortest. This visual tapering down of the bars gives the appearance of a tornado, as can be seen in Figure 28. This is why sensitivity reports are commonly referred to as "Tornado Charts."

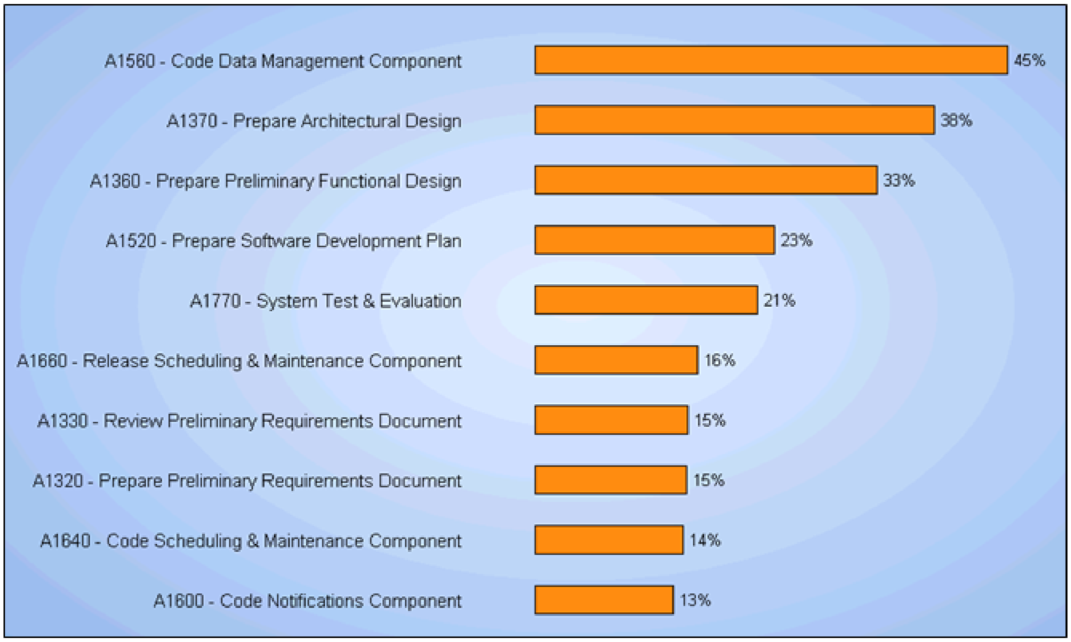


Figure 28. SRA Sensitivity Graph

Predictive Nature

The primary purpose of sensitivity analysis is to aid in the identification of the tasks that are most crucial to the successful completion of the project. The tasks at or near the top of a sensitivity report are the most likely to:

- Cause a delay to project completion
- Provide an opportunity to reduce the remaining duration of the project.

In either case, sensitivity analysis provides an assessment of the tasks requiring increased management attention. These tasks are also identified as providing the best direction when making decisions about which tasks to mitigate in an effort to improve project completion dates.

Possible Questions

- Is it reasonable that the tasks listed on the sensitivity graph could drive project completion?
    - If not, investigate the IMS to see why LOE or other lower priority effort is being highlighted.
- Are there groupings or natural break points in the sensitivity values?
    - It may be more feasible to mitigate a lower-ranked task, with very little drop-off in effectiveness if sensitivity values are closely packed.
- Is the same resource applied to more than one of the most sensitive tasks?

Caveats

- As with all aspects of an SRA, having a sound IMS is a must. An immature or incomplete IMS will produce inaccurate and misleading results.

- Sensitivity values can be due to a random correlation. For example, a task that has a constant duration during the analysis will have a random correlation with the project duration. This random correlation value is usually low enough to be ignored.

5.4 Schedule Margin Burn-Down

Metric Definition

A Schedule Margin task is a tangible representation of the time associated with the risks to an end-item deliverable or contract event. As a project progresses, the length of the schedule margin task is re-evaluated and adjusted as needed to protect the deliverable from risks that arise from natural variances in duration. A Schedule Margin Burn Down is a graphical display of Schedule Margin duration over time.

Note: Schedule Margin duration, as described in this section, is determined by an estimate of remaining schedule/duration risk. With this method, shorter Schedule Margin tasks are indicative of smaller schedule/duration risks remaining on the program (a favorable condition). Alternatively, some companies use Schedule Margin tasks as a buffer between the forecasted completion of a major milestone in the IMS and its required/contractual completion date. With this approach, shorter Schedule Margin tasks represent less of a buffer available to protect the required/contractual completion date (an unfavorable condition). It is important to have a consistent use of Schedule Margin in order to effectively monitor its consumption.

Calculations

The original length of a Schedule Margin task is determined by considering the risk and uncertainty associated with a particular effort. This is ideally determined by performing a Schedule Risk Assessment (SRA) and calculating the number of working days between the forecasted completion of the event from the IMS (with no schedule margin tasks applied) and an acceptable risk adjusted date (such as the P80 date – the date supported by 80% of the SRA simulation runs).

Schedule Margin is re-evaluated by project management each reporting period and then plotted along a timeline that runs from the start of the project through the current status date.

In addition to graphing the actual value of schedule margin over time, a depiction of the planned consumption of schedule margin is plotted for comparison. Unless some other consumption pattern is known, this planned schedule margin plot can be as simple as a straight line drawn from the original schedule margin value at the project start to zero at the planned completion of the deliverable milestone.

Output/Threshold

Because Schedule Margin is meant to compensate for duration uncertainties associated with project risks, the faster those risks are mitigated/reduced, the steeper the plot of historic Schedule Margin will be. When the current Actual Schedule Margin is lower than Planned Schedule Margin, it is an indicator that duration risks for the project are being mitigated faster than planned. Conversely, elevated Actual Schedule Margin values indicate potential trouble ahead, as risks has not been controlled as quickly as planned. An example is shown in Figure 29.

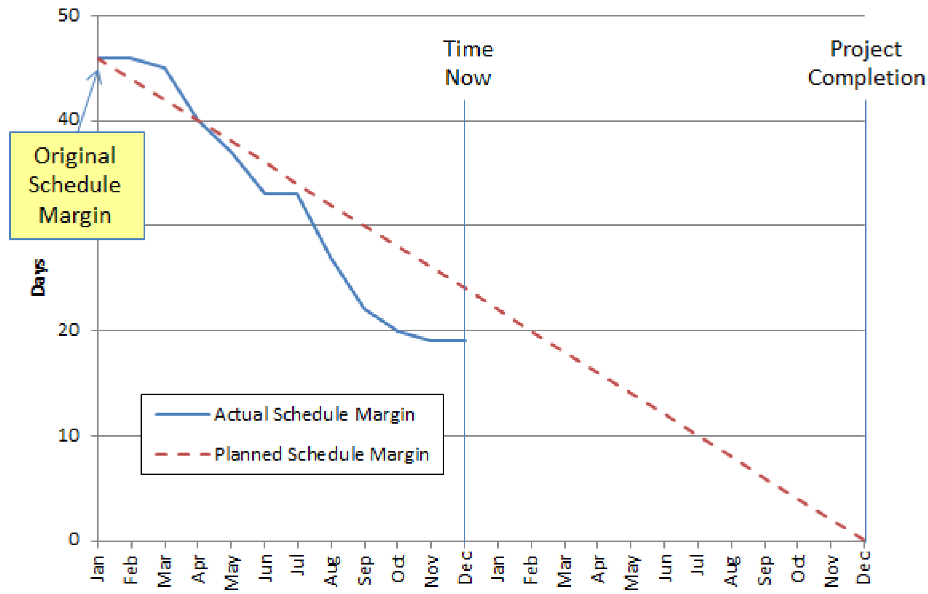


Figure 29. Schedule Margin Burn Down

Note: The use of schedule margin is an optional project management technique. In lieu of plotting a burn down of schedule margin, other values such as total float or baseline finish variance can be substituted to track project completion trends over time.

Predictive Nature

There is no duration uncertainty associated with completed tasks. Because of this, completed tasks should not have any schedule margin. Both Schedule Margin and the remaining duration to the deliverable milestone converge to zero virtually simultaneously.

The Schedule Margin Burn Down relies on this relationship between schedule margin and remaining duration. If the current schedule margin is higher than planned, there is an increased risk that the remaining duration is also higher than planned, which would result in a slip to the deliverable milestone. Conversely, if the current schedule margin has eroded faster than the plan, it is more likely that the remaining duration to the deliverable is also shrinking faster than planned, which could result in an earlier delivery.

Possible Questions

- Has the recent trend of schedule margin consumption been steeper or flatter than the overall slope? If so, what is causing the change?
- Is the total float on the deliverable milestone falling? Is this due to an increase in schedule margin, or a slip to the driving path to that milestone?
- How is any projected slip to the deliverable milestone being mitigated?
- Are there any opportunities to reduce durations that have yet to be explored?
- Is the IMS in sound enough condition for an SRA to be effective?
    - Is the IMS overly constrained?

- Is the IMS properly linked?
- Are duration estimates overly optimistic (or pessimistic)?

<u>Caveats/Limitations/Notes</u>

- Schedule Margin should be used to compensate for duration uncertainty and never merely to consume positive total float. If float consumption becomes the overriding goal, the relationship between schedule margin and remaining duration is broken, greatly hindering the predictive ability of the Schedule Margin Burn Down.
- Just as Management Reserve (MR) is consumed when risks occur, duration is as well. Schedule Margin should include the estimated duration associated with the mitigation for risks, similarly to MR for cost.
- Care should be taken when analyzing an IMS that contains Schedule Margin tasks. These tasks may need to be removed (dissolved or deleted) in order to perform certain types of analysis or run certain metrics.
- While the reduction of the duration of a Schedule Margin task has been depicted as a desirable occurrence (since it would be modeling a reduction in risk/uncertainty), this may not always be the case. In the event that a risk is not mitigated, but instead manifests itself as an issue, the Schedule Margin task may shrink (since there is now less risk/uncertainty), but the overall forecast may have shifted to the right.

6 Requirements Metrics

Section Summary

Requirements Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
Requirements Completeness	Requirements Completeness	Indicates progress in eliciting and documenting all the requirements necessary for a final, completed system design.		6.1
Requirements Volatility	Requirements Volatility	A measure of a not-yet-stable requirements baseline. It is an indicator of uncertainty or risk in the architecture, functionality, or performance of a system.		6.2
TBD	To-Be-Determined	TBD is used whenever the project requires some performance-level or system attribute, but that level or value is yet unknown.		6.3
TBR	To-Be-Resolved	TBRs refer to system, subsystem, or product performance levels or attributes that have been identified but require further confirmation for finalization.		6.3
Requirements Traceability	Requirements Traceability	A measure that determines how accurately a program's requirements are maturing to support a baseline solution at various Acquisition Phases.		6.4

6.1 Requirements Completeness

Metric Definition

The Requirements Completeness metric [9] indicates progress in eliciting and documenting all the requirements necessary for a final, completed system design. It compares planned completion with actual completion. This may or may not be a good indicator of progress, depending on the goals of the project. Consider if requirements or objectives are more relevant measures to the stakeholders of the project.

Calculations

The base measures are:

- Total Requirements consisting of two major components:
  - The physical count of system-level requirements statements at the transition from the system requirements phase to preliminary design might come from the material that supports the Materiel Development Decision.
  - The expected count of requirements analyzed from the system level to be eventually allocated to the system elements (configuration items) might be a product of heuristics internal to the organization based on performance in prior system development efforts.
- Requirements Planned – The time-phased profile count of total requirements fully articulated given resource capability and capacity. This value might come from Control Account Plans for completion of specifications.
- Requirements Completed – The count of completed requirements as determined from work-package level schedule status reports or system requirements database.

The basic algorithms are:

$$Planned\ \%\ Complete = \frac{Requirements\ Planned}{Total\ Requirements}$$

$$Actual\ \%\ Complete = \frac{Requirements\ Completed}{Total\ Requirements}$$

Output/Threshold

The top-level output might be a time series plot of planned vs. actual progress such as the example in Figure 30. As the program matures, the high level requirements spawn subsystem interface requirements and as the design reaches the critical design phase, technical requirements are developed as technical specifications are defined to fulfill the high level requirements. The summation of all these requirements being fully met are depicted by the increase in requirements as the program progresses through the various phases.

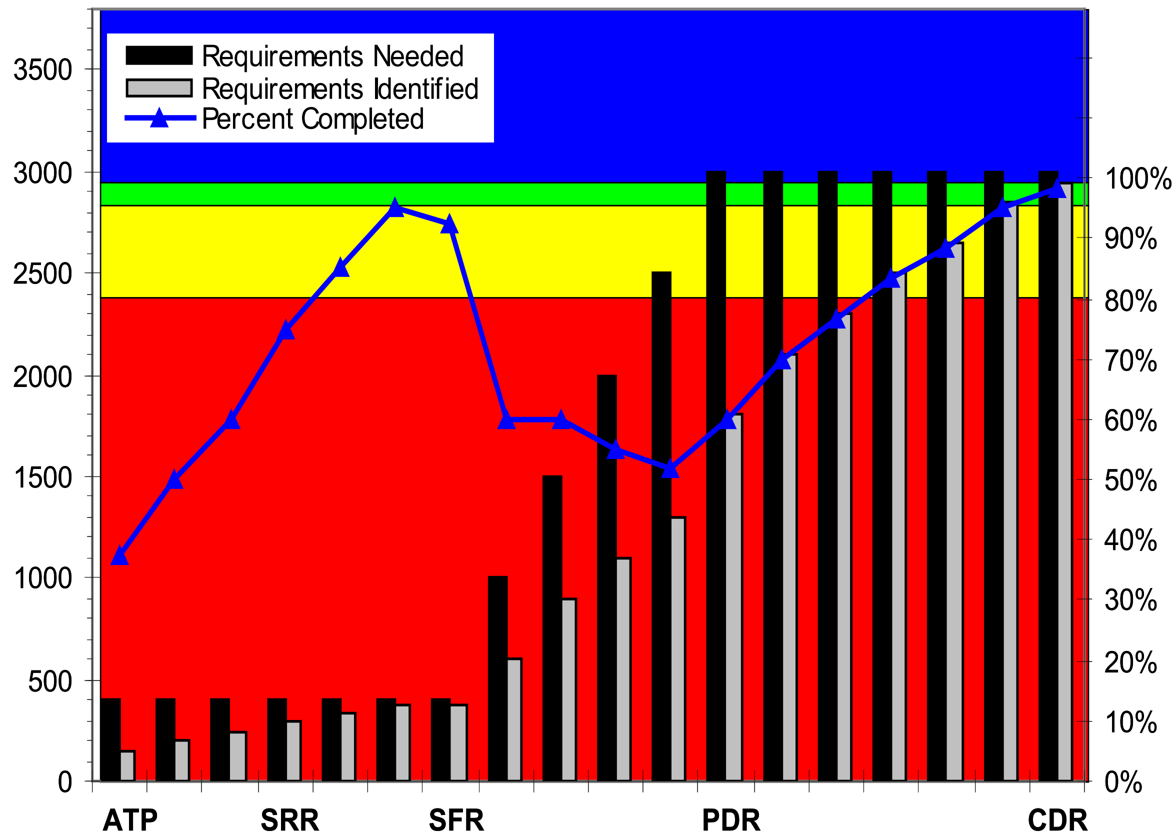


Figure 30. Planned vs. Actual Requirements Progress

Output can also be limited to elements of the system or to disciplines.

Completion metrics can be computed from three base measures: total requirements, requirements planned, and requirements completed.

Total requirements is the count of all necessary requirements for a system-level specification as well as those eventually needed to specify functionality and performance of all the system's elements. Careful consideration should be made to determine the necessary requirements to adequately define and document interfaces among system elements or with elements of the system's environment.

Requirements planned is the intended number of total requirements as of a given point in time that are fully documented and reconciled with higher-level requirements.

Requirements completed is the actual number of total requirements as of a given point in time that have been fully documented and reconciled with higher- level requirements.

Full documentation may require details such as verification and validation plans, citations of proper industry standards, or "budgets" for system resources such as power, volume, or mass. Completion status may also imply that all outstanding issues awaiting resolution have been resolved.

The basic measure (number of requirements), whether total, needed, or completed, may be further described by attributes such as WBS element, type (specification or Interface Control Document), or time period. Such attributes will help to isolate problems or resource contentions for timely resolution. It may be difficult to determine the total number of requirements until TBDs or TBRs are resolved. Additionally, agile management initially addresses high level requirements in manageable increments to create product "backlogs." The full number of requirements may not be quantified until the "sprint" for addressing the backlog is completed.

The requirements needed measure typically is baselined at the same time that system-level requirements are first brought under change control. The total needed may be a computed measure in which an algorithm or heuristic is applied to the system-level value to arrive at the total requirements value. The algorithms or heuristics ought to be calibrated based on history in the domain. The time-phasing of the needed measure (the shape of the curve) will depend on the capacity of the systems engineering resource expected to be applied to the system's preliminary design.

Predictive Nature

Unfavorable differences in requirements completion metrics indicate a threat to timely delivery of a capable system that satisfies stakeholders' needs.

Variance analysis performed as part of the requirements management activities should analyze each significant difference between the planned and actual completion metrics. The analysis should identify the reasons for the difference, forecast the impacts that the difference is likely to have, and identify corrective actions (if any) that are intended to mitigate the difference at a specific point in time.

Possible Questions

- Are the significant variances concentrated in a discipline? Does that discipline need additional or different resources?
- Is an unresolved system-level requirement causing the metric to suffer?
- Did the completeness metric suffer this month from the addition of requirements? If so, is a change to the baseline in scope, appropriate and worthwhile?
- Does the change in requirements warrant coordination through the contracting officer?
- Did the completeness metric benefit from the deletion of as-yet-incomplete metrics? Should a baseline change be considered?
- Do requirements completeness metrics correlate with schedule variance and SPI? If not, why?

6.2 Requirements Volatility

Metric Definition

Requirements Volatility is a measure of a not-yet-stable requirements baseline. It is an indicator of uncertainty or risk in the architecture, functionality, or performance of a system. It is a driver of rework in requirements management if it happens early, and also in system design, test, and integration if it happens late. A high level of Requirements Volatility also indicates a risk of undetected errors surviving the design phase. Thus, early control of volatility is important to control schedule and cost outcomes and to ensure adequate system quality. The volatility has many potential causes such as novel technologies or architectures or a project being undertaken in an unfamiliar domain. The cause can be as simple as inadequate levels of systems engineering resources or as complex as immature technologies being incorporated into the system design. In addition, for development programs, consider the software development lifecycle (SDLC) acquisition phase of the program to determine if this is a valid measure to implement. For some programs during an analysis phase, requirements will naturally be volatile and not a good measure of progress.

The top-level volatility metric is the sum of three base measures: the counts of added requirements, deleted requirements, and modified requirements in a given period compared with the total count of requirements at the end of the prior period.

All three types of requirements changes are typically estimated from historical data on similar projects and ought to be consistent with the basis of the baselined project resource estimates, schedules, and costs. A variance from the estimated volatility can be a reason to question the resource levels needed to complete the project and to modify schedule and cost forecasts accordingly.

Tracking of the metric should begin when system-level requirements are baselined and extend into production or operations. The levels of requirements volatility should decline as the project moves into detail design and would ideally be negligible before manufacturing begins. For Software Development programs, the level of requirements volatility should decline as the program moves through Software Integration and Testing.

The level of the changed requirements should gradually migrate away from the system level, where a single change can have a large cascade effect, to lower levels of the requirements hierarchy to reflect fine-tuning of the system architecture.

Output/Threshold

- Time series plots of actual volatility vs. threshold (see Figure 31).
- Analyses of cause, impact, and corrective action when actual volatility exceeds threshold.

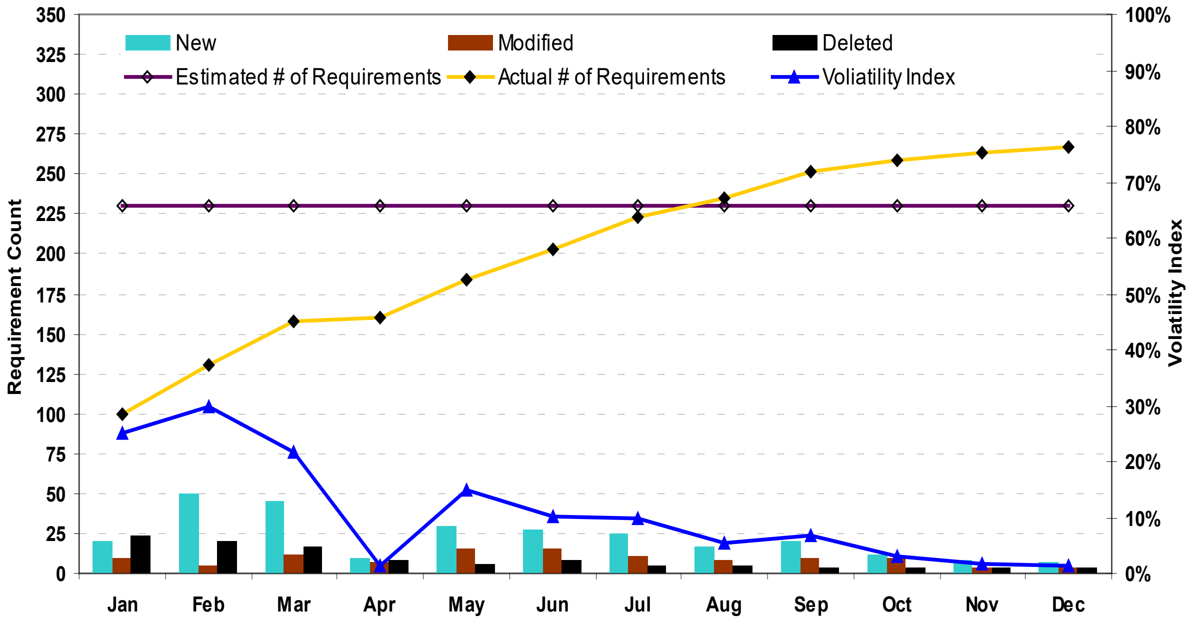


Figure 31. Time series plots of actual requirements volatility vs. threshold

Volatility is to be expected in early phases when stakeholder needs are being initially analyzed and allocated as requirements and as a preliminary design emerges. As the design matures and the project approaches the manufacturing phase, the level of volatility falls to a level of relative insignificance. During this phase, a threshold breach (significantly higher or lower than the target) ideally triggers analyses of cause, impact, and corrective action and that consider attributes such as type, WBS element, or level. When volatility exceeds the thresholds over several periods, a special analysis may be warranted. When volatility exceeds the threshold late in design, careful attention should be given to delaying events such as Preliminary Design Review (PDR) or Critical Design Review (CDR).

Calculations

The planned levels are based on historical records for analogous work. Actual levels will be gathered from requirements databases and change control records.

$$Requirements\ Volatility = \frac{Changes\ [add, delete, modify]\ in\ Current\ Period}{Total\ Requirements\ from\ Prior\ Period}$$

Predictive Nature

Unfavorable levels of volatility indicate significant risks for proceeding to manufacturing.

Possible Questions

- Did additions drive an unfavorable completeness metric? If so, have forecasts for the amount and type of resources been updated? Is a baseline change appropriate?

- Is the volatility driven by customer direction or by internal changes? Does the level of internal change cause concern for program schedule and cost outcomes?
- Have the implications for changes been flowed through to manufacturing and Operations and Support (O&S) phases?

6.3 TBD/TBR Burn Down

Metric Definition

"To-Be-Determined" (TBD) or "To-Be-Resolved" (TBR) refers to the system, subsystem, or product requirements that have not been finalized, as listed or specified in the requirements documents or models.

TBD is used whenever the project requires some performance-level or system attribute, but that level or value is yet unknown. For example, in, *"The Service Module shall provide venting at (TBD-ESA-044) rate in support of depressurization of unpressurized volumes during ascent,"* the rate has not been determined yet but the need for the functionality/capability is known.

TBRs refer to system, subsystem, or product performance levels or attributes that have been identified, but require further confirmation for finalization, for example in the statement *"The coarse attitude sensor system shall be capable of observing 2 pi steradians (TBR-ESA-093)."* In this case, additional analysis, prototyping or a more refined design may be required before a final number can be set.

The plan or process for TBDs/TBRs should be developed early during the formulation phase and documented with the first version of the Systems Engineering Management Plan. TBDs should be tracked separately from TBRs, as there is generally higher risk associated with TBDs. The level to which the project tracks TBDs/TBRs is negotiable and typically depends on the product breakdown. The technical team should consider tracking TBDs/TBRs in system-level requirements separately from subsystem/product-level requirements; TBDs/TBRs in system documents impact the lower-level requirements and, depending on the requirement decomposition, a single system-level TBD/TBR could create many more lower-level TBDs/TBRs. Therefore, understanding how the unresolved requirements are impacting the lower level design could be important.

It would be expected that a program begins with some manageable number of TBDs/TBRs, reflective of the amount of development work required. The number of TBDs should approach zero at the Preliminary Design Review stage, while the number of TBRs should approach zero at the system's Critical Design Review. As a project moves later in the lifecycle, remaining design TBD/TBRs hold the potential for significant impact to designs, verifications, manufacturing, and operations and, therefore, present potentially significant impacts to performance, cost, and/or schedule.

Calculations

TBDs/TBRs are counted.

Output/Threshold

Typically this indicator is seen as a "burn down" plot, usually against the planned rate of closures. An example is shown in Figure 32.

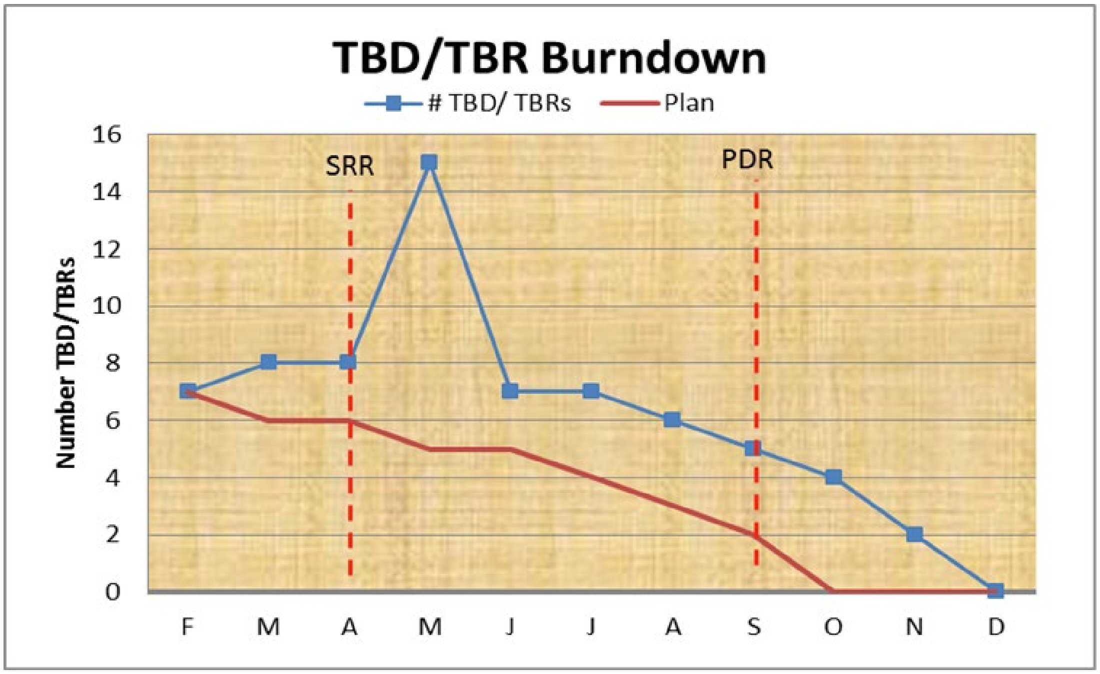


Figure 32. TBD/TBR Burn Down Plot

The TBD/TBR tracking list is key to generation of the development tasks or formulation of the engineering work required.

Predictive Nature

The intent of this metric is to drive the technical team to a stable design early in the project's lifecycle. This will tend to drive out late design changes that could possibly lead to cost overrun and schedule slip.

Possible Questions

- Have the Systems Engineering and Project Management teams developed, agreed upon, and documented a plan to allow for, track, and manage TBDs/TBRs?
- Does the planned and actual burn down of TBDs approach zero at PDR?
- Does the planned and actual burn down of TBRs approach zero at CDR?
- Have TBDs/TBRs been considered in the evaluation of project risk?
- Have TBDs/TBRs been prioritized to ensure that the most important or critical have sufficient attention?
- Has the program assigned tasks and allocated sufficient resources to the engineering efforts required to resolve the TBDs/TBRs per schedule?

6.4 Requirements Traceability

Metric Definition

Requirements Traceability [6] is a measure that determines how accurately a program's requirements are maturing to support a baseline solution at various Acquisition Phases. In the DoD acquisition environment, technical requirements like military standards or industrial and product specifications identified for systems in Engineering and Manufacturing Development (EMD) and PD phases will be derived from higher-level (functional) requirements. The functional requirements are evolved from user capabilities that are identified in earlier acquisition phases such as Materiel Solution Analysis (MSA) and Technology Development (TD). It is important to establish traceability of these technical requirements back to the higher-level requirements to ensure that the system has met the original functional need of its development. Failure to trace the linkages of the technical requirement to the higher-level requirement could result in omission of a capability that negatively affects the system's performance or provides a capability that was not originally required (i.e., gold plating).

The goal of this metric is to measure how well the technical requirements that are used to produce the system are traced to higher-level requirements. Orphan requirements are the technical requirement or specification that cannot be linked to a functional requirement or user capability. The optimum goal is to identify and eliminate all orphan requirements prior to full rate production and delivery of a system.

Calculations

$$Requirements\ Traceability\ Completeness = \frac{Total\ number\ of\ linked\ requirements}{Total\ number\ of\ all\ requirements\ **}$$

$$Orphaned\ Requirements\ Percentage = \frac{Total\ number\ of\ orphaned\ requirements}{Total\ number\ of\ all\ requirements\ **}$$

$$**\ Total\ number\ of\ all\ requirements = Number\ of\ capabilities + Number\ of\ functional\ requirements + Number\ of\ technical\ requirements$$

These percentages can be analyzed as a ratio throughout the various stages of product development with the intent of reducing orphaned requirements to zero prior to production and deployment.

Note: As the development of a system matures, the total number of requirements will increase as the technical requirements and product specifications that are derived from the functional requirements and capabilities will result in a "many-to-one" traceability. Many technical requirements and product specifications will be necessary to meet functional requirements. Many functional requirements will be needed to fulfill a capability, also resulting in a many-to-one traceability between the capability and functional requirements.

Output/Threshold

Figure 33 illustrates the ratio analysis between orphaned and traceable requirements. During the DoD Acquisition Life Cycle, the identification of orphaned requirements should ideally be zero prior to production and deployment.

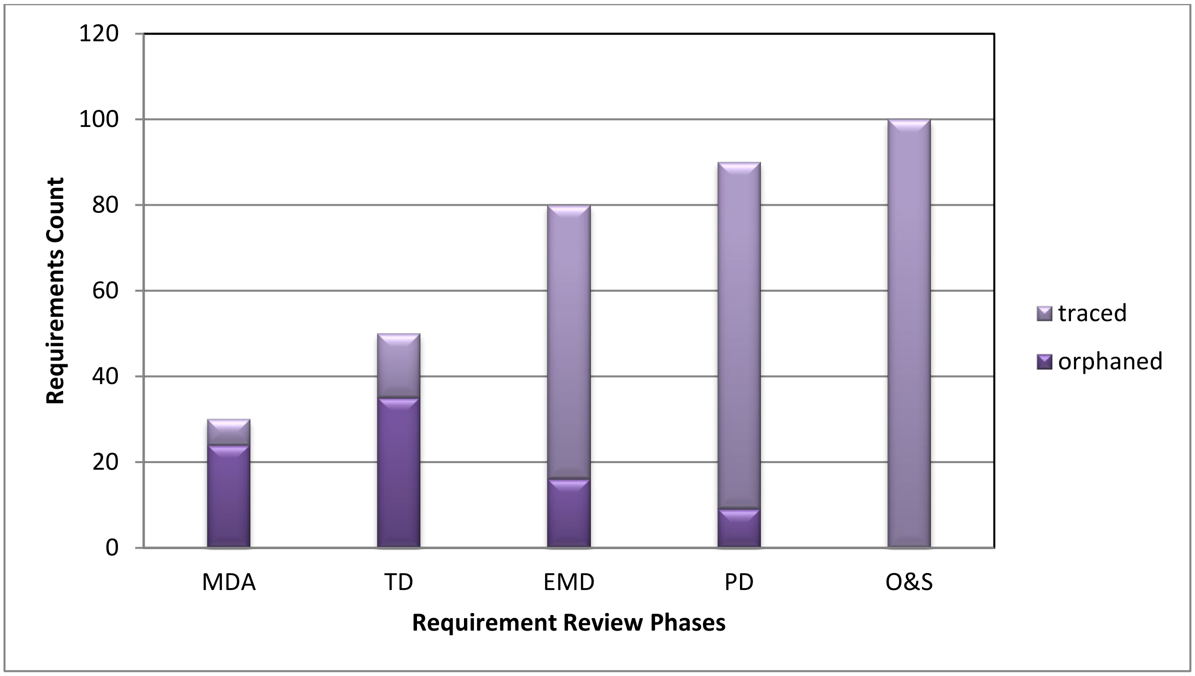


Figure 33. Requirements Traceability Metric

Use of the Requirements Traceability metric drives traceability of stable and complete requirements through the use of one of the following:

1. A requirement management tool to track all requirements.
2. A numbering schema that quantifies and describes the type of traceability link (i.e., documentation, reference, constraint, verification) for the requirements.
3. Any viable method that captures requirements relationships within the engineering and programmatic products produced during the acquisition phases.

Figure 34 illustrates the types of data that are used to establish links between the capabilities and requirements.

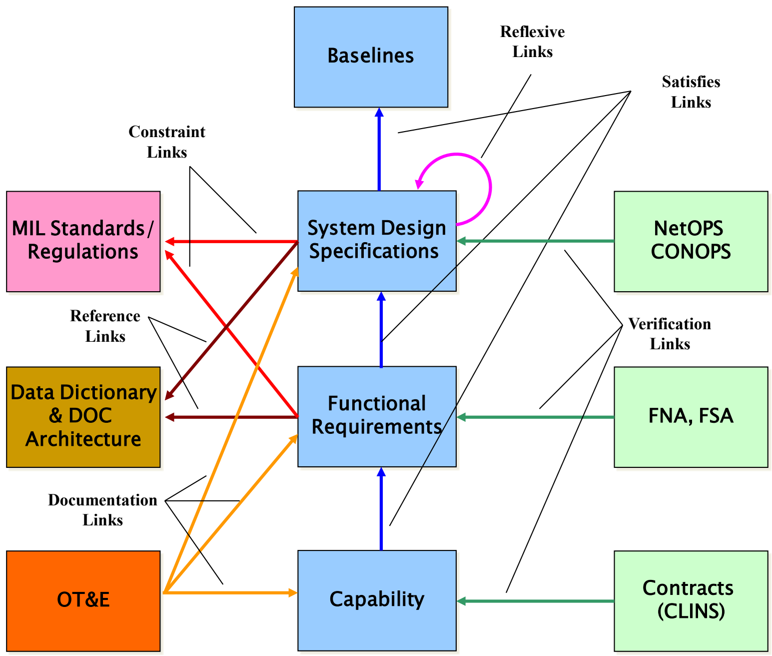


Figure 34. Requirements Traceability Linkages

Program teams that can effectively manage and trace requirements among the various work products associated in a major acquisition have a higher percentage of success in maintaining cost, schedule, and performance.

Predictive Nature

When properly analyzed, the Requirements Traceability metric can monitor the orphaned and traced requirements to inform the program of the following:

1. Technical Documentation Maturity.
2. Technical Constraints driven by requirements.
3. Contract products influenced by requirements.
4. Concept of Operations influenced by requirements.
5. Costs of the system driven by the requirements.

Possible Questions

- What programmatic risks can be mitigated with the requirements traceability metric?
- What are the engineering benefits of the requirements traceability metric?
- What will prevent a program from initiating a requirement management plan that establishes the requirements traceability metric as a predictive measure?
- What are the challenges associated with capturing the requirements traceability metric?

- How can the requirements traceability metric benefit/impact key program milestones during the Acquisition Phases?

Caveats/Things to Watch for/Limitations

The Requirements Traceability metric is dependent on a stable and well-executed Requirements Management Plan.

From the Defense Acquisition Guidebook: 3.4.1.4 Requirements Management Process

The Requirements Management process maintains a current and approved set of requirements over the entire acquisition life cycle. This helps ensure delivery of a capability that meets the intended mission performance, as stipulated by the operational user. The end-user needs are usually identified in operational terms at the system level during implementation of the Stakeholder Requirements Definition and Requirements Analysis processes (see CH 3–4.2.1.Stakeholder Requirements Definition Process and 4.2.2. Requirements Analysis Process, respectively).

Requirements Management provides bottom-up traceability from any derived lower-level requirement up to the applicable source (system-level requirement) from which it originates. This bi-directional traceability is the key to effective management of system requirements. It enables the development of an analytical understanding of any system-wide effects of changes to requirements for a given system element, updating requirements documentation with rationale and impacts for approved changes. At the same time, bi-directional traceability ensures that approved changes do not create any "orphaned" lower-level requirements (i.e., that all bottom-up relationships to applicable system-level requirements remain valid after the change).
Bi-directional traceability also ensures that higher-level requirements are properly flowed to lower-level requirements and system element designs so that there are no "childless parent" higher-level requirements (i.e., each high-level requirement is ultimately being addressed by lower-level requirements and system element designs).

Activities and Products
The Program Manager (PM) should keep leadership and all stakeholders informed of cost, schedule and performance impacts associated with requirement changes and requirements growth.

7. Technical Performance Measures (TPMs)

Section Summary

Technical Performance Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
TPM	Technical Performance Measurement	TPM involves predicting the future values of a key technical performance parameter of the higher-level end product under development based on current assessments of products lower in the system structure		7.1
Product Roadmap Completeness Measure	Product Roadmap Completeness Measure	Product Roadmap Completeness Measure involves monitoring the features documented in the program's roadmap. The features should represent the means to meet the objectives documented in the contract.		7.2

While many of the other measures documented in this guide are associated with cost and schedule aspects of the program, Technical Performance Measures (TPMs) are usually considered in the domain of Systems Engineering. The NDIA Systems Engineering Division published a study entitled "System Development Performance Measurement" in October 2011 that contained recommendations for key information needs, indicators, and measures that could be used in the acquisition and management of defense programs from the Systems Engineering perspective. TPMs, as well as, other system engineering oriented predictive measures are cited in that report.(15)

7.1 Technical Performance Measure Compliance

Metric Definition

Technical Performance Measurement (TPM) involves predicting the future values of a key technical performance parameter of the higher-level end product under development based on current assessments of products lower in the system structure. Continuous verification of actual versus anticipated achievement for selected technical parameters confirms progress and identifies variances that might jeopardize meeting a higher-level end product requirement. Assessed values falling outside established tolerances indicate the need for management attention and corrective action.

A well-thought-out TPM program provides early warning of technical problems, supports assessments of the extent to which operational requirements will be met, and assesses the impacts of proposed changes made to lower-level elements in the system hierarchy on system performance.

A good TPM has the attributes of:

- **Traceability** – The traceability of the Technical Requirements to WBS to Technical Performance Measures to EVM Control Accounts. In the Control Account, a description of the TPM and its allowed range of values for the Period of Performance of that Control Account should be defined.
- **Impact** – How much of the WBS work, and therefore how much budget (BCWS), is covered by the TPM(s)? What is the impact of a non-compliant TPM at any specific stage of the program?
- **TPM Banding/Sensitivity** – What banding (R/Y/G) and sensitivity (EV impact) should be used for each TPM?
- **Technical Readiness Level** – What's the state of the technology supporting the requirement(s) for which TPM is a metric?

Calculations

The TPMs are calculated using the attributes listed above for the system as a whole and for critical components of that system. This calculation can be for any Key Performance Parameter that will jeopardize the success of the program if it is outside the allowable band of values at a specific point in the program. The graph in Figure 35 shows a notional example of how to plot the progress of the TPM against the planned value of that Key Performance Parameter.

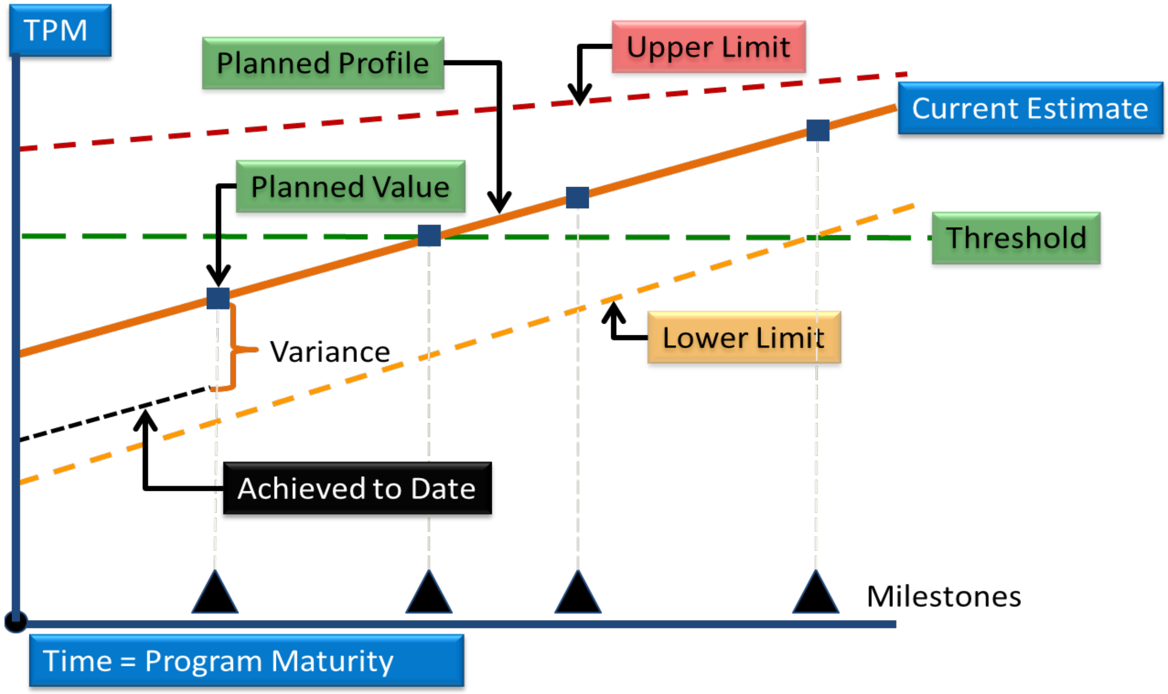


Figure 35. Plotting the Progress of TPMs against KPPs

Output/Threshold

The Technical Performance Measure of a key deliverable is typically defined during the requirements definition phase of the program and continually assessed for compliance at every stage of the program.

The TPM is used to:

- Assess the design process;
- Define compliance to the performance requirements; and
- Identify technical risk.

The TPMs are limited to critical thresholds for program elements that are critical to the customer's success and critical to technical compliance.

Candidate for Technical Performance Measures include:

- Physical size and stability – Useful life, weight, volumetric capacity.
- Functional correctness – Accuracy, power performance.
- All the "*…ilities*" – Supportability, maintainability, dependability, reliability, operability.
- Efficiency – Utilization, response time, throughput.
- Suitability of purpose – Readiness.

Predictive Nature

For any Key Performance Parameter that is not within the allowed limits at a specific time in the program, more work and more budgets will be needed to take corrective action. As a result, the EVM metrics must be assessed to confirm that they reflect this *out-of-compliance* condition for the TPM.

With this assessment of the TPM compliance, a recovery plan can be developed and the impact on the CPI/SPI of the program can be assessed.

An example of using the TPM to make EVM adjustments is shown in Figure 36. The Cost Variance and Schedule Variance are adjusted with the compliance values of the Technical Performance Measures shown in the first column, in this case WBS element 1.1. The example shows the aircraft weight as the system TPM and the composite elements of that weight as individual TPMs: airframe, aircraft, weapons, cooling system, displays/wiring, navigation system, and radar.

Each element TPM is assigned a percentage contribution, totaling 100%. The budget impacted by the TPM is assigned to each TPM as well. The TPM's technical compliance is then used to calculate a "TPM Informed" BCWP for that WBS element.

This BCWP is not the one reported in the Integrated Program Management Report (IPMR) or Integrated Program Management Data and Analysis Report (IPMDAR), but it is used to inform the program decision makers of the confidence in the IPMR or IPMDAR values. In the example shown in Figure 36, the result is a favorable measure of the weight against the planned weight and its impact on BCWP.

WBS				TPMs	TPM Coverage (quantification of WBS element)	BCWP Affected by TPMs	TPM T.S.	New BCWP 'TPM Informed'
1.1 Aircraft Weight				Airframe Weight	0.462	138.6	0.97	134.44
	Current	New		Aircraft Weight	0.077	23.1	0.97	22.41
BAC	$350M			Weapons Weight	0.384	115.2	1.00	115.20
BCWP	300	291.44		Cooling System Wt	0.031	9.3	0.78	7.25
BCWS	295			Displays/Wiring Wt	0.023	6.9	0.80	5.52
ACWP	305			Navigation Sys Wt	0.011	3.3	0.99	3.27
CV%	-1.67	-4.65		Radar Weight	0.012	3.6	0.93	3.35
SV%	1.69	-1.21		TOTAL	1.00	300		291.44
					Composite Technical Score		0.97	

Figure 36. Using the TPM to make EVM adjustments

Caveats/Limitations/Notes

- Developing the TPM starts after requirements definition based on the Measures of Effectiveness, and the Measures of Performance for the resulting system or product. The System Engineering Management Plan (SEMP) and the resulting system engineering architectural documents are used to further define the TPMs and to set threshold values.
    - The Measures of Effectiveness are operational measures of success that are closely related to the achievements of the mission or operational

objectives evaluated in the operational environment under a specific set of condition.

- The Measures of Performance characterize the physical or functional attributes relating to the system operation, measured or estimated under specific conditions.
- Key Performance Parameters represent the capabilities and characteristics so significant that failure to meet them can be cause for reevaluation, reassessing, or termination of the program.
- The Technical Performance Parameters are attributes that determine how well a system or system element is satisfying or expected to satisfy a technical requirement or goal.

Each of these must be determined before TPM can inform the EVM values.

Weighting and assigning impacts for each TPM also is a Systems Engineering process.

7.2 Product Roadmap Completeness Measure

Metric Definition

Product Roadmap Completeness Measure involves monitoring the features documented in the program's roadmap. The features should represent the means to meet the objectives documented in the contract. Each feature within the roadmap should be monitored for completeness, as well as the holistic roadmap completion. This measure compares planned feature completion with actual feature completion.

Calculations

The base measures are:

- The physical count of all features and all epics in the roadmap.
- The physical count of the sum of the "weight" (stories/story points) of all features and epics in the roadmap.

The basic algorithms are:

$$Roadmap\ Actual\ \%\ Complete = \frac{Features + Epics\ Completed}{Total\ Feature + Epic\ Count}$$

$$Roadmap\ Weight\ Actual\ \%\ Complete = \frac{Sum\ of\ Feature + Epic\ Story\ Points\ Completed}{Sum\ of\ Total\ Feature + Epic\ Story\ Point}$$

Output/Threshold

The top level output may appear as a flow chart diagram, with each feature as a box and the program increment or release cadence represented across the top, to show the notional time frame for which a feature is targeted to be completed.

The program roadmap will also convey to the program backlog in the agile tool chosen for the contract.

Predictive Nature

Unfavorable progress in completion and a slow start to the actual % complete indicate a threat to timely delivery of features and meeting the overall contract goals.

Be careful to commit to many features being completed in an early program increment/release, as especially in the case of new development projects, environments may need to be established and system engineering decomposition may need to be performed prior to the delivery of working code and features.

In some cases, the reassignment of many features from an earlier program increment/release to a later program increment/release may be an indicator of the scope "bow-wave" pushing delivery of capability to the back end of the program.

Possible Questions

- Is the entire roadmap sized for the entire contract?
- Does the roadmap include features and epics?
- How do the features and epic relate? Can an epic start as many features grouped together? The key is to understand the agile hierarchy terms for the program being measured.
- Does the program require each feature to be decomposed to a level so that each feature will complete within one program increment/release? (note: the reference to program increment or release assumes the duration is approximately three months.)

Caveats/Limitations/Notes

- Not all development programs have a roadmap.
- Weighting and determining features also is a Systems Engineering process.

8. Contract Metrics

Section Summary

Contract Health Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
Contract Mods	Contract Modifications	Contract mod metrics show the trending contract budget base modifications, which helps predict the accuracy of the Performance Measurement Baseline (PMB) and ensures that the contract was written correctly.		8.1
Baseline Revisions	Authorized Baseline Revisions	Tracking PMB revisions helps predict the accuracy of the PMB, on which all basic earned value data elements are dependent.		8.2
Program Funding Plan	Program Funding Plan	The Program Funding Plan metric is a measure of the funding stability on the program.		8.3
Program Funding Status	Program Funding Status	The Program Funding Status metric shows actual and projected cumulative program funding compared to projected program expenditures plus potential termination liability.		8.4
Contract Change Value	Contract Change Value	The Contract Change Value metric measures the volume, value, and timing of contract change activity and the status of Undefinitized Contract Actions (UCAs). .		8.5
RDT&E Actual Billings vs. Forecast Billings	Research, Development, Test, and Evaluation (RDT&E) Actual Billings vs. Forecast Billings	The RDT&E Actual Billings vs. Forecast Billings is a funds execution metric that measures how well the contractor.		8.6

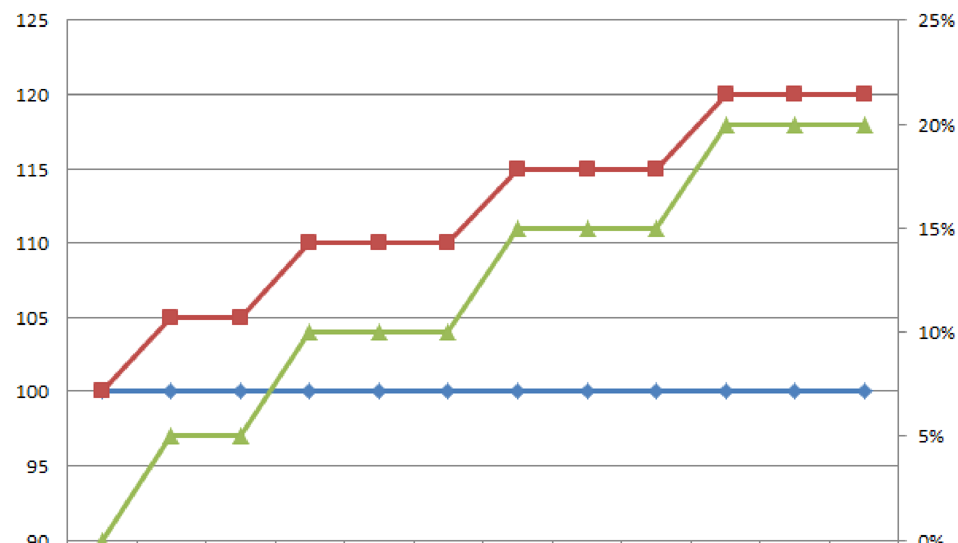
8.1 Contract Mods

Metric Definition

One of the biggest challenges is getting the earned value management requirements on contract appropriately. Some challenges include incorrectly tailoring the data item descriptions for the Integrated Program Management Report (IPMR) or Integrated Program Management Data and Analysis Report (IPMDAR) and the IMS, and specifying contract requirements that are inconsistent with the policy and EVM system guidelines. It's important to get the requirements right up front because fixing problems later is more difficult. Contract mod metrics show the trending contract budget base modifications, which helps predict the accuracy of the Performance Measurement Baseline (PMB) and ensures that the contract was written correctly.

Output/Threshold

Using the contract mod metrics drive PMB accountability. Programs with contract budget base changes of greater than 10% may have failed to include all applicable requirements and respective budget in the original contract. The contract budget base changes directly increase the number of PMB changes, as well as the program's accountability to incorporate the changes. The example provided in Figure 37 reflects that the contract value increased by 20% within the first nine months.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Original Contract Target Cost	100	100	100	100	100	100	100	100	100	100	100	100
Contract Budget Base	100	105	105	110	110	110	115	115	115	120	120	120
Percent Change	0%	5%	5%	10%	10%	10%	15%	15%	15%	20%	20%	20%

Figure 37. Original CTC vs. CBB

Calculation

Plot the **Contract Budget Base** minus the **Original Negotiated Cost** divided by the **Original Negotiated Cost** over time.

Predictive Nature

The intent of this metric is to influence the program team to focus on the accuracy of the PMB. Trending contract modifications helps validate the integrity of the PMB metrics and predicts potential cost overrun and schedule slip.

Possible Questions

- Are changes to the performance measurement baseline made as a result of contractual redirection, formal reprogramming, internal replanning, application of undistributed budget, or the use of management reserve properly documented and reflected in the Integrated Program Management Report?
- Are records maintained to track usage of management reserves and undistributed budget?
- Is authorization of budgets in excess of the contract budget base controlled formally? Is it done with the full knowledge and recognition of the procuring activity and is the management of scope supported by the appropriate funding source? Are the procedures adequate?
- Do procedures specify under what circumstances replanning of open work packages may occur, and the methods to be followed? Are these procedures adhered to?

Caveats/Limitations/Notes

- Have you considered the impact of the nature and probability of your risks and opportunities in establishing your budgets for the PMB?

8.2 Baseline Revisions

Metric Definition

Once the PMB is established, cost and schedule changes must be processed through formal change control procedures. Authorized Baseline Revisions must be incorporated into the PMB in a timely manner. Baseline changes may occur as a result of contractual modifications, the use of management reserve, application of undistributed budget, replanning, or formal reprogramming.

The Baseline Revision measure that indicates lack of control to the PMB in the near term is when the percent change of baseline dollars approaches 6% or more, when there are no changes in scope, and use of MR. This metric, similar to contract modifications, helps to validate the integrity of the PMB.

Output/Threshold

Tracking PMB revisions helps predict the accuracy of the PMB, on which all basic earned value data elements are dependent. Tracking PMB revisions assists in the identification of revisions where questions need to be raised about the BCWS.

Calculation

Using Contractor Performance Data, review the forecast of the PMB BCWS (Non-Cumulative. Compare **Performance Measurement Baseline (End of Period) Budgeted Cost for Work Scheduled (BCWS)** to what was previously reported for that current period. The resultant calculation is **current BCWS minus original reported BCWS divided by original reported BCWS.**

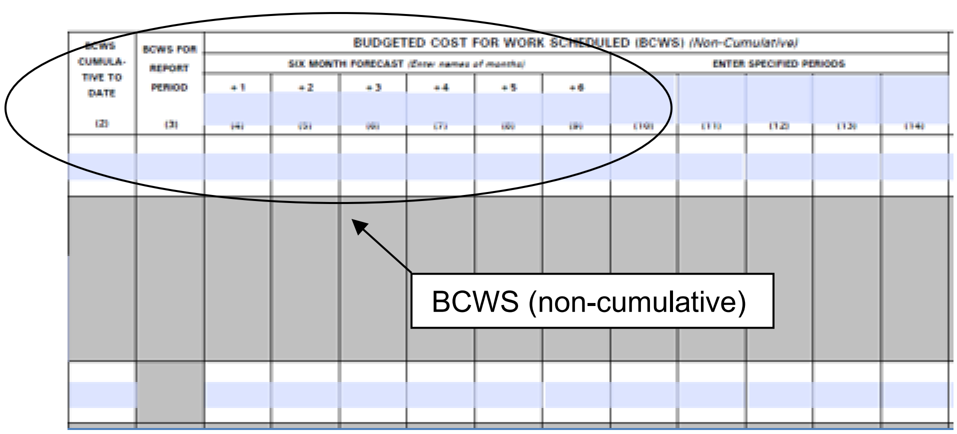


Figure 38. BCWS Data Comparison

Predictive Nature

The intent of this metric is to focus on the accuracy of the PMB. Trending baseline revisions helps validate the integrity of your baseline metrics.

Possible Questions

- Are changes to the PMB made as a result of contractual redirection, formal reprogramming, internal replanning, application of undistributed budget, or the use of management reserve properly documented and reflected correctly in the

Integrated Program Management Report (IPMR) or Integrated Program Management Data and Analysis Report (IPMDAR)?

- Do work packages reflect the actual way in which the work will be done?
- Are the work packages meaningful products or management-oriented subdivisions of the higher-level elements of work?
- Do the scope and timing of the work packages align with the contract?
- Are detailed work packages planned as far in advance as practicable?
- Are authorized changes being incorporated in a timely manner?
- Is the Baseline tracking with what was proposed? (i.e. Does it still meet expectations?)

In summary, this process is a means to surface problems with the intent of achieving early warning of potential problems so that effective resolution can be provided.

Caveats/Limitations/Notes

- Has the Internal Team bought into the Baseline?
- Do they “own” the pieces of the Baseline for which they are responsible and accountable?

8.3 Program Funding Plan

Metric Definition

The Program Funding Plan metric is a measure of the funding stability on the program. It compares the funding planned in the initial bid or current contract budget base and the actual funding authorized by the customer over the life of the program, as well as the EAC implications for funding differences between planned and authorized values. The implications of underfunding situations should show up in the EVM metrics (e.g., CPI and SPI).

Calculation

Use of time-phased initial bid or current contract budget base.

Output/Threshold

Figure 39 depicts the planned program funding versus the authorized funding actually provided for contract performance. When the actual funding is less than planned, work must be delayed or deferred, which results in program disruption.

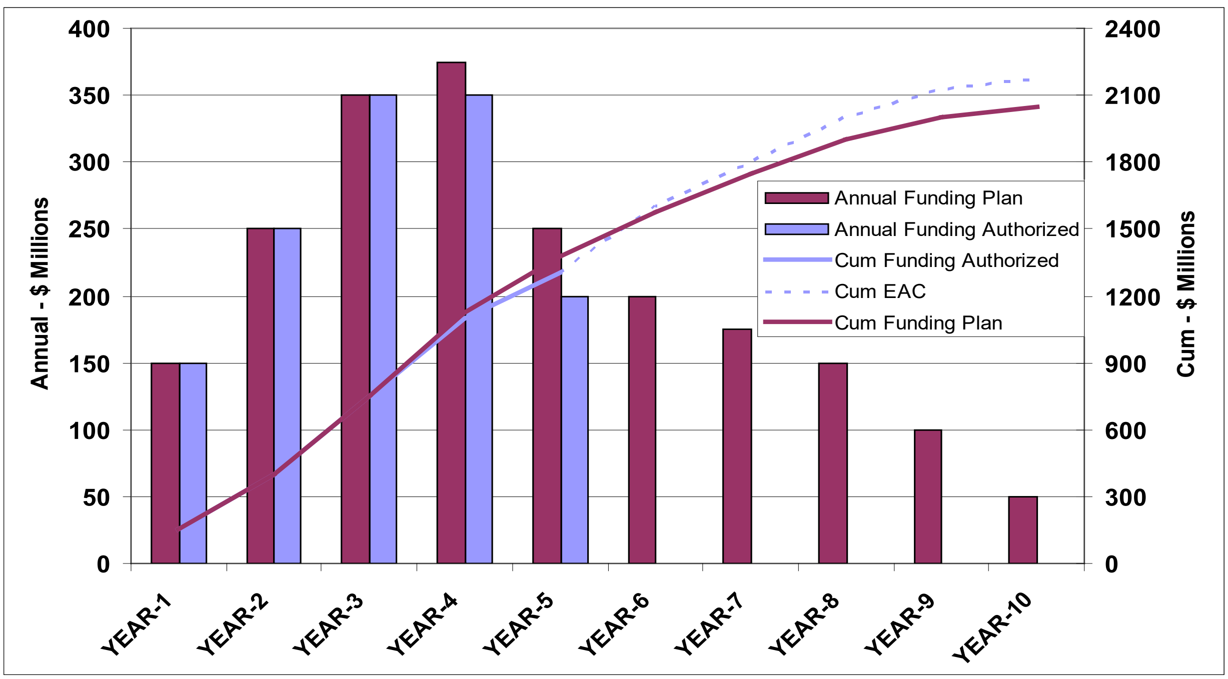


Figure 39. Planned Program Funding vs. Authorized Funding

Predictive Nature

When extrapolated, indicates when expected authorized funding may deviate from original planned funding.

Possible Questions

- Has the program reviewed the trend of authorized funding to planned funding?
- Are the program's planning assumptions still valid?
- Does it indicate that the customer may have possible funding constraints?

What is the impact of the funding constraints to the program execution plan?

Note: This metric is only valid for incrementally funded contracts and should not be used for fully funded programs, Indefinite Delivery/Indefinite Quantity-type contracts funded by task/delivery order, or other contracts that may be funded by task/delivery order.

8.4 Program Funding Status

Metric Definition

The Program Funding Status metric shows actual and projected cumulative program funding compared to projected program expenditures plus potential termination liability. Expenditures include cost expenditures, commitments, and earned fee or profit. Potential Termination Liability includes cumulative expenditures plus termination liabilities. Termination liabilities include costs such as severance pay, return of field service personnel, costs continuing after termination, loss of useful value, rental on unexpired leases, termination settlement expenses, etc.

Note: in some instances such as award fee contracts, fee is separately funded and is not included in expenditures.

Calculations

Customer Funded Amount minus Contractor Potential Termination Liability

If greater than or equal to 0, Contractor has Customer Funding to cover Potential Termination Liability. If less than zero, Contractor is at risk because Customer Funding has not covered the Potential Termination Liability.

Output/Threshold

This chart shown in Figure 40 is specifically intended for use only on incrementally funded contracts and is not applicable to fully funded contracts.

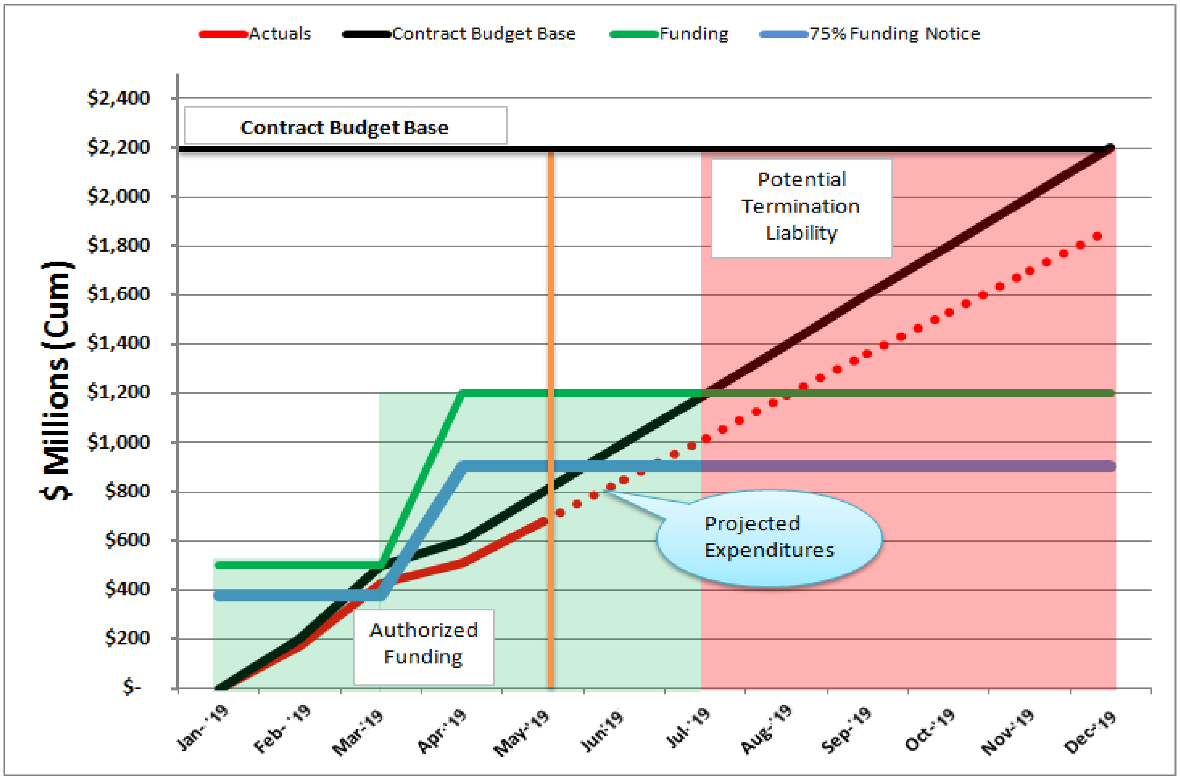


Figure 40. Program Funding Status

Predictive Nature

If the program is underfunded (i.e., Customer Funding is less than Contractor Potential Termination Liability), disruption is likely to result due to work delays and deferrals necessary to reduce Contractor Potential Termination Liability.

Possible Questions

- If the Contractor Potential Termination Liability is greater than or equal to 75% of customer authorized funding, is funding being closely monitored and is the customer being notified, as required by the contract terms?
- Are funding notice requests being communicated in a timely manner?
- Have all the baseline budget changes been incorporated so that the projection is accurate?
- Is the frequency of funding distribution consistent with projection established at contract formation?

8.5 Contract Change Value

Metric Definition

The Contract Change Value metric measures the volume, value, and timing of contract change activity and the status of Undefinitized Contract Actions (UCAs). UCAs represent contract direction authorized by the customer whereby the contract terms, specifications, and price are not agreed upon for finalization, definitization of the agreement. Unauthorized change proposals represent changes requested by the customer that have not been authorized for implementation.

Calculations

Proposals in Process – This is quantity and values for proposals currently being worked.

Proposals Submitted – This is the quantity and values for proposals that have been completed and submitted to the customer.

Initial Contract Value – The full value of the scope authorized by the initial Negotiated Contract Cost (NCC).

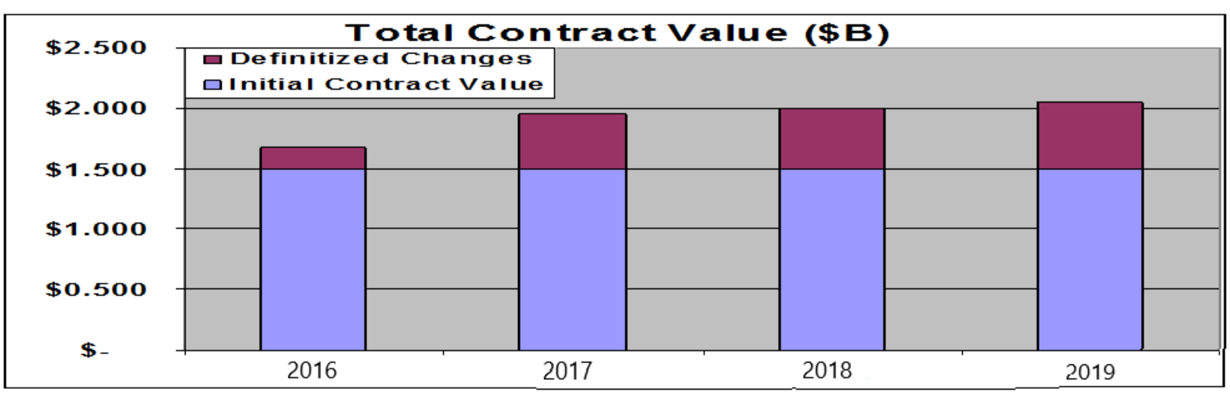
Definitized Changes – The number of contract modifications (changes) that have been made to the contract and are fully negotiated.

Output/Threshold

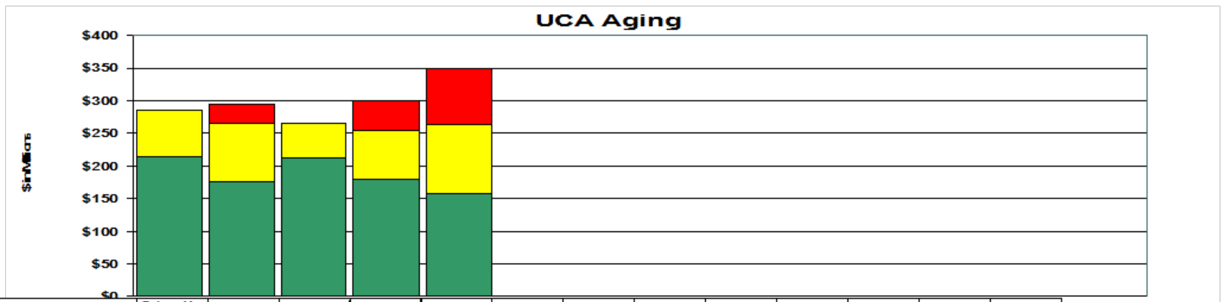
The example charts shown in Figure 41 can be used for any program type throughout the program lifecycle. Thresholds may vary based on the nature of the contract work.

Unauthorized Change Proposals

	At Prior Year End		Current Period		
$ in Millions	No.	Value	No.	Value	CCB
Proposals In-Process	2	$ 40	2	$ 60	1
Proposals Submitted	1	$ 25	4	$ 135	4
Negotiated/Pending Definitization	1	$ 50	1	$ 10	1
Total Unauthorized Undefinitized	4	$ 115	7	$ 205	6



Undefinitized Contract Actions (UCAs)					
	At Prior Year End		Current Period		
$ in Millions	No.	Value	No.	Value	CCB
Proposals In-Process	5	$ 175	1	$ 25	-
Proposals Submitted	3	$ 75	9	$ 125	9
Negotiated/Pending Definitization	1	$ 35	5	$ 200	5
Total Authorized Undefinitized	9	$ 285	15	$ 350	14



	Prior Yr-End	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
No. ≤150 days	7	9	8	9	10								
No. >150≤180 days	2	2	2	3	3								
No. >180 days	0	1	0	1	2								
Total	9	12	10	13	15								

Figure 41. Contract Change Volume

Predictive Nature

Contract change volume and UCA cycle time will usually predict cost increases to the contract budget base. A large number of contract changes or a significant change or extremely long UCA cycle times can indicate that the customer's requirements were not adequately identified in the initial contract or they may have changed. This metric allows the program to track the contract change volume and UCA process at a glance and its potential impact to program cost. Excessive change volume or a significant contract change may indicate the need for a program re-baseline activity.

Possible Questions

- Did the proposal team correctly understand the contract requirements?
- Are the program requirements correctly identified?
- What is driving the changes in contract requirements?
- Are UCAs being definitized in a timely manner?
- Is a re-baseline needed?

Caveats/Limitations/Notes

- Are the resources available to execute the proposals and contract actions should they be definitized?

8.6 Research, Development, Test, and Evaluation (RDT&E) Actual Billings vs. Forecast Billings

Metric Definition

The RDT&E Actual Billings vs. Forecast Billings is a funds execution metric that measures how well the contractor is performing against forecast or planned billings. The information needs to be tracked for each fiscal year of RDT&E funding that is placed on contract because the Government Program Office has to report its RDT&E execution by fiscal year of funding against established Office of the Secretary of Defense (OSD) and Service benchmarks. Performance against these benchmarks often becomes a key indicator used to help determine budget marks (cuts in funding) that may be levied on the program by the Service, OSD, or Congress. The benchmarks are used to help determine if program funding is out of phase – that is, does the program have the correct amount of funding at the correct time. The benefit of using this metric is that it provides an early indicator to the Government Program Office on their performance as it relates to funds execution benchmarks. It also provides the prime contractor with an indication of cash flow performance as it relates to the particular contract and can indicate if the contractor will run out of funds before the end of the fiscal year.

The goal of this metric is to measure and indicate how well the contractor is performing to plan and to indicate if the future plan is realistic and achievable.

Calculation

The formula is straightforward. It is a comparison of actual billings to planned billings. From the Government's perspective, it is important to understand the actual versus planned billings for each fiscal year of contract RDT&E funds. Because RDT&E funds are available for obligations for two years and the expenditure benchmarks are tracked for those two years, it is necessary to show at least two fiscal years of performance data. For example, while FY12 RDT&E funds are being expended it is necessary to track those expenditures at least until the end of FY13. Ideally, the tracking of FY12 RDT&E funds would be tracked until all FY12 RDT&E funds were fully expended. This will most likely result in the need to track more than two fiscal years at a time with this metric.

Output/Threshold

Although there is no threshold for this metric, the RDT&E funds obligation and expenditure (outlays) benchmarks do provide a threshold against which the Government Program Office's funds management performance is measured. The prime contractor effort usually represents 80% to 90% of the Government Program Office's RDT&E funds in a given fiscal year. Therefore, the contractor's actual billings will be the largest contributing factor to how the program office performs against the RDT&E expenditure benchmarks. The OSD publishes Financial Summary Tables that establish the obligation and expenditure (outlays) benchmarks for all DoD appropriations. These benchmarks may be slightly different for each service and type of appropriation. In recent years, there has been an attempt to minimize the use of these benchmarks, but more than 50% of budget marks that get issued site "funds ahead of need" as the reason for the budget mark. Although not the only thing considered, the benchmarks provide the primary measure against which the funds-ahead-of-need determination is made.

Predictive Nature

When tracked over time, the cumulative actual performance line will show trends that indicate whether the billings are meeting the plan. It will indicate if action needs to be taken to understand and correct for significant variances between the actual and planned billings. It may indicate that the plan needs to be adjusted to better represent what will happen with future actual billings. This information can be used by the Government Program Office to better understand the likely performance against expenditure benchmarks and, more importantly, to better understand if the RDT&E funding profile is appropriately time-phased. The predictive information can be used by the program office in preparation for budget reviews and to help understand the potential impacts associated with budget marks resulting from being under-expended. Mitigation plans and alternative courses of action can be developed based on an improved understanding of the proper time-phasing of the budget. Unexpected budget marks can result in significant cost and schedule impacts to the program and the contract. Figure 42 includes an example with actual and forecasted RDT&E billings.

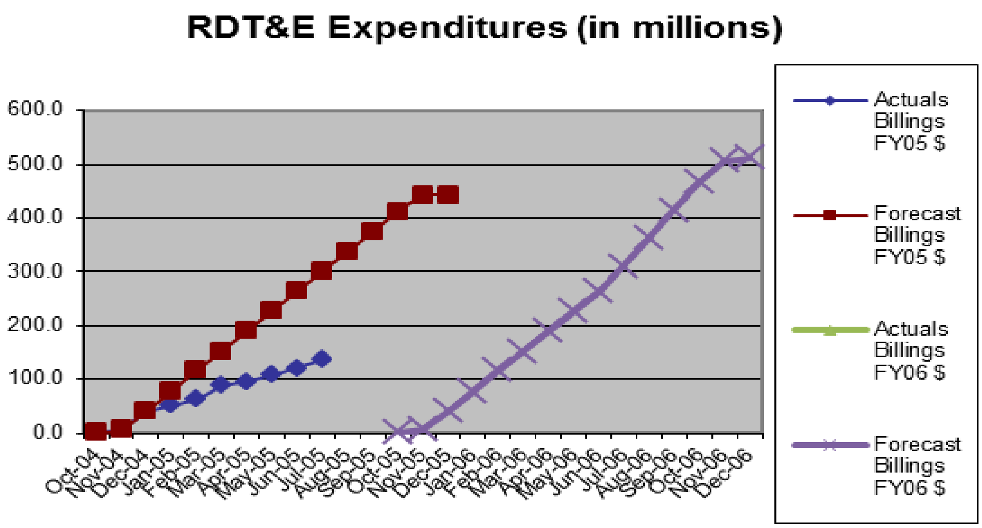


Figure 42. RDT&E Expenditures

The metric may indicate a trend that predicts that the contract will run out of funds before the end of the fiscal year. This could result in a work stoppage or schedule and cost impacts or could cause the contractor to work at risk. This metric can help the Government Program Office identify this situation early in the fiscal year, allowing for more time to mitigate the issue.

Potential Questions

- Where are the substantial deviations occurring?
- What is the real root cause of the variation?

- Is there any corrective action that needs to occur as a result of the identifying the root cause?
- When do corrective actions need to be initiated so that there will not be a negative impact on funding availability? (This includes factoring in the necessary processing time associated with all the internal and external organizations involved.)
- Is the billing cycle for all Subcontractors understood and forecasted properly?

Caution

There are many considerations which, if not accounted for when building the forecast billing plan, will result in a plan that cannot be executed. For instance, most prime contractors are outsourcing significant portions of the work. This naturally results in delays of billings to the government. The outsourced work can represent up to 80% of the effort. The effect of the delays in billing can be significant, especially early in the performance of the contract. The plan needs to account for these known and predictable delays. Because the prime contractor effort usually represents 80% to 90% of the Government Program Office's RDT&E funds in a given fiscal year, the contractor's billings have a significant effect on the funds execution performance as measured against RDT&E expenditure benchmarks. Another factor that can affect funds execution for a particular fiscal year of RDT&E funding, is how soon in the fiscal year the government obligates the funding. Congressional action, such as operating under a continuing resolution as opposed to passing an appropriation bill, will have an effect on when the funds are available to be obligated and how much funding is available to be obligated. Other factors that need to be considered but that are not measured by this metric are the "limitation of funds" clause on the contract and termination liability. Termination liability for any point during the execution year is dependent upon the contractor's status with regards to actual expenditures against that year's PMB. To know actual expenditures' measurement against the plan gives the PM a good initial indication of the termination liability in the unlikely event that the program is cancelled and the government terminates the contract.

It is important to understand the potential effects of focusing too much on trying to achieve expenditure benchmarks. Actions should be prevented that get funds expended to achieve benchmarks that use those funds inefficiently and ineffectively. This is not about simply trying to find ways to expend funds in order to meet benchmarks. Rather, proper use of this metric will result in early identification of funding phasing issues and improve a program's ability to prevent or mitigate impacts that may result from unanticipated budget marks.

9 Supply Chain Metrics

Section Summary

Supply Chain Metric	Full Name	Summary	Relationship to Other Metrics	Found in Section:
Parts Demand Fulfillment	Parts Demand Fulfillment	Parts Demand Fulfillment is tied to On-Time Delivery (OTD), the percent measurement of total items received at the agreed upon Due Date.		9.1
Supplier Acceptance Rate	Supplier Acceptance Rate	The basis of the quality calculation is derived from the percentage of acceptable versus rejected delivered parts in a month for all approved suppliers.		9.2
DPPM	Defective Parts per Million	An alternate way of presenting a percent acceptable metric. It states the rate of defective parts per million shipped.		9.2
Supplier Late Start	Supplier Late Start	A Supplier Late Start is any course of events that prevent a supplier from being able to begin manufacturing the items on a Purchase Order.		9.3
LOB	Production Line of Balance	A technique for assembling, selecting, interpreting, and presenting in graphic form the essential factors involved in a production process from raw materials to completion of the end product against a background of time.		9.4

9.1 Parts Demand Fulfillment

This section provides measures of supply chain activities that can be used during the different program phases. These activities range from large subcontractors to small suppliers which can become a critical element during program execution. To best apply predictive measures for supplier performance, one must understand the entire path from design to part delivery. In the development phase on a program, supply chain activities are mainly engineering driven in collaboration with supply chain. Using predictive metrics supply chain can help drive engineering towards sources that meet their program requirements. Once the program is in production, supply chain activities focus on items such as volume, efficiency and quality..

Metric Definition

Parts Demand Fulfillment is tied to On-Time Delivery (OTD), the percent measurement of total items received at the agreed upon Due Date. This due date is determined based upon conversations between the buyer and supplier, factoring in the lead time it takes to make parts along with other factors. This lead time is calculated using certain criteria for items such as complexity of the material, supplier capacity, size of the item, whether the supplier has to send the item to sub-tier, along with any other criteria deemed production-critical. Once everything has been factored in and agreed upon, a date is set within the system. From there, it is the buyer's job to monitor the purchase order, ensuring that it is delivered on or before the date set within the system. If for some reason the business delays getting information to the supplier – for example due to engineering drawing changes or delays in getting material to the supplier – the business has the right to update dates within the system to prevent the supplier from getting penalized for a late delivery. On the other hand, if the supplier is having issues with meeting the original agreed-upon delivery date, the system will indicate this and a new, updated delivery date will be set. A case like this will penalize the supplier with an incident of lateness due to the fact that they were not able to meet the contractual date.

Calculations

- **On-Time In Full (OTIF)/OTD –** Delivery Performance is measured as an On Time In Full (OTIF) or also known as On Time Delivery (OTD), of Purchase Order (PO) order lines for the measured time period. A line item is delivered OTIF/OTD when it is supplied at the agreed time (within the "delivery window"), in the agreed quantity and according to the agreed freight-terms and packaging specifications.
- **Delivery Window –** The current delivery window is as early as the supplier can provide the material up to the agreed-upon due date. Once the item is delivered past the due date window, it is considered late; and the supplier will get penalized for a late delivery. The agreed-upon due date within the Purchase Order system is the Statistical Date, or Stat-Date. This is the date the Buyer and supplier have agreed upon to deliver the item. If it becomes known that an issue arises on the Buyer side preventing the supplier from delivering on-time; the Buyer has the authority to change the Statistical Date as to not penalize the supplier.

- **OTIF% = (# of order lines delivered on time/# of order lines due to be delivered) X 100.**

Output/Threshold

Each month and/or week, an overall OTD should be calculated for all the deliveries from a supplier; this is also known as OTIF delivery of Purchase Order (PO) order lines for the measured time period. A line item is delivered OTIF/OTD when it is supplied at the agreed time (within the "delivery window"), in the agreed quantity, and according to agreed freight terms and packaging specifications. An example chart showing a program's OTD performance is provided in Figure 43.

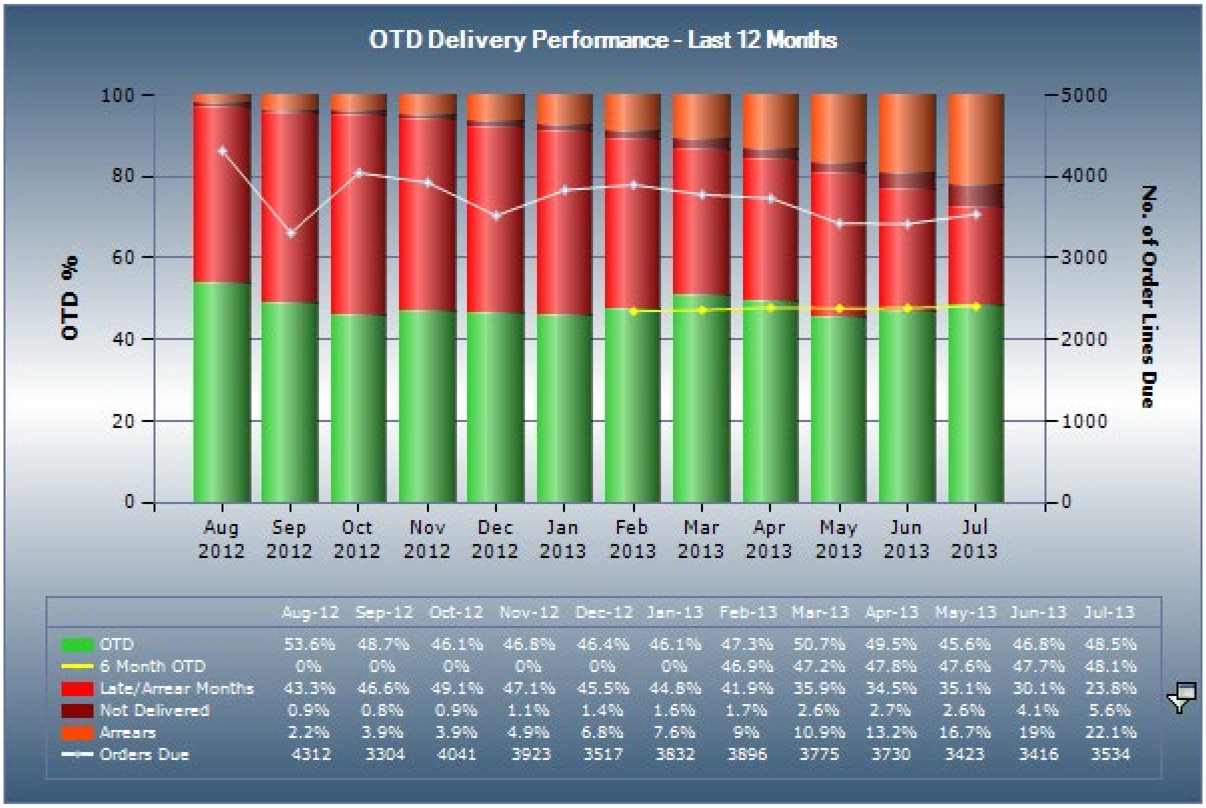


Figure 43. Program's OTD Performance

Predictive Nature

For analysis purpose, it is good to calculate OTD pre-scrubbed (date pulled directly from the system) versus scrubbed (data reviewed by buyer/supplier). Pre-scrubbed OTD data are pulled directly from the Supply Chain Purchase Order system. Reviewing such information gives insight into buyer/supplier management. The buyer then needs to take the pre-scrubbed information and give the supplier a few days to appeal all late items, verifying that they are truly late. The definition of a late item is anything that is later than the contractual due date. During the appeal process, suppliers are given the chance to provide reasons an item should not be considered late even though it is shown as being late in the system. After the appeals process has been completed, a similar OTD calculation is done and compared to the pre-scrubbed OTD to see how many items and which types of item were appealed. A sample of an OTD pre-scrubbed versus scrubbed (appealed) data is shown in Figure 44.

APRIL OTD PRE-SCRUBBED	
PO Lines Due	1940
PO Lines Received	1736
Not Delivered	204
Early	290
On Time	1218
1 day late	74
< 5 days late	68
< 15 days late	80
> 15 days late	6
OTD %	78%

APRIL OTD SCRUBBED	
PO Lines Due	1940
PO Lines Received	1897
Not Delivered	43
Early	290
On Time	1514
1 day late	35
< 5 days late	20
< 15 days late	33
> 15 days late	5
OTD %	93%

Figure 44. OTD Pre-scrubbed vs. Scrubbed

Possible Questions

- What if a supplier and buyer agree to split the shipment on a line and the first part of the split shipment comes in on time and the other portion comes in late, how is the OTD calculated for this item?
- What is an acceptable percentage threshold for OTD? If OTD falls below that threshold, what actions are taken?
- How are late items that are received in a subsequent month factored into the OTD calculation (i.e., arrears)?
- Is OTD on an upward or downward trend? Depending on the trend, what are the drivers for this?

Caveats/Limitations/Notes

- No matter how well dates are managed for POs, there are dates that will have to be changed due to unforeseen circumstances, causing them to be measured in arrears and affecting the overall OTD percentage.
- Since OTD is based upon the receipt of parts in the building, a part can be received on time but not entered into the system until a later date. The system will show this as late, when in actuality the delivery was on time. A company decision will need to be made on how to handle such items and what impact they will have on the OTD calculation.

9.2 Supplier Quality

Metric Definition

After the OTD process is complete, the quality Supplier Acceptance Rates can be calculated. The basis of the quality calculation is derived from the percentage of acceptable versus rejected delivered parts in a month for all approved suppliers.

Supplier Acceptance Rate Calculations

Defective Parts per Million (DPPM) – An alternate way of presenting a percent acceptable metric. It states the rate of defective parts per million shipped.

Parts per Million (PPM) Calculation = **(Quality Rejected/Quality Inspected) X 1MM**, or Number of defective pieces received from suppliers/Number of pieces received x 1MM.

Escape (Supplier) –Can include problems, inefficiencies, or administrative errors for returned parts (wrong paperwork sent with product, wrong part number shipped, wrong quantity shipped, etc.). An individual event is recorded for a single reason/root cause against a single part number. An event can include multiple pieces per part.

Example: Supplier Escapes – 1 escape reported per part per line on each supplier PO

10 parts delivered against PO ABC
- Line 1, all 10 parts are rejected for same issue
- 1 QN is written for all 10 parts
- 1 QN = 1 Supplier Escape

20 parts delivered against PO ABC
- Line 1 Part XYZ 10 pieces,
- Line 2 Part QRS 5 pieces,
- All 20 parts are rejected for dimension,
- 2 QNs are written – 1 for Part XYZ (10 pieces), 1 for Part QRS (5 pieces)
- 1 QN or Supplier Escape for the 10 pieces against Part XYZ
- 1 QN of Supplier Escape for the 5 pieces against Part QRS

An example is shown in Figure 45, which shows a month-over-month total of the parts inspected, with the DPPM for each month. Based on the rolling total, an average is calculated. This average becomes the DPPM Target baseline.

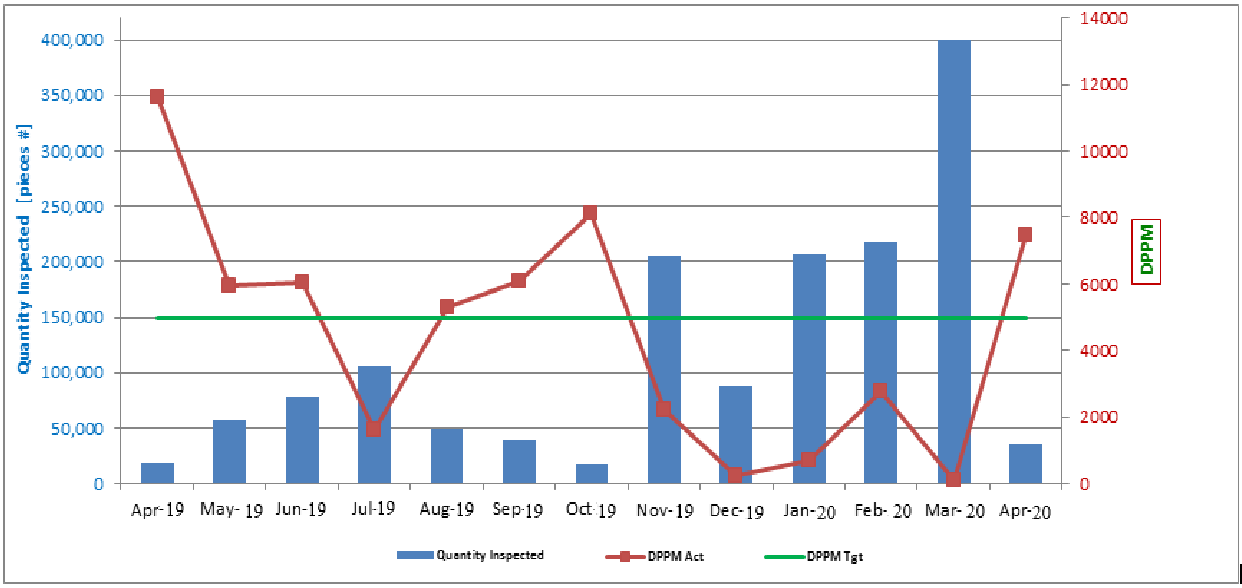


Figure 45. Monthly total of the parts inspected, with the DPPM for each month

Output/Threshold

An example output is shown in Table 2.

Table 2. Summary of DPPM Calculations

QUANTITY INSPECT =			**35,584**
QUANTITY ACCEPT =			**35,319**
QUANTITY REJECT =			**265**
% ACCEPTED			**99.26**
DPPM =			**7447**
Escapes =			**14**

It is to the responsibility of the Quality Team to inspect all delivered parts to determine if they are acceptable. During inspection, if a part does not meet the criteria of the drawing laid out in the purchase order, it will be rejected and considered non-conforming. Each instance of a rejected part is considered a supplier escape, which could initiate the creation of a corrective action for performance by the supplier. Such an action is determined by the Quality Engineer. Reviewing these metrics from period to period will allow for a forecasting trend to be developed with realistic program DPPM and escape goals, and subsequent performance projections.

Figure 46 shows accept and reject percentages for a 12-month timeframe. Using this trending we can easily identify problem months and do further research to prevent such issues in the future.

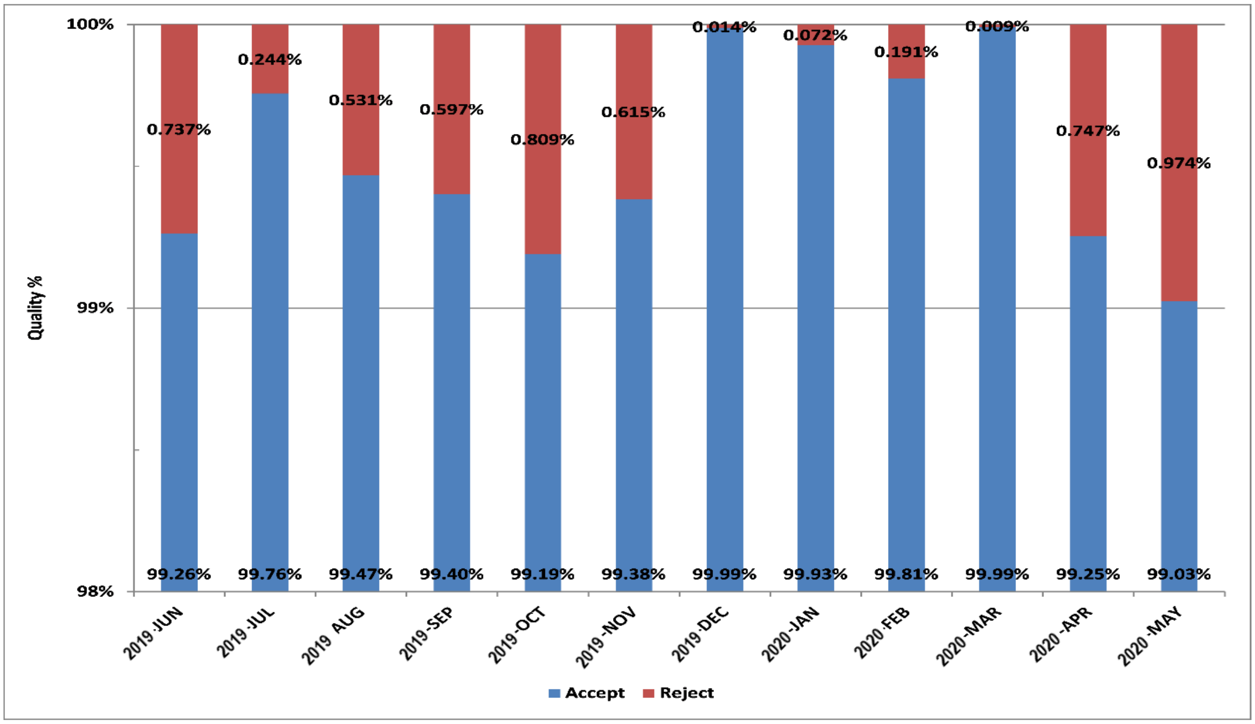


Figure 46. 12-Month Rolling Aging Metrics

Predictive Nature

Before the information is published, the Quality Team should scrub the data to validate that the items that the system shows as rejected (non-conforming) are truly rejected. Once this has been completed, a high-level visual summary illustrating the monthly quality issues is created.

Possible Questions

- Are current Supplier Acceptance Rates trending up or down? If so what are the key drivers?
- If a percentage of rejection falls below the agreed-upon threshold, what is the plan to improve the supplier's quality? When this does not work; when does a supplier get disqualified for orders?
- Do Supplier Acceptance Rates get skewed with purchase orders with higher item quantities versus lots?
- How are rejected items conveyed back to the supplier notifying them of the issues?
- How are suppliers that do not deliver regularly but have fluctuating performance addressed?

Caveats/Limitations/Notes

- Quantity inspected is a major player in the overall breakout of the percentages in that a lower number of items inspected means that the effect on percentage is more drastic if there are rejects.
- The number of items inspected is tied to OTD. This means that, if deliveries are rushed to meet a due date, the Supplier Acceptance Rates can potentially be impacted.

9.3 Supplier Late Starts

Metric Definition

A Supplier Late Start is any course of events that prevent a supplier from being able to begin manufacturing the items on a Purchase Order. They are directly impacted by both parts demand fulfillment and the supplier acceptance rate.

- Supplier Metrics
  - Parts demand fulfillment drives supplier starts
  - Integration of Supplier Late Starts predicts late finishes
  - Product Acceptance Rate (Planned vs. Actual)
    - Supplier product delivery should be included in the IMS
    - Supplier delivery rate is a definitive leading indicator of prime contractor performance where the supplier is an external dependency on or near the critical path
  - Fraction on-time deliveries
    - Measures the portion of deliveries from the supplier that were on time
  - Supply Lead Time
    - Measures the average time between when an order is placed and when the product arrives
  - Commitment Integrity
    - Measures the forecast accuracy of supplier commitments.

Calculations

- Subcontractor Tasks where actual start is later than baseline start.
- This identifying threshold looks for tasks in a schedule (formal or informal) that have already begun but that have a Percent Complete value that is 0% or has any inconsistencies when compared to the approved schedule.
- Tracking rolling late start/late finish values.

Predictive Nature

Customer-supplied material late starts (starts that are delayed because of wait times for materials) have an impact on OTD if no action is taken on that program. Engineering activities and changes cause dates to be pushed forward in order to accommodate the proper lead time needed to acquire parts for the program. This is particularly the case in development programs when design drives the program. Drawing release measures indicate future impacts on part deliveries.

Based on historical supplier performance and any facility/output constraints, a meaningful forecast can be derived as shown Figure 47.

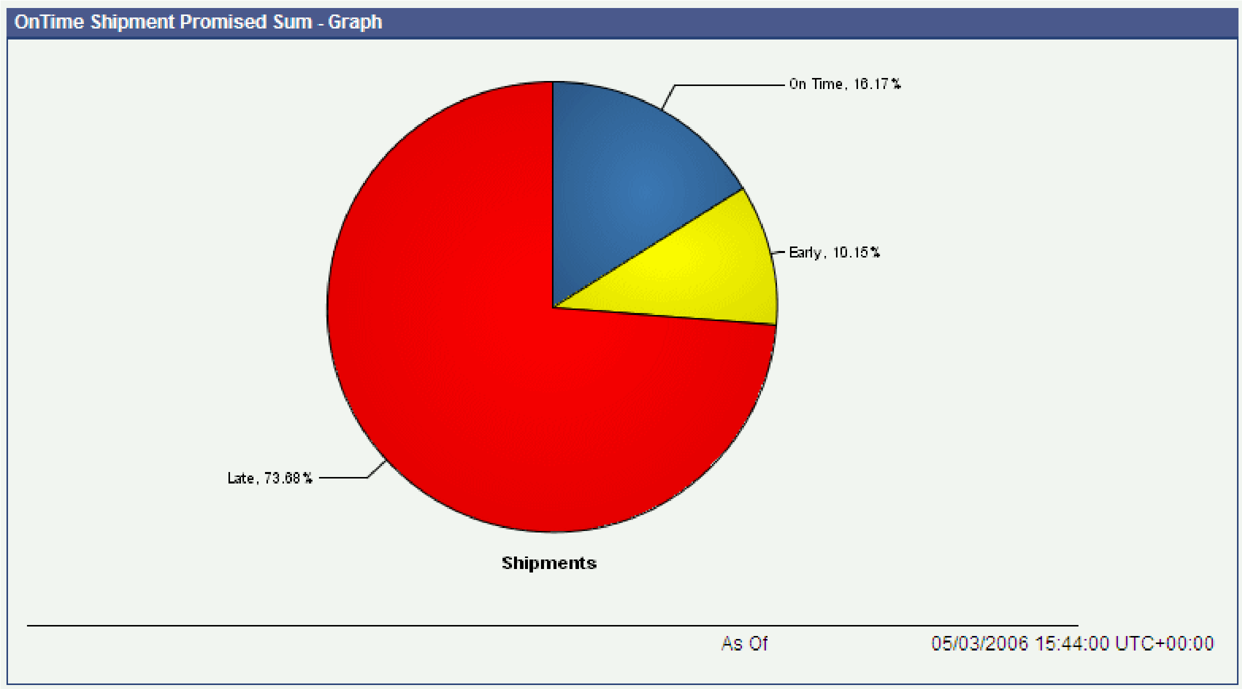


Figure 47. On-time Forecast (Late- Start)

Output/Threshold

Each organization that tracks supplier late starts determines its own an acceptable percentage of OTD after a supplier has indicated that a deliverable was started late to plan. This will become the threshold used to determine corrective action once a forecast is generated.

Possible Questions

- What impact will late starts have on parts demand fulfillment and supplier acceptance rates?
- Will late starts cause a lower demand fulfillment and supplier acceptance percentage?
- If there is a tight deadline for the completion of a program, what can be done to ensure that a late start does not occur?
- If a program has a late start, what can be done to get it back on track to meet the agreed upon supplier deadline? What tools can be used to help?
- What are the key drivers for program late starts?

Caveats/Limitations/Notes

- Program late starts can have a negative impact on demand fulfillment and supplier acceptance. To mitigate this risk, a buffer should be factored in when calculating the life of a program. This will take into consideration any issues that may arise that could cause a delay in the program.

- If parts being supplied for a program are delayed at a supplier, this could limit the work that can be done on a program. When issues arise that are out of a company's hands, the company should have alternative solutions ready just in case a delay in a program occurs.

9.4 Production Line of Balance

Metric Definition

LOB [7] [8] is a technique for assembling, selecting, interpreting, and presenting in graphic form the essential factors involved in a production process from raw materials to completion of the end product against a background of time. It is management information using the principle of exceptions to show only the most important facts to its audience. It is a means of integrating the flow of materials and components into the manufacture of end items in accordance with time-phased delivery requirements.

Though the Line of Balance (LOB) techniques preceded the development of MRP/MRPII/ERP by almost 20 years, it is still a valuable tool today. Specifically, those programs with recurring effort transitioning from development to production, entering into low-rate production, or using concurrent engineering and production (e.g., Spiral) will find significant value in the use of the LOB technology. Likewise, programs impacted by large quantities of design changes being retrofitted on the production line will equally benefit.

Assumptions: Program is in transition to, initial, pilot, low-, or full-rate production with a preliminary or approved first unit flow (consistent with Manufacturing Resource Planning [MRP]/MRP II/Enterprise Resource Planning [ERP]) and a manufacturing production schedule

Benefits

LOB relates actual status of the elements of a production program to planned progress. It identifies those elements which are lagging prior to experiencing a delay in delivery of the end item. It sets forth time relationships between various elements in the manufacturing process and points out deficiencies in the availability of materials, parts, and assemblies at selected control points along the production line.

LOB is a predictive assessment tool based upon a series of known attributes. These attributes include the end item Bill of Materials (BOM), procurement lead-times, assembly durations, test durations, queue times, and logical dependencies. It is through the use of this knowledge for specific activities that leadership may collect information useful in the mitigation of existing or future risks. The use of the LOB technique has connectivity with the IMS, Critical Path Analysis (CPA), and Schedule Risk Assessment (SRA), but operates at a level where discrete actions may have beneficial results. Tracking activity starts rather than finishes can significantly improve performance

Purpose

The basic use of the LOB technique is to measure the current relationship of production progress to scheduled performance and to predict the feasibility of accomplishing timely deliveries. It is a positive means for determining which areas in the process need corrective action. Continued vigilance provides validation of the effectiveness of mitigation actions. The LOB technique provides quantifiable performance indicators for the manufacturing process from initiation of purchase orders through the shop floor to delivery completion.

LOB Elements

The LOB technique comprises four elements:

1) The Objective – Cumulative delivery schedule
2) The Program – The production plan
3) Program Progress – Current status of performance
4) Comparison of Program Progress to Objective – The LOB.

Output

Figure 48 illustrates the LOB technique.

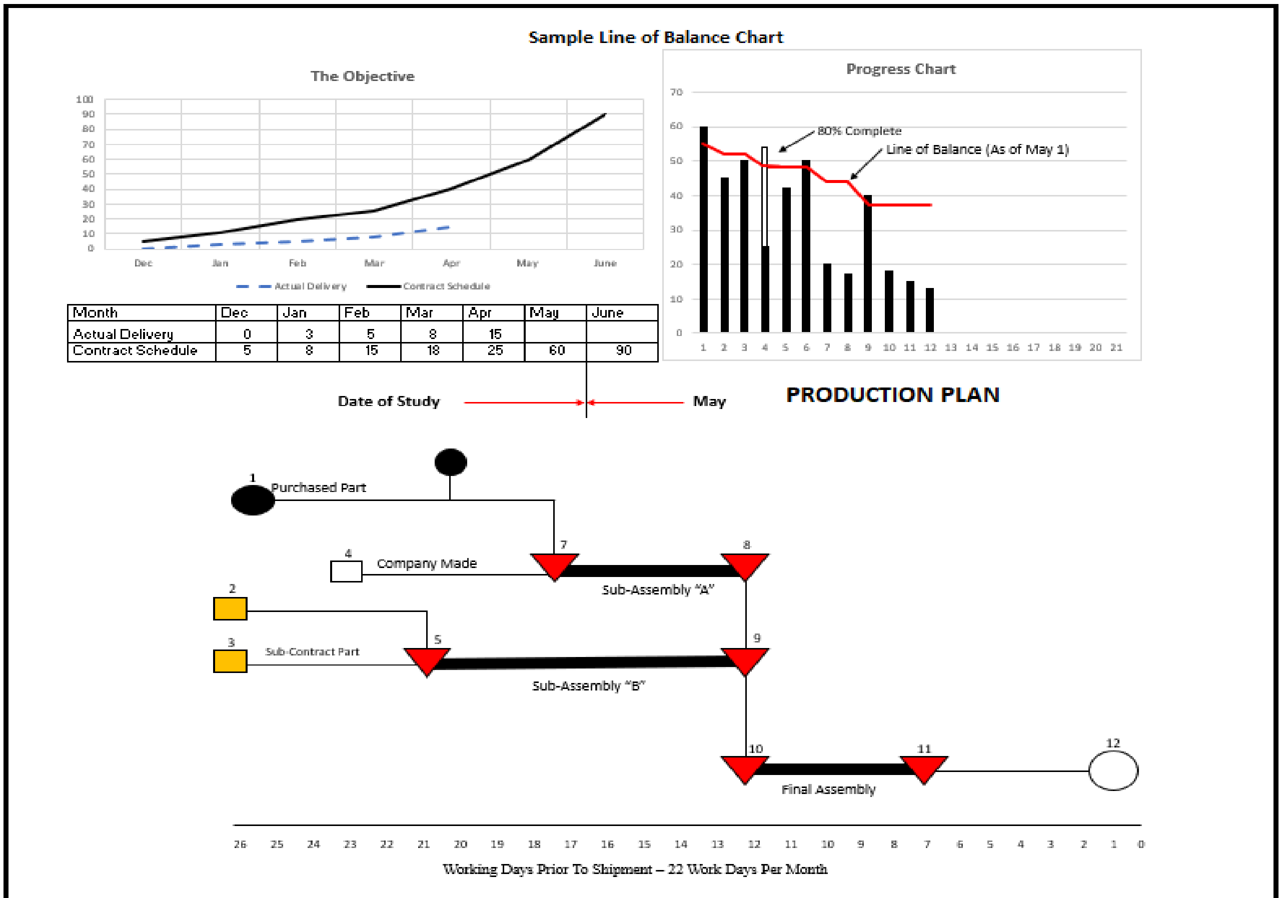


Figure 48. Line of Balance Plot

Comparison of Program Progress to Objective

Once the LOB is developed (inclusive of Element 1- 3) there remains the task of relating the intelligence already gathered. This is accomplished by striking a "Line of Balance" that is the basis to be used for comparing progress to the objective. The balance line quantity depicts the quantities of end item sets for each control point which must be available as of the status date to support the delivery schedule. In different words, it specifies the quantities of end item sets for each control point which must be available in order for progress on the program to remain in phase with the objective.

The specific LOB Technique procedure may be found in the NDIA IPMD Planning and Scheduling Excellence Guide. [1]

Predictive Nature

The use of a LOB as an exception-based analytical tool is beneficial in relating manufacturing progress to the defined objective whenever:

- Delivery of high-priority end items lag
- There is an indication of potential delays
- Late delivery of an end-item or intermediate assembly will cause a corresponding delay and/or cost impact in a strategically important assembly, end-item, or external program dependency
- Effective manufacturing risk mitigation is required.

Additionally, the LOB technique may be effectively used:

- Where management needs a reporting medium that can be operated by exception but that positively brings limiting factors into focus
- When there is a need for a means of synchronizing phased deliveries of incoming materials, components, and subcontracted parts with the in-plant manufacturing effort
- When it is known that the original delivery schedule will not be met and there is a need to ensure that the revised delivery dates are realistic by relating current progress to a revised or proposed delivery schedule.

The LOB technique is, by definition, a predictive tool. Therefore, all control points and their associated performance are forward looking. The following control points are generally applicable to any production, manufacturing, or naval construction project**:**

- Parts available to be issued to the floor/shop
- Assembly kits issued to the floor/shop
- Kits issued complete/kits issued not complete
- Detail assembly (start and finish)
- Intermediate assembly (start and finish)
- Final assembly (start and finish)
- Test (start and finish).

Possible Questions

- Why would I use the LOB Technique when I have MRP/MRP II/ERP?
- Why would I use the LOB technique when I have an IMS?

Caveats/Limitations/Notes

- MRP/MRP II/ERP are backward-scheduling tools that develop a just-in-time schedule. However, when the schedule gets overwhelmed by problems (e.g., Engineering, parts, equipment), it ceases to provide useful information. At that time, the LOB Technique is more flexible in providing reliable, forward-looking information.
- It is rare for an IMS to include all the manufacturing control points that actually exist in the construction of recurring end items. The LOB technique uses the same logic of predecessors and successors as the IMS but at a much more detailed level. It not only defines the detailed manufacturing critical path but, it also predicts likely performance based upon projected and actual performance.

10 Contributors

This guide was compiled by the NDIA Integrated Program Management Division (IPMD) Program Management Working Group. NDIA IPMD thanks the authors and reviewers from across industry and government who contributed to the generation and improvement of this publication. Their diverse perspectives, expertise, and insight defined proven practices of predictive measures for program and project efforts applicable to any industry managing projects of any size.

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Appendix A: Predictive Measures Commonly Used in the DoD Acquisition Phases

The following matrix lists the metrics in the order they are discussed in this Guide and maps them to the five DoD Acquisition Phases:

- Materiel Solution Analysis (MSA)
- Technology Development (TD)
- Engineering and Manufacturing Development (EMD)
- Production and Deployment (P&D)
- Operations and Support (O&S).

	MSA	TD	EMD	PD	O&S
Schedule Metrics					
Schedule Performance Index (SPI)		X	X	X	X
Baseline Execution Index (BEI)		X	X	X	X
Critical Path Length Indicator (CPLI)		X	X	X	X
Current Execution Index (CEI)		X	X	X	X
Total Float Consumption Index (TFCI)		X	X	X	X
Earned Schedule					
Time-based Schedule Performance Index (SPI_t)		X	X	X	X
SPI_t vs. $TSPI_{ed}$		X	X	X	X
Independent Estimated Completion Date - Earned Schedule $iECD_{es}$)		X	X	X	X
Cost Metrics					
Cost Performance Index		X	X	X	X
Cum CPI vs. $TCPI_{EAC}$		X	X	X	X
Range of IEACs (Independent Estimates at Completion)		X	X		
Staffing Metrics					
Critical Skills Key Personnel Churn/Dilution Metric		X	X		
Critical Resource Multiplexing Metric		X	X	X	X
Staffing Profile		X	X	X	X
Risk and Opportunity Metrics					
Risk/Opportunity Summary	X	X	X	X	X
Risk/Opportunity $ vs. Management Reserve (MR) $			X	X	X
Schedule Risk Assessment (SRA)		X	X	X	X
Schedule Margin Burn Down		X	X	X	X
Requirements Metrics					
Requirements Completeness		X	X		
Requirements Volatility		X	X	X	
TBD/TBR Burn Down	X	X	X		
Requirements Traceability		X	X	X	X
Technical Performance Measures (TPMs)					
Technical Performance Measures Compliance		X	X	X	X
TPM Progress/Regress Burn Dow		X	X	X	
Defect Containment		X	X	X	
Contract Health Metric					
Contract Mods	X	X	X	X	X
Baseline Revisions	X	X	X	X	X
Program Funding Plan		X	X	X	X
Program Funding Status		X	X	X	X
Contract Change Value		X	X	X	X
RDT&E Actual Billings vs. Forecast Billings		X	X	X	X
Supply Chain Metrics					
Parts Demand Fulfillment		X	X	X	X
Supplier Acceptance Rate		X	X	X	X
Supplier Late Starts		X	X	X	X
Production Line of Balance			X	X*	

*Transition from development to production, LRIP, Full Rate Production