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Indian Standard

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परियोजना, कार्यक्रम और पोर्टफोलियो प्रबंधन — अर्जित मूल्य प्रबंधन कार्यान्वयन मार्गदर्शिका

Project Programme and Portfolio Management — Earned Value Management Implementation Guidance

ICS 03.100.40

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NATIONAL FOREWORD

This Indian Standard which is identical to 'ISO 21512 : 2024 Project, programme and portfolio management — Earned value management implementation guidance' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Management and Productivity Sectional Committee and approval of the Management and Systems Division Council.

The text of the International Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as `Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, references appear to certain International Standard for which no Indian Standards exist. The technical committee have reviewed the provisions of the following International standards referred in this standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO/TR 21506 Project, programme and portfolio management — Vocabulary	IS/ISO/TR 21506 : 2018 Project programme and portfolio management — Vocabulary	Identical
ISO 21508 : 2018 Earned value management in project and programme management	IS/ISO 21508 : 2018 Earned value management in project and programme management	Identical

Annex A and B are for information only.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Introduction

This document provides guidance when implementing an earned value management system based on ISO 21508. This document shows how an organization can take a systematic approach to implement and maintain an earned value management system that enables improved project and programme management. This document is not intended to be prescriptive; each organization should determine its approach for earned value management and to what extent the organization should adopt ISO 21508. Users are encouraged to use this document along with ISO 21508.

This document provides guidance to users either establishing or maintaining an earned value management system.

The text in each clause is topically arranged to assist the organization in establishing or improving its earned value management system. The topics are arranged in the following order:

a) general introduction to the material contained in the clause;

b) guidance on how an organization can approach the subject;

c) practical tools, methods, strategies and examples.

The examples and approaches presented in this document are for illustrative purposes only, and are not necessarily suitable for every organization, project or programme. In implementing, maintaining or improving an earned value management system, it is important that organizations select approaches, tools and methods appropriate to their needs and governance framework.

Earned value management tools and methods are sustainable and useful, when they are integrated within an organization's overall governance for projects and programmes.

This document is applicable to:

a) practitioners and professionals of earned value management, project management, programme management and portfolio management;

b) management, sponsors and other governing bodies overseeing projects, programmes, and portfolios;

c) project, programme and portfolio management office professionals;

d) project, programme and portfolio stakeholders;

e) academia including faculty, students and researchers;

f) developers of national standards, organizational standards and public policy.

Indian Standard

PROJECT PROGRAMME AND PORTFOLIO MANAGEMENT — EARNED VALUE MANAGEMENT IMPLEMENTATION GUIDANCE

1 Scope

This document specifies guidance and examples for establishing, implementing and maintaining an earned value management system based on ISO 21508:2018. This document also provides practises for earned value management, as set forth in ISO 21508:2018. This document can be used by any organization.

This document is aligned with and complements the information contained in ISO 21508:2018 which is the higher tier international standard and companion document for this document.

Further guidance on project, programme and governance and other related guidance are set out in relevant standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 21506, *Project, programme and portfolio management — Vocabulary*

ISO 21508:2018, *Earned value management in project and programme management*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO/TR 21506 and ISO 21508 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
100 % rule
concept concerning the entire work required to be accomplished to achieve the *project* (3.1.57) or *programme* (3.1.53) scope captured in the *work breakdown structure* (3.1.89)

Note 1 to entry: The 100 % rule applies to the parent and child elements. The child-level of *decomposition* (3.1.23) of a *work breakdown structure element* (3.1.90) represents 100 % of the work applicable to the parent-level.

[SOURCE: ISO 21511:2018, 3.1]

3.1.2
activity
identified piece of work that is required to be undertaken to complete a *project* (3.1.57) or *programme* (3.1.53)

Note 1 to entry: It can also be considered a work element. It is a defined, discrete piece of work.

[SOURCE: ISO 21508:2018, 3.1.1, modified — a second sentence has been added to the Note 1 to entry.]

3.1.3
actual cost
cost incurred for work performed

Note 1 to entry: Actual cost is also known as "actual cost of work performed".

[SOURCE: ISO 21508:2018, 3.1.2]

3.1.4
actual time
number of time periods between the actual start date and the date on which the *project* (3.1.57) data is reported

3.1.5
agile development
agile approach
agile management
agile project management
agile programme management
iterative approach to *project* (3.1.57) and *programme* (3.1.53) planning and implementation to allow continuous adaptation for the delivery of scope and the final deliverable or outcome

3.1.6
baseline
reference basis for comparison against which performance is monitored and controlled

[SOURCE: ISO 21502:2020, 3.1]

3.1.7
baseline plan
tool to facilitate the comparison against which performance is monitored and controlled

3.1.8
basis of estimate
documentation that supports the calculation of resources required to perform activities

3.1.9
budget at completion
total forecasted cost for accomplishing the work related to a *work package* (3.1.91), *activity* (3.1.2) or *control account* (3.1.11)

[SOURCE: ISO 21508:2018, 3.1.3]

3.1.10
change order
documentation to alter the *baseline* (3.1.6) of a *project* (3.1.57) or *programme* (3.1.53)

Note 1 to entry: Documentation prior to the formal change order is often referred to as a baseline change proposal or a change request.

3.1.11
control account
management *control point* (3.1.15) where scope, budget, *actual cost* (3.1.3) and schedule of a *project* (3.1.57) or *programme* (3.1.53), *work package* (3.1.91) or *activity* (3.1.2) are integrated

[SOURCE: ISO 21508:2018, 3.1.4]

3.1.12
control account manager
cost account manager
person with the authority and responsibility to manage a management *control point* (3.1.15) where cost and scope are integrated and compared to the designated performance metrics for *earned value* (3.1.26)

3.1.13
control account plan
cost account plan
management tool for organizing work within one or more work or *planning packages* (3.1.91)

3.1.14
control period
established time frame in which the actual *project* (3.1.57) or *programme* (3.1.53) results are compared with the *performance measurement baseline* (3.1.51) to assess performance and take management action, if needed

3.1.15
control point
point in the processes of *project* (3.1.57) or *programme management* (3.1.54) that can serve as a decision time or gate and can be further defined by one or more individual *activities* (3.1.2)

3.1.16
corrective action
direction and *activity* (3.1.2) for modifying the performance of work to bring performance in line with a plan

[SOURCE: ISO/TR 21506:2018, 3.15]

3.1.17
cost management system
set of tools for estimating, allocating and controlling costs in a *project* (3.1.57) or *programme* (3.1.53)

3.1.18
cost performance index
measure of the *actual cost* (3.1.3) efficiency of a *project* (3.1.57) or *programme* (3.1.53)

3.1.19
cost variance
measure of cost performance on a *project* (3.1.57) or *programme* (3.1.53)

Note 1 to entry: Actual cost compared to planned cost.

3.1.20
critical chain project management
scheduling method for planning and managing a *project* (3.1.57) or *programme* (3.1.53) that focusses on resource availability to complete project or programme *activities* (3.1.2)

3.1.21
critical path
sequence of *activities* (3.1.2) that determines the earliest possible completion date for a *project* (3.1.57), *programme* (3.1.53) or phase

[SOURCE: ISO 21502:2020, 3.8, modified — "programme" has been added to the definition.]

3.1.22
data tracing
activity (3.1.2) of end-to-end to performance data quality checks

3.1.23
decomposition
iterative process to incorporate an increased level of detail as identified during the *lifecycle* (3.1.43) of a *project* (3.1.57) or *programme* (3.1.53)

Note 1 to entry: Decomposition can be accomplished through a hierarchal, functional or other method to achieve a manageable set of elements.

3.1.24
demonstration review
check for compliance with the *governance* (3.1.35) of *earned value* (3.1.26) criteria on a new or modified *earned value management system* (3.1.30)

3.1.25
earned schedule
time-based technique used to provide status and predictions regarding the schedule, using earned value data

Note 1 to entry: Earned schedule is analogous to the use of cost to determine earned value.

Note 2 to entry: Earned schedule is also a measure of the number of time periods in the *performance measurement baseline* (3.1.51) in which the earned value is greater than the *planned value* (3.1.52).

3.1.26
earned value
value of completed work expressed in terms of the budget assigned to that work

Note 1 to entry: Earned value is also known as budgeted cost of work performed.

[SOURCE: ISO 21508:2018, 3.1.5]

3.1.27
earned value management
method that integrates the *project* (3.1.57) or *programme* (3.1.53) scope, *actual cost* (3.1.3), budget, and schedule for the assessment of progress and performance

[SOURCE: ISO 21508:2018, 3.1.6]

3.1.28
earned value management methodology
approach that permits progress achieved to be objectively measured

3.1.29
earned value management planning
delineation of steps, methods and reporting necessary for the creation and tracking of the *performance measurement baseline* (3.1.51)

3.1.30
earned value management system
earned value management tool
selected toolset that integrates the *project* (3.1.57) or *programme* (3.1.53) scope, *actual cost* (3.1.3), budget, and schedule for assessment of progress and performance

3.1.31
earned value measurement
earned value metrics
metrics used to determine the *earned value* (3.1.26) of *projects* (3.1.57) or integrated *programmes* (3.1.53)

3.1.32
estimate at completion
forecasted total cost to accomplish the work on a *project* (3.1.57), *programme* (3.1.53), *work package* (3.1.91) or *activity* (3.1.2)

[SOURCE: ISO 21508:2018, 3.1.7]

3.1.33
estimate to completion
forecasted cost of the work remaining in a *project* (3.1.57), *programme* (3.1.53), *work package* (3.1.91) or *activity* (3.1.2)

[SOURCE: ISO 21508:2018, 3.1.8]

3.1.34
feeding buffer
time cushion placed at the end of a sequence of tasks that lead into the critical chain

3.1.35
governance
principles, policies and framework by which an organization is directed and controlled

[SOURCE: ISO 21502:2020, 3.10]

3.1.36
integrated baseline review
assessment to establish a common understanding of the *performance measurement baseline* (3.1.51) for verification of the technical content of the *project* (3.1.57) or *programme* (3.1.53)

[SOURCE: ISO 21508:2018, 3.1.9]

3.1.37
integrated baseline review handbook
document that compiles guidance for the preparation, conduct and closeout of an integrated *baseline* (3.1.6) review

3.1.38
issue
event that arises during a *project* (3.1.57) or *programme* (3.1.53) needing resolution for the project or programme to proceed

[SOURCE: ISO 21502:2020, 3.11, modified — "or programme" has been added to the definition.]

3.1.39
issue register
document to record *issues* (3.1.38), responses and other relevant issue information

3.1.40
lag
attribute applied to a logical relationship to delay the start or end of an *activity* (3.1.2)

[SOURCE: ISO/TR 21506:2018, 3.28]

3.1.41
lead
attribute applied to a logical relationship to advance the start or end of an *activity* (3.1.2)

[SOURCE: ISO/TR 21506:2018, 3.29]

3.1.42
lessons learned
knowledge gained throughout a *project* (3.1.57), *programme* (3.1.53) or portfolio that shows how events were addressed or should be addressed for the purpose of improving future performance

[SOURCE: ISO/TR 21506:2018, 3.30]

3.1.43
lifecycle
systematic and organized grouping or staging of necessary *activities* (3.1.2) to be completed to provide the expected deliverable or outcome of a *project* (3.1.57) or *programme* (3.1.53)

3.1.44
management reserve
amount of budget or schedule external to the *performance measurement baseline* (3.1.51), withheld for management control in response to unforeseen events or *activities* (3.1.2) that are a part of the scope

[SOURCE: ISO 21508:2018, 3.1.10, modified — "or schedule" has been added to the definition.]

3.1.45
milestone
significant planned, or to be planned, point in a *project* (3.1.57), *programme* (3.1.53) or portfolio

[SOURCE: ISO/TR 21506:2018, 3.34]

3.1.46
organizational breakdown structure
decomposition (3.1.23) of the management team of an organization or decomposition of the management team that performs the work of a *project* (3.1.57) or *programme* (3.1.53)

Note 1 to entry: The organizational breakdown structure can include partnering or subcontracting. It is used to illustrate the relationship between project and programme activities and the organizational units that will manage or perform the work activities.

[SOURCE: ISO 21511:2018, 3.5]

3.1.47
parent element
work that is decomposed into two or more lower level elements of work

[SOURCE: ISO 21511:2018, 3.6, modified — Note 1 to entry has been deleted.]

3.1.48
performance management framework
basis for the assignment of management responsibility for *project* (3.1.57) or *programme* (3.1.53) performance to the project or *programme management* (3.1.54) team

3.1.49
performance management methodology
formalized methods governing *earned value management* (3.1.27)

3.1.50
performance measurement
quantitative units of measure that are placed to track progress

[SOURCE: ISO 21508:2018, 3.1.12]

3.1.51
performance measurement baseline
total time-phased scope of work and budget plan against which *project* (3.1.57) or *programme* (3.1.53) performance is measured, not including *management reserve* (3.1.44)

[SOURCE: ISO 21508:2018, 3.1.13]

3.1.52
planned value
time-phased budget (3.1.80) authorized for the work scheduled

Note 1 to entry: Planned value is also known as budgeted cost of work scheduled.

[SOURCE: ISO 21508:2018, 3.1.14]

3.1.53
programme
group of programme elements managed in a coordinated way to realize benefits

[SOURCE: ISO/TR 21506:2018, 3.50]

3.1.54
programme management
coordinated *activities* (3.1.2) to direct and control the realization of identified benefits and deliverables

[SOURCE: ISO 21504:2022, 3.11]

3.1.55
programme manager
person appointed with the accountability and responsibility of the *programme* (3.1.53) to realize identified benefits, outcomes and deliverables

[SOURCE: ISO/TR 21506:2018, 3.55, modified — "outcomes" has been added to the definition.]

3.1.56
progressive elaboration
progressive decomposition
iterative process to incorporate an increased level of details identified during the *lifecycle* (3.1.43) of a *project* (3.1.57) or *programme* (3.1.53)

[SOURCE: ISO/TR 21506:2018, 3.58]

3.1.57
project
temporary endeavour created to produce agreed deliverables

[SOURCE: ISO/TR 21506:2018, 3.59]

3.1.58
project management
coordinated *activities* (3.1.2) to direct and control the accomplishment of agreed objectives

[SOURCE: ISO/TR 21506:2018, 3.61, modified — "deliverables" has been changed to "objectives" in the definition.]

3.1.59
project management office
office established to provide guidance, assistance and documentation to assist in the implementation and delivery of a *project* (3.1.57)

Note 1 to entry: Such offices can also be established at the *programme* (3.1.53) level.

3.1.60
project manager
person appointed to lead the *project* (3.1.57) team and to be accountable and responsible for the project's agreed objectives

[SOURCE: ISO/TR 21506:2018, 3.63, modified — "deliverables" has been changed to "objectives" in the definition.]

3.1.61
project plan
project management plan
documented description of the technical and management *baselines* (3.1.6) to be followed for a *project* (3.1.57)

[SOURCE: ISO/TR 21506:2018, 3.64, modified — the admitted term "project management plan" has been added.]

3.1.62
quality assurance
planned and systematic procedures necessary to provide adequate confidence that a process, measurement or service satisfies given requirements for quality

[SOURCE: ISO/TR 21506:2018, 3.67, modified — "actions" has been changed to "procedures" in the definition.]

3.1.63
quality control
monitoring specific results to determine compliance to *quality assurance* (3.1.62) and other relevant standards and to identify the steps to eliminate unsatisfactory performance

[SOURCE: ISO/TR 21506:2018, 3.68, modified — "assessment of" has been changed to "monitoring" and "conformity with" has been changed to "compliance to quality assurance and other" in the definition.]

3.1.64
residual risk
estimated level of *risk* (3.1.67) remaining after completion of approved *risk treatment actions* (3.1.72)

3.1.65
resource loading
identification of the *project* (3.1.57) resources needed to complete the work identified for the project or *programme* (3.1.53)

Note 1 to entry: Often bounded by hours available for personnel, contract terms and conditions or material availability.

3.1.66
responsibility assignment matrix
documented structure that shows the allocation of delegated work responsibilities designated for delivery of scope or benefits

[SOURCE: ISO 21511:2018, 3.10]

3.1.67
risk
uncertain event or set of events with a potential positive or negative impact

[SOURCE: ISO 21505:2017, 3.3]

3.1.68
risk assurance
processes and actions needed to provide the knowledge and confidence that the *project* (3.1.57) or *programme* (3.1.53) can deliver on the investment

3.1.69
risk contingency reserve
estimated funding for the management of identified *risks* (3.1.67)

Note 1 to entry: Risk contingency reserve can be added to the *project*'s (3.1.57) estimates for cost, schedule or both to cover identified risks, where the use of *management reserve* (3.1.44) is not allowed.

3.1.70
risk exposure
potential level of impact on cost, schedule, or both that can be incurred if *risks* (3.1.67) occur

Note 1 to entry: The estimate of risk exposure can include emergent risk, as yet unknown, but based on previous known risk criteria.

3.1.71
risk register
risk log
documentation for recording identified *risks* (3.1.67), risk analysis, and *risk treatment actions* (3.1.72), as well as other necessary information for managing risks on a *project* (3.1.57) or *programme* (3.1.53)

3.1.72
risk treatment action
documented response to respond to an identified *risk* (3.1.67)

Note 1 to entry: Risk treatment actions include preventative, mitigation, fallback and recovery actions.

3.1.73
rolling wave planning
form of *progressive elaboration* (3.1.56) where planning is accomplished in phases or time periods

[SOURCE: ISO 21511:2018, 3.12]

3.1.74
schedule buffer
time inserted into the schedule at identified points to absorb unforeseen delays

3.1.75
schedule performance index
measure of how close the *project* (3.1.57) or *programme* (3.1.53) is to completion compared to the approved performance measurement *baseline* (3.1.6)

3.1.76
sponsor
person responsible for obtaining the resources and executive decisions to enable success

Note 1 to entry: In some organizations, the sponsor also has the responsibility to promote and protect the *project* (3.1.57) or *programme* (3.1.53).

[SOURCE: ISO 21502:2020, 3.26, modified — Note 1 to entry has been added.]

3.1.77
stakeholder
person, group or organization that has interests in, can affect, be affected by or perceive itself to be affected by any aspect of the *project* (3.1.57) or *programme* (3.1.53)

[SOURCE: ISO 21502:2020, 3.27, modified — "or portfolio" has been deleted.]

3.1.78
surveillance review
periodic check to confirm the *earned value management system* (3.1.30) is continuing to meet the *governance* (3.1.35) criteria

3.1.79
task order
documentation for specific services placed against an established contract

3.1.80
time-phased budget
planning tool that focuses on the sequence and timing of the *project* (3.1.57) or *programme* (3.1.53) implementation

3.1.81
to complete cost performance index
metric to calculate the cost efficiency and financial effectiveness of a *project* (3.1.57) or *programme* (3.1.53)

3.1.82
to complete performance index
comparative metric to determine whether the *estimate at completion* (3.1.32) is reasonable

Note 1 to entry: Also defined as the computation of future required cost efficiency necessary to achieve the target estimate at completion.

3.1.83
uncertainty
amount of potential variation of an *activity*'s (3.1.2) cost or duration due to an estimating error

3.1.84
undistributed budget
cost for authorized work that has not been distributed to a *control account* (3.1.11)

[SOURCE: ISO 21508:2018, 3.1.17]

3.1.85
variance
difference between the *baseline* (3.1.6) and the actual performance

3.1.86
variance at completion
difference between *budget at completion* (3.1.9) and *estimate at completion* (3.1.32)

[SOURCE: ISO/TR 21506:2018, 3.86]

3.1.87
variance threshold
prior agreed upon amount of difference to be allowed before an action can be needed

Note 1 to entry: Variance threshold is generally expressed as a percentage of deviation from the *baseline* (3.1.6).

3.1.88
work authorisation document
part of a system to facilitate approval of work throughout the *project* (3.1.57) or *programme* (3.1.53)

3.1.89
work breakdown structure
decomposition (3.1.23) of the defined scope of the *project* (3.1.57) or *programme* (3.1.53) into progressively lower-levels consisting of elements of work

[SOURCE: ISO 21502:2020, 3.29]

Note 1 to entry: Conceptual work breakdown structure is one that precedes the project or programme authorization.

3.1.90
work breakdown structure element
work at a designated level that is either a *parent element* (3.1.47) or a child

[SOURCE: ISO 21511:2018, 3.15]

3.1.91
work package
one or more groups of related activities that are within the *control account* (3.1.11)

[SOURCE: ISO 21508:2018, 3.1.19]

3.2 Abbreviated terms

The following abbreviated terms are used in this document.

AT	actual time
AC	actual cost
BAC	budget at completion
CA	control account
CAD	computer-aided design
CAM	control account manager
CPI	cost performance index
CV	cost variance
CPLI	critical path length index
ES	earned schedule
EV	earned value
EVM	earned value management
EVMS	earned value management system
EAC	estimate at completion
ETC	estimate to completion
IEAC(t)	independent estimate at completion (time)
IECD	independent estimate of completion date
IBR	integrated baseline review
PCSD	project control system description
PD	planned duration
PF	planned finished date
PMB	performance measurement baseline
PV	planned value
PM	project manager
SPI	schedule performance index
SPI(t)	schedule performance index (time)
SV(t)	schedule variance (time)
TCPI	to complete performance index
TSPI	to complete schedule performance index
VAC(t)	variance at completion (time)
WBS	work breakdown structure
WP	work package

4 Overview of earned value management

4.1 Overview

Clause 4 describes earned value management within the context of an organization conducting project and programme management. Clause 4 offers an explanation of the overall method of earned value management and what the method is intended to produce to enable better performance and performance measurement.

4.2 Earned value management

The earned value management methods should allow the comparison of the work completed in the project or programme with a baseline budget, as a measurement of how the project or programme is performing. In other words, what work was planned, at a specific control point, to have been done, the planned value; what work has been done, the earned value; and, what resources were used to do that work, the actual cost. Further, it should include an analysis of metrics using earned value management indices and variances, and an estimate or forecast of the cumulative cost and schedule and that can include management reserve at the end of the project. Earned value management is a methodology that uses a designated approach to integrate the project's or programme's scope of work with schedule and cost elements for planning and control.

NOTE Methodology is the overall study of how the methods or actions are done. Methods are the tools and processes to be applied within the methodology.

The objectives of earned value management can vary depending on the context. One common objective should be to provide objective quantification of progress and productivity. This progress and productivity can be monitored at a variety of levels, including work package, control account, project and programme levels.

4.3 Purpose and benefits of earned value management

4.3.1 The purpose of earned value management should be to provide control and analysis of the project or programme[6]. The analysis improves the situational awareness of project or programme status and the assessment of the cost, schedule and technical performance. Corrective actions can then be designed and implemented, as needed.

Once designed and implemented, an earned value management system should provide internal controls, including documentation and project and programme processes. The system can include communication of the status from pre-established metrics, corrective action development, and a common framework and vocabulary[6].

4.3.2 The application of earned value management should result in three overall benefits:

a) objective performance measurement techniques;

b) data for project or programme management decisions;

c) system to monitor the project or programme[6].

4.3.3 The specific benefits of earned value management can include:

a) forecasts of future performance and estimates at completion based on past performance;

b) objective metrics for comparison of project or programme performance across an organization and between or among organizations;

c) development of budgets and baselines;

d) compilation of estimates;

e) consistent objective measurement of completion for work packages;

f) comparison of work performed against planned performance and budget;

g) objective measurement of risk contingency reserve;

h) identification of inconsistencies in the metrics in earned value reports;

i) consistent reporting and performance measurement framework;

j) documented analysis that enables timely and reliable estimate at completion[6].

4.4 Initiation considerations for an earned value management system

4.4.1 The organization should select a tool for its earned value management system that meets the needs of its projects and programmes. Other considerations can include:

a) the need to meet contract or customer specifications for the system;

b) the ease of use by the project or programme management teams;

c) the need for access by stakeholders;

d) the need for the data to be easily imported from or exported to other systems.

An earned value management system should provide for consistent performance metrics. To achieve a consistent view of performance metrics, the system should integrate the baselines established for the project or programme, including the scope of work that should be defined through the work breakdown structure and performance measurement baseline. The system should also allow for formal, controlled incorporation of changes in baselines, authorized users and procedures[6]. The procedures and policies that govern the earned value management system should be documented, accessible, kept up-to-date and reviewed on a periodic and need basis.

To implement an earned value management system, the project's or programme's control metrics should be accessible and understood by the persons within the organization or organizations performing the work. The system should be established to allow systematic review of the data, common assessment methodologies, targeted levels of performance and an assessment feedback process. The system can be tailored to accommodate different project or programme process area integration, more than one organization reporting, and other tailoring.

The essential data contained in an earned value management system should be the earned value, the actual cost, the planned value, the estimate to completion and the budget at completion. The earned value management system should be able to show the planned status, as well as the actual status[6].

To implement an earned value management system, the performing organization or organizations, as well as the customers and other stakeholders as determined to need the information, should have a common agreement on the assignment of value and performance. The common agreement on the assignment of value and performance can be tailored for the project or programme based on organizational or contract considerations.

The review of metrics of performance should be accomplished on a regular, scheduled basis to allow for comparison and analysis of performance[6].

4.4.2 An earned value management system should be able to do the following:

a) determine what work is to be accomplished, by whom and when;

b) establish resource requirements;

c) measure work achievement and record associated costs;

d) report deviations from the plan for which metrics have been established;

e) forecast the completion date and cost;

f) plan and implement corrective and preventive action plans;

g) authorize scope changes; any approved changes to the prior approved baselines contained in the earned value management system should be controlled, traceable and documented[6].

4.5 Earned value management planning

4.5.1 Earned value management planning should enable:

a) establishing of individual project or programme objectives;

b) establishing the integrated view of the planning of the set of projects or programmes;

c) monitoring of progress to measure deviations from the plan;

d) planning by the users of the performance management system for objective assessment of progress and use of resources[6].

Earned value management planning should begin with planning of the project or programme to support earned value management analysis and reporting. Items that can be considered during the planning of projects and programmes include modifying report formats and allowing for the use of agile development approaches.

Establishing an earned value management system to meet customer needs or establishing the initial earned value management system for an organization not currently using a system can be considered during planning. To enable the planning, preparation of the earned value management system should begin, as soon as possible, following the approval of the business case or similar business objective documentation. This preparation should involve an iterative process to provide for the needs of the various stakeholders of the system and reporting.

Planning the use of an earned value management system for a specific project or programme should begin with the preliminary work breakdown structure. Once the preliminary work breakdown structure is in place, it should provide the framework for integrating management systems, developing schedules and accumulating performance information.

4.5.2 Depending upon the specific project or programme governance of the organization or contract terms, the management systems and elements of the project or programme should include:

a) plan of the project or programme, including the statement of work;

b) organizational breakdown structure;

c) responsibility assignment matrix;

d) earned value management system selected tool;

e) organizational governance procedures and processes;

f) financial system;

g) cost models;

h) earned value management system analysis and reporting procedures and processes;

i) risk analysis, including any risk analysis found in the business case or similar documentation.

During earned value management planning, disconnects and mismatches among various systems for project and programme management, such as financial systems, should be eliminated or minimized. Eliminating such inconsistencies should result in estimates, budgets, schedules, costs and other measures to align with the approved work breakdown structure. This earned value management planning action should reduce workarounds and reconciliations that can be necessitated to obtain reliable data for decision-making.

For programme management, the work breakdown structures for each project should be the same structure through the lowest level of breakdown required under the organization's project and programme

management governance documentation[7]. Further, common coding of the work breakdown elements will facilitate reporting and communication among the stakeholders. Subcontractor, partners, and other contributing organizations should use this approach for earned value management. This approach is necessary during the planning of earned value management to facilitate the development of the preliminary information management system and the selection and initialisation of the earned value management tools.

4.6 Using earned value measurements and performance metrics

4.6.1 Earned value measurements should be used to determine performance metrics to assess the status of a project or programme at a selected point in time. These metrics should enable informed decisions about the management of the project or programme. The metrics derived can be used to compare actual cost and schedule performance with the approved performance measurement baseline. The performance measurement baseline should be used to establish variance thresholds for cost and schedule that when exceeded identify significant variances for further analysis and management attention[6].

4.6.2 The two major elements for variance analysis are whether the project or programme is:

a) ahead of schedule versus behind schedule;

b) over budget versus under budget.

4.6.3 These two project or programme performance factors have a direct impact on the total cost. The initial questions to be asked should be:

a) What will be the total cost if the project or programme is ahead of schedule, but costs are higher than expected?

b) What will be the total cost if the project or programme is behind schedule, but costs are lower than expected?

4.6.4 The information acquired by using the earned value performance measurements should be used to determine:

a) progress of a project or programme;

b) progress towards work accomplished;

c) completion of the deliverables;

d) progress towards delivery of a project or programme[6];

e) work accomplished as earned value compared with work planned;

f) work accomplished as earned value compared with actual costs;

g) root causes of performance variances, corrective actions needed and impacts to the performance of remaining work.

4.6.5 The information should also be used to forecast future performance. The data to establish a performance forecast for a project or programme based on historical performance should include:

a) estimate to completion;

b) estimate at completion;

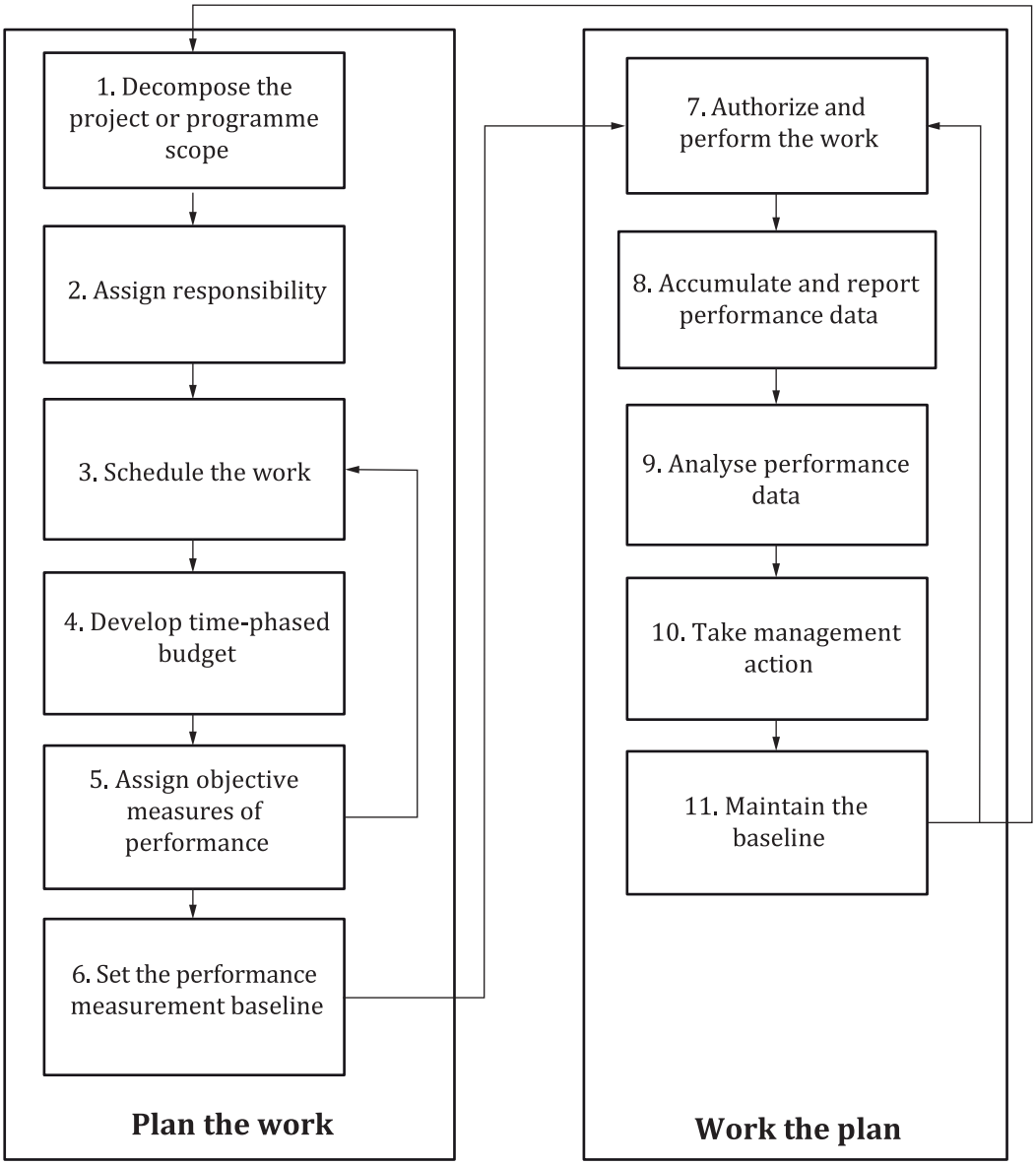
c) variance at completion;

d) to complete performance index[6].

5 Implementation of the earned value management process steps

5.1 Overview

The earned value management process steps are shown in Figure 1 to illustrate one view of the process steps for earned value management. Each process step is defined and the guidance for each step is set forth in the clause or subclause related to the process step in Figure 1.



NOTE 1 Steps 3, 4 and 5 are performed iteratively.

NOTE 2 Not all relationships are shown in this figure.

Figure 1 — Example of the earned value management process steps[6]

The earned value management process steps can be used to establish a performance management methodology.

5.2 Step 1: Decompose the project or programme scope

5.2.1 Introduction

The work breakdown structure developed from the decomposition of a project or programme can be represented by several different approaches. The work breakdown structure can be decomposed as deliverable-oriented, result-oriented, product-oriented, location-oriented, functional-oriented, process-oriented, phase-oriented, capability-oriented, or a combination. In addition, depending on the lifecycle, the work breakdown structure should be defined by the requirements that define the project or programme and its delivery[7].

5.2.2 Context

The work breakdown structure should be tailored to the objectives and the approved and documented needs of the project or programme. The work breakdown structure should take into account the industry sector, type of project or programme, and other factors. Other factors can include project phases, major deliverables, scope, organization performing the work and location of resources. The work breakdown structure should be flexible enough to accommodate alternative ways of organizing and representing the work.

NOTE The work breakdown structure represents not only the way work is planned and managed, but also how it will be delivered, in other words, incremental or progressive elaboration, iterative, agile, or any other method or modified method.

The work breakdown structure should be used throughout the project or programme to establish the framework for the management of the work. The structure should provide a logical framework for decomposing 100 % of the work defined by the scope or of the work elements at any given point, such as phases, stages or other pre-determined interval in time during the lifecycle[7]. Depending on the scope, the work can be accomplished by a single organization or multiple organizations, such as a subcontractor, partnership or other limited agreement to achieve the scope.

5.2.3 Work breakdown structure creation

The work breakdown structure should be based on approved and documented requirements of the expected deliverables, outcomes or benefits and the governance of the project or programme. Certain work breakdown structure elements can be defined to a lower level than others under conditions such as: high-cost, high-risk, high-visibility or when involving multiple stakeholders.

The creation of a work breakdown structure can be accomplished by using one of three approaches in conjunction with the appropriate organization, project or programme governance, procedures, policies and processes governing work breakdown structures and the integration with the other management processes, including earned value management:

a) top-down identification of the end deliverable, followed by successive subdivision of the work breakdown structure elements into detailed and manageable units;

b) bottom-up identification of elements of scope and merging, categorizing and ordering those elements in a hierarchy;

c) a combination of top-down and bottom-up approach[7].

The level of detail provided by the initial work breakdown structure can vary.

EXAMPLE Using progressive elaboration, a review of the work breakdown structure can be conducted by checking that each element represents the appropriate level of detail per the governance for the project or programme.

A prior work breakdown structure can be helpful in identifying the breakdown of the scope of work for a new project or programme, where similar work and activities have been done in the past or where the format of the work breakdown structure is similar.

5.2.4 Decomposition

A conceptual work breakdown structure can be created during the business case or similar documentation process and can be re-evaluated or further decomposed once the project or programme is authorized. The conceptual work breakdown structure should be updated as soon as the project or programme is authorized. If a conceptual work breakdown structure was not created, one should be created as soon as the work scope elements are understood for the phase, stage, other interval designated or for the complete project or programme. Once developed, the work breakdown structure should:

a) provide a basis for gathering cost data across projects and programmes and be correlated with the cost management system;

b) serve to maintain the breakdown of the scope;

c) allow for status to be continuously visible and integrated;

d) serve to facilitate communication among project or programme team members, as well as with both internal and external stakeholders, such as customers and suppliers;

e) provide for the allocation of resources according to the work breakdown structure elements identified;

f) provide for maintaining and updating, as needed, until the final deliverables have been completed, delivered, or transitioned to the customer.

5.2.5 100 % rule

Whether the effort and resources can be associated with the element to be supported is important to work breakdown structure development. If the association can be made, the effort and resources should be included within that element. Under the 100 % rule of the work breakdown structure, the sum of work at the child-level should be the total work at the parent-level.

The various options to create parent-child relationships depend on the type of project or programme and the work breakdown structure developed.

Each parent element can have zero child elements or at a minimum two child elements. The work breakdown structure should represent the collective inputs of the project or programme team and relevant stakeholders.

The work breakdown structure should be the agreed upon decomposition of the work to be performed by the project or programme team. Each change made to the work breakdown structure should also be reviewed with the management team, the identified performing organization and performers within that organization, as well as other stakeholders identified as necessary to the work breakdown process.

These parent-child relationships can be combined to create a comprehensive decomposition of the scope of a project or programme into the work breakdown structure.

The benefits of lower-level parent-child relationships are:

a) facilitating communication among primary project or programme team members, both internal and external;

b) assigning stakeholders, such as customers and suppliers; allowing for organizational alignment.

5.2.6 Description of the project or programme work breakdown structure elements

Work breakdown structure elements can become the control points and can be further defined by one or more individual activities. The development of control points at an appropriate level of detail should enable the following:

a) definition of activities in the schedule;

b) elimination of overlaps by providing that a deliverable is represented in only one work breakdown structure element;

c) identification of the person responsible, their direct manager and matrix organization, sub-contractor, or partner organizational unit;

d) identification of the person to facilitate or initiate communication about the work breakdown structure element such as changes in:

   1) deliverable;

   2) approved baselines;

   3) personnel;

   4) communication chains, including reporting;

e) allocation of work to the project or programme team by dividing work breakdown structure elements to provide for accountability and control.

5.2.7 Hierarchical decomposition

Work breakdown structures are usually hierarchical in design. Each descending level of the work breakdown structure should provide a more detailed definition of the work[7]. Additionally, the work can be focused on project or programme phases, disciplines or locations. The entire scope of work should include work to be done by the project or programme management team, team members, subcontractors and other stakeholders.

The work breakdown structure should provide a decomposition of elements to the level necessary to plan, manage and communicate the work to meet the objectives, outcomes, deliverables and benefits.

Some of the work breakdown structure process actions are given below.

a) Extending the work breakdown structure to lower levels: The reporting level of the work breakdown structure depends on the level of interest where work is accomplished. Reporting at levels below the levels of interest should be considered, if the work breakdown elements are high cost, high risk, or special interest or any combination of those considerations[7]. For those elements, extension of the work breakdown structure to lower levels can be necessary to get needed visibility, but only for those elements. Not all work breakdown structure elements should be extended to the lowest level.

b) Identifying the parent-child relationship: In some cases, items cannot be specifically associated with the element supported.

Software is a critical element that is part of a major electronic system and can be the child-level to the parent system, in other words, a transmitter. However, depending on how software is developed, it can include more functionality than just the identified transmitter. It can, for instance, also include functionality for a parent subsystem. In this case, the software cannot be associated with the specific elements supported due to how the functionality of the software was built. Without the ability to separate each subsystem's software functionality, it should become appropriate to associate that total software deliverable to the parent-level electronic system work breakdown structure. This action should eliminate allocation of the effort across multiple work breakdown structure elements, where it can be difficult to determine what level of support each piece of work should receive.

5.2.8 Project and programme relationship

Within a programme, the projects, other programmes and other related work should be decomposed in a similar manner throughout the programme. The programme should become the highest level of the work breakdown structure. The same parent-child convention should apply to the logical relationships in the hierarchy. Each project, programme or other related work element under a programme can be developed into a standalone work breakdown structure that can be represented as a separate work breakdown structure or part of the combined programme work breakdown structure. This work can come from the organization, such as operations or through subcontractor agreements.

Some projects or programmes possibly do not have a fixed scope based on their lifecycle development approach; therefore, any unknown or undefined scope can be left blank or can be an empty set on the work breakdown structure diagram. These projects can use agile, progressive elaboration or rolling wave planning techniques, where the scope is defined as incremental as the project progresses through its lifecycle. As scope is identified during the life of the project or programme, the identified scope should be considered within the work breakdown structure, while maintaining the logic flow of the levels of the work breakdown structure and the parent-child relationship.

5.2.9 Progressive elaboration

Progressive elaboration can entail one, concurrent or successive modifications to the work breakdown structure. The addition of detail to the work breakdown structure through progressive elaboration should produce a more accurate work breakdown structure and enhance the use of the structure to manage the project or programme. Progressive elaboration can entail one, concurrent or successive modifications to the work breakdown structure[7].

NOTE Rolling wave planning is a form of progressive elaboration that is time-based.

5.2.10 Characteristics of a work breakdown structure

The characteristics of a work breakdown structure should be related to the scope of the project or programme. The following are typical characteristics of a work breakdown structure.

NOTE In the following bullets stands for structure (S) and stands for element (E).

a) S: can be represented by a variety of formats including graphical, outline and tabular;

b) E: need not be decomposed to the same work breakdown structure level but to the level where the element is managed;

c) E: can be assigned to one person, entity, or function to be responsible;

d) S: should reflect the technical complexity, size, and other information, as deemed necessary for the scope;

e) S: defines the structure of the work and not the processes involved in accomplishing the work;

f) S or E: provides a hierarchical decomposition of elements, applying the 100 % rule, to the level necessary to plan and manage the work to satisfy the objectives;

g) S or E: can be related to scope, but not limited to, considerations such as industry standards, organizational procedures, or contract terms and conditions; and

h) E: assigned a unique identifier to distinguish one element from another.

5.3 Step 2: Assign responsibility

5.3.1 General

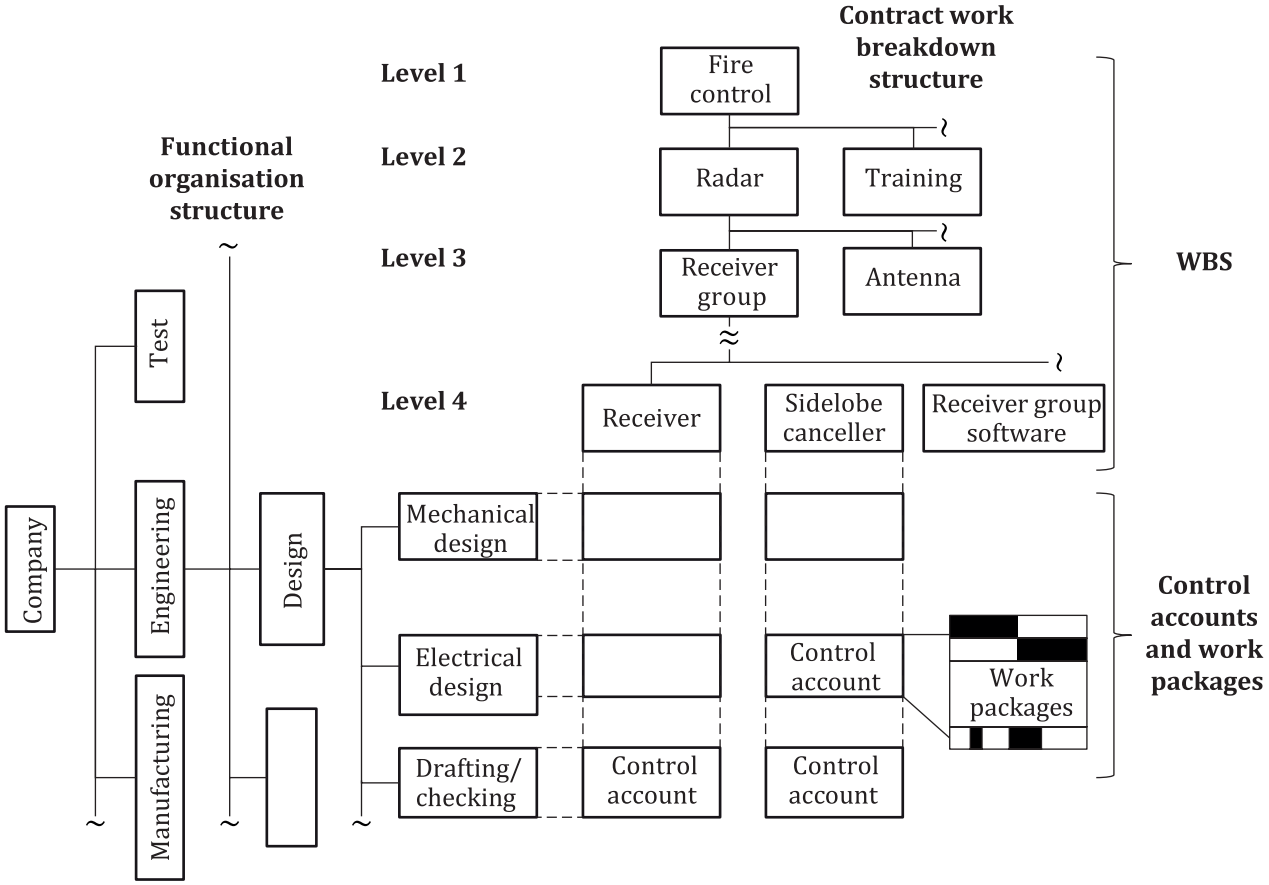
The assignment of responsibility should be the basis of aligning the work breakdown structure with the roles and responsibilities associated with the organizational, functional, product, capability or other breakdown structure (see 5.2). This alignment is based on the decomposition of scope into manageable, measurable work efforts that are assigned a manager to enable work to be accomplished by those persons, groups or organizations responsible for completing the work assignments, as documented in the organizational breakdown structure. The organizational breakdown structure should be integrated to form a responsibility assignment matrix (see Figure 2). The responsibility assignment matrix can be used to establish a performance management framework for the project or programme management team.

The assignment of responsibility can depend on numerous factors. Depending on how the performing organization is structured, the assignment can be to a group lead or organizational lead, individual team member or whatever organization level is dictated by project or programme. These assignments can be dependent on the industry sector, the country performing the work efforts or the governance documents within the organization. These roles can also be assigned by discipline or function, in other words,

engineering, procurement, construction or other organizationally recognized assignment categorization, including type of project or programme, phase, major deliverables, organization or location of resources. Responsibility can start within the design phase and carry over into the development, production and even the sustainment phase, if these efforts are the objectives and needs of the project or programme.

EXAMPLE Responsibility is assigned to mechanical design, electrical design, drafting and checking. The responsibility is to complete the items assigned through the work breakdown structure within those organizations, as shown in Figure 2.

The use of the work breakdown structure should allow organizations performing the work scope to be accountable for their efforts. These organizations can be influenced by departmental, functional, matrix or external variables or regulatory interfaces, which can affect the work structure and deliverables.



NOTE This figure depicts a functional organization but it can easily be adapted to any other type of organizational structure.

Figure 2 — Example of a responsibility assignment matrix: Integration of a work breakdown structure and an organizational structure[18]

5.3.2 Work assignment

Assignment of responsibility should be directly traceable to the decomposition of the work breakdown structure into work elements and the organizational breakdown structure. Through this process, continuity of the work breakdown structure and the assignment of responsibility should be aligned to a person or set of persons within an organization. This assignment of responsibility allows for accountability with approval and reporting requirements being driven by governance, contract or another managerial stakeholder[7]. In addition, the assignment of responsibility for scope can serve to facilitate communication among project or programme team members, as well as with both internal and external stakeholders.

The assignments should also be aligned so that the work elements can be adjusted for conditions such as: high-cost, high-risk or high-visibility concerns. By providing clear designation within the responsibility

assignment matrix, inside or outside the project or programme, these interactions can be facilitated. The assignment of responsibilities should be manageable and proportionate with responsibility of authority needed to achieve the activity and align with the breakdown of the parent-child relationship[7].

5.3.3 Assigning responsibility during work breakdown structure decomposition

The work breakdown structure should be one of the first items created. Its decomposition can be created during the business case or similar document process or early in the project or programme identification phase. This decomposition should allow for the assignment of responsibility by the organization, project or programme management team, which addresses lower-levels of detail, specifically the parent-child relationships. Since the work breakdown structure is a living document or part of a living document, assignments can be planned or accomplished during progressive elaboration for each phase or stage of the project or programme or when other conditions create the need to update the document.

Assigning the responsibilities for budget in summary, planning or control accounts for acceptance and approval of responsibility should be assigned at the project or programme level.

5.3.4 Description of the project or programme assignment of responsibility

The project or programme manager, with either internal organizational control or external control, such as contractual control, should have the responsibility to assign work efforts to an organization of persons identified, such as control account managers.

The control account manager has the responsibility to review the scope of work and confirm it is in alignment with the work breakdown structure decomposition of work through the associated parent-child relationships. The control account manager can then accept the responsibility through an informal acceptance or through formally approved work documents, whether internal or contractual. Once the approved control account manager is assigned resources, coordination with the integrated plan and budget should include the assignment of responsibilities based on risk, scope, schedule or performance, with the objective of enabling integration of budget and schedule. This assignment and review process should support the project or programme manager in the management of the project budget, cost, schedule and performance.

5.3.5 Work packages

Work packages should be identified as one of three types:

a) discrete activities: work that has a specific end product or result that can be directly planned and measured;

b) apportioned effort: work that cannot be readily measured or divided into discrete work packages but can be directly related to the planning and performance on other identified discrete tasks; examples include quality control and inspection;

c) level of effort: support or management work that does not result in a specified product or output; neither performance nor achievement can be measured as there is no tangible output.

NOTE Level of effort work packages can include supervision and administration.

5.4 Step 3: Schedule the work

5.4.1 General

The schedule for work that identifies activities, durations, milestones and interdependencies at an appropriate level should be the basis for earned value determination[6]. This basis means the activities should be identified at or below the level of the work breakdown structure. This identification of activities needs accurate time phasing of planned work that should be integrated with the scope, schedule and cost of the programme.

Work scope should align to the earned value management structure through the decomposition of scope into work breakdown structure elements with assigned activities and milestones. These milestones should reflect the interdependencies and constraints, with planning for potential risk and risk treatment actions. Through the assignment of activity durations, resource loading of control accounts can be completed to allow for resource levelling and validation of the expected value.

NOTE The same process can be done using planning packages.

The final step of scheduling should be to validate the critical path in alignment to the integrated baseline, so that the project or programme manager and control account managers can approve a time-phased budget baseline. This scheduling of work should assist with the actual cost and performance to be measured.

The scheduling of the work should include supporting the development of the performance measurement baseline. The schedule should be structured in a manner that will enable progress to be:

a) calculated using the schedule;

b) compared with the performance measurement baseline.

Comparison of the progress with actual costs can occur within the schedule or outside the schedule model depending on the methodology being used.

5.4.2 Planning the work

Planning the work should be accomplished through the review of the scope of work or contract scope and terms, including the authorized milestones. The milestones should be reviewed against the governance, policies and procedures for dividing the work scope into control accounts for productivity and management. This planning output should be utilized with specific organizational governance for delegation of the authority from the project manager to the control account managers.

The identified milestones and activities should then be reviewed for their dependencies and logical relationships that allow for the objectives, outcomes, deliverables and benefits to be met with assigned resources and budget.

5.4.3 Identification activities

The work breakdown structure should be documented in further detail as described by parent-child relationships[7]. This work breakdown structure detail should provide the development of a sequence of activities and logically rolled up to the levels that achieve the activities that can be aligned to the control account level.

Identifying the activities to schedule the work scope should be done using the responsibility assignment matrix. The activities should be developed to provide sequence tied to establishing a network logic with the assignment of activities and durations that should establish the critical path.

The identification of activities should be aligned at the control account level to allow for resource loading. Utilization of summary level activities or control accounts to support the lower work activities should be defined in the initial planning of the project or programme and align to the work breakdown structure and the organizational breakdown structure. This alignment should be accomplished to allow the activities for resource loading to support control accounts to be validated.

5.4.4 Durations

Durations are identified through vertical traceability to horizontal traceability based upon the sequence of work[6].

Work should be traceable throughout the project or programme to each level of the schedule consistent with the level of planning[6].

The assignment of activities should establish the basis for the assignment of activity durations. The duration review should be done to verify activities are logically tied and the critical path can be established.

As developed and approved, the schedule should be used by the management team to plan and monitor the work performed. The schedule or schedules should provide a way for evaluating actual progress against pre-defined objectives.

Durations of the activities should be estimated considering available data, resource demand and availability, as well as risks and uncertainties. The basis for determining activity durations should be documented in the basis of schedule documentation. The basis of schedule documentation defines the reasoning or logic for the schedule development, including assumptions and exclusions. Durations can be used in the detail work scopes or packages to align and support the control accounts. Durations can also be summarized into summary level or planning packages using a rolling wave concept.

Work package durations should roll up to the control account activities. These work packages should be integrated into the scope of work and have the earned value technique assigned to them.

5.4.5 Milestones

Major milestones should be determined based on significance, constraints and interfaces[7]. Significance in this context can be the importance of the effect of the milestones to the outcomes, deliverables and benefits. Milestones can be assigned as contractual, programme or value milestones. Milestones have zero duration and cannot be resource loaded but are logically tied into the relationships to validate scope, logic and critical path.

Programme or project milestones should reflect key areas or control points that allow for the measurement and progress of significant elements of the work.

Value milestones should be used to measure points of work within longer duration control accounts or work packages.

5.4.6 Interdependencies

Activities sequenced for interdependencies should be placed in a network that has a single point of entry and concludes with one point of exit (see 5.4.2 and 5.4.3). Each activity identified should have a predecessor and successor, so that activities are logically tied with no open ends.

The interdependencies, which are logically tied with no open ends, should allow for the forward and backward pass to establish the critical path. The forward pass is the method of moving forward through a diagram to calculate total activity duration, and the backward pass is the other direction view. The critical path should be complete once resources are validated and loaded. The project can be baselined to establish the earned value management system's performance measurement baseline.

5.4.7 Schedule validity

5.4.7.1 For a schedule to be valid, it should be:

a) complete – representing authorised effort for the entire contract, with essential subcontracted or other external work for milestones integrated, yet distinguished from internal work;

b) traceable – reflecting realistic and meaningful network logic that horizontally and vertically integrates the likely sequence for project or programme implementation (see ISO 21508:2018, Figure 2);

c) transparent – providing full disclosure of project or programme status and forecasts, and including documented ground rules, assumptions and methods for building and maintaining schedules;

d) updated – reflecting a consistent and regular update of completed work, interim progress, achievable remaining durations relative to the status date and accurately maintained logic relationships;

e) predictive – accurately forecasting the most likely completion dates and impacts to the project or programme baseline plan through valid network logic and achievable task durations from the status date through project or program completion[13].

5.4.7.2 A schedule should also be:

a) usable – producing meaningful metrics for timely and effective communication and tracing and improving performance, treating issues and risks;

b) resourced – with labour, materiel and facilities aligned with the schedule baseline and forecast to enable stakeholders to view and assess the time-phased labour and other direct cost to achieve the project baseline and forecast targets;

c) controlled – with the schedule baselined and maintained using a rigorous, stable, repeatable and documented process. Schedule additions, deletions and updates should conform to this process and result in valued and accurate results for sound schedule configuration control and maintenance.

5.5 Step 4: Develop a time-phased budget

5.5.1 Overview

The purpose of this step is to distribute cumulatively the project or programme budget over the period of time for which the work implementation has been planned. This cumulative distribution of the budget should be the basis to establish the performance measurement baseline.

This step should directly influence the calculations and values of earned value management metrics and indices.

To develop the time-phased budget, one should use the schedule, where budget should be allocated to the schedule activities. This allocation should schedule activities according to the budget value of the resources contained in the approved baseline to be used during implementation.

Substantiated cost and schedule estimation, approved and documented risk treatment actions and progressive elaboration are factors that should be considered in the production of the time-phased budget and of the performance measurement baseline.

The cumulative time-phased distribution budget should mirror, as close as possible, the planned cumulative implementation of the scope over the duration. The cumulative time-phased distribution should not be confused with the financial or accounting cash flow needed for the funding of the project or programme over time.

5.5.2 Concepts and considerations

5.5.2.1 General

The following items should be considered in the preparation of the time-phased budget:

a) resource use;

b) economic valuation of the project work;

c) progressive elaboration;

d) approved risk treatment actions;

e) subcontracted work;

f) cost estimating and budgeting.

5.5.2.2 Resource use

Resource use allocated to a work activity should equate to accountability for a cost to be incurred due to the use and depreciation of a resource.

EXAMPLE Table 1 provides an example of the budget.

Table 1 — Example of a project budget

Resource	Unit cost	Quantity	Observations
Trainer	$ 100/h	80 h	20 h per activity
Video-projector	$ 1 000	1 unit	Acquired by the project at the beginning Used only in activities A (40 h) and C (20 h) Book value at the project end is $ 400
The total budget of the project is: $ 8 000 + ($ 1 000 – $ 400) = $ 8 600. While the project is accountable for the upfront acquisition of the video-projector, the correct budget valuation of the cost caused by the project with the video-projector is not $ 1 000 because at the end of the project the video-projector is estimated to have a book value of $ 400 by accounting for depreciation. The video-projector, depending upon organizational governance or contract terms, can either be sold or considered as an organizational asset. Therefore, the real cost incurred by the organization is: $ 1 000 – $ 400 = $ 600.			

Based on this information, the budget value of the activities A, B, C and D is calculated as follows:

— Activity A:
  — 20 h of a trainer's time at $ 100/h totals to $ 2 000;
  — use of a video-projector:
    — 40 h out of 60 h; in other words, $\frac{40}{60}$ or 67 %;
    — cost of a video projector to the project equals the purchase cost minus book value: $ 1 000 – $ 400 = $ 600;
    — cost for which activity A is accountable in the budget: $\$600 \times \frac{40}{60} = \$400$;
  — the total budget allocated to activity A is: $ 2 000 + $ 400 = $ 2 400.
— Activity B:
  — 20 h of a trainer's time at $ 100/h totals $ 2 000;
  — the total budget allocated to activity B is $ 2 000.
— Activity C:
  — 20 h of a trainer's time at $ 100/h totals $ 2 000;
  — use of a video-projector:
    — 20 h out of 60 h; in other words, $\frac{20}{60}$ or 33 %;
    — cost of a video projector to the project equals purchase cost minus book value: $ 1 000 – $ 400 = $ 600;
    — cost for which activity C is accountable in the budget:
      — $\$600 \times \frac{20}{60} = \$200$;
      — the total budget allocated to activity C is: $ 2 000 + $ 200 = $ 2 200.
— Activity D:
  — 20 h of a trainer's time at $ 100/h totals $ 2 000;
  — the total budget allocated to activity D is $ 2 000.

Table 2 shows the total allocation of the project budget to the activities and schedule.

Table 2 — Example of a project budget allocation

Week no.	Activity	Budget value	Cumulative time-phased
Start	—	—	$ 0
1	A	$ 2 400	$ 2 400
2	B	$ 2 000	$ 4 400
3	C	$ 2 200	$ 6 600
4	D	$ 2 000	$ 8 600

The adequate allocation of resources, in kind and quantity, of the budget to the schedule activities should be at the core of the development of the time-phased budget: what resources will be consumed in the implementation of which activity and in what quantity.

Resource use by work activity should be accounted by cost to be incurred by resources for an activity. These calculations can range from depreciation (such as for equipment), physical use (such as for concrete), direct allocation (such as for effort of human resources) to indirect allocation (such as for overheads).

5.5.2.3 Economic valuation of the project or programme work

The budget and actual schedule should be bound to the scope via the work breakdown structure. This integration should be maintained throughout the life of the project or programme.

The cost items of the budget, such as the resources planned to be consumed, are allocated in quantity to the scope elements. These cost items at the more detailed level will be the schedule activities. The economic value can be calculated based on the budget value of the resource units.

The economic perspective of the budget valuation of the work of the project or programme is distinctive from the financial perspective used in cash-flow management: the cost should not be allocated based on a time perspective of when invoicing and payments of the resources consumed will occur, but rather based on a scope perspective of accountability for resource use.

In the example of 5.5.2.1, a financial perspective would allocate the full cost of $ 1 000 with the video projector to activity A, because the activity is the first activity that needs acquisition and payment of this resource. However, such over-evaluation of activity A can lead to an incorrect time-phased distribution of the project budget. The over-evaluation results in skewed performance measures with false variances that can lead to a lack of trust in the earned value management system and possibly poor decision-making.

5.5.2.4 Progressive elaboration

The progressive detailing of the scope and schedule should be integrated with the progressive adjusting and granularity of the time-phased distribution of the budget of the project or programme, which should lead to greater accuracy and detail.

Unsubstantiated estimates can lead to under- or over-performance measures.

Scope elements that are not yet detailed should be mirrored by high-level planning elements in the schedule, and high-level budget allocation or undistributed budget.

As the project or programme progresses, scope and schedule elements should be detailed along with sufficient granularity to sustain, as much as possible, the objective allocation of the planned resource use to the work scope elements and ultimately to the schedule activities.

The criteria used to allocate resource use in this planning step should be documented and consistently followed during implementation and control, in order to record the actual use of the resources. Therefore, practical considerations in terms of feasibility, data availability, and effort needed should be considered during progressive elaboration.

The progressive detailing of the scope definition and schedule should also sustain the adequate and accurate assignment of objective measures of performance (see 5.6).

5.5.2.5 Establishment of a residual risk position

Any risk treatment actions needed to achieve the residual risk position should be approved in the risk management system and transferred into the performance measurement baseline. There should be a mechanism for tracing these actions to the risk management system in order to monitor their progress during project or programme implementation.

Any adverse effects caused by the introduction of these actions into the baseline should be assessed to re-evaluate the overall net benefit to the project or programme. Progressive evaluations can be carried out to achieve an optimal position.

Risk contingency reserves and schedule buffers can be established in the baseline for the implementation of contingency plans or additional treatment actions for known risks. These actions should only be necessary if management reserve cannot be held at the project or programme level (see 9.1.4.5).

5.5.2.6 Subcontract work

Subcontracted work, assigned in total or in part to suppliers, should be part of the scope. The subcontracted work time and budget values are integral to the overall project or programme to be controlled by the earned value management system.

The contracted services or materials should be valued from the perspective of the project or programme owner, who is responsible for the budget, therefore under a pricing, as opposed to the actual cost to the supplier. This approach should apply to any type of contract.

Contractual terms and conditions should be established with the suppliers for the necessary information to be available in a timely manner and with the necessary detail to sustain the development of the time-phased budget.

While different approaches and alternatives can be used to document the subcontracted work and resources in an earned value management system, during the invitation for bid and when requests for proposal are issued, the organization interested in implementing earned value management should set forth the mandatory terms and conditions regarding planning and controlling information and data that should be transmitted in specified time periods. Such mandatory terms and conditions should also be communicated during a sole source contracting option, if there is only one source available for the work or resources needed.

5.5.2.7 Cost estimating and budgeting

Cost estimates should be:

a) realistic;

b) objectively assignable to the detailed project or programme scope;

c) auditable.

The breakdown of the cost elements should be organized and classified making it easier and more accurate for the allocation to the work. The project or programme manager and team benefit from the traceability that results from the objective apportionment criteria applied to the use of the cost for work.

The basis of the estimates and assumptions should be documented to enable auditability, which is essential to analyse and communicate performance variances and accountability. The documentation should also be used in the identification of risk development of preventive and corrective actions.

NOTE Point estimating can be used where there is significant uncertainty relating to cost or schedule elements.

5.6 Step 5: Assign objective measures of performance

5.6.1 General

5.6.1.1 The purpose of assigning objective measures of performance should be an agreed upon selection of the method of measuring performance.

An objective measure should be one that is not only agreed upon but understood by the stakeholders. An objective measure can be seen as impartial, unbiased and fair, as long as the stakeholders agree. Measures of objective performance should be agreed upon to accurately assess progress. Without this agreement on objective performance, the performance reported can fail to accurately reflect the amount of progress achieved in any given reporting period.

NOTE Objective measures of performance are also known as earned value techniques or rules of credit.

The objective measures of performance should be the primary method of measuring achievement or physical progress.

The objective measure of performance chosen should be the most representative of the effort needed to achieve the work within a specific work package (see 5.3.4) or activity. It should also be the most appropriate method for planning, scheduling and evaluating performance.

5.6.1.2 Work packages should be identified as one of three types:

a) discrete activities: work that has a specific end product or result that can be directly planned and measured;

b) apportioned effort: work that cannot be readily measured or divided into discrete work packages but can be directly related to the planning and performance on other identified discrete tasks; examples include quality control and inspection;

c) level of effort: support or management work that does not result in a specified product or output; neither performance nor achievement can be measured, as there is no tangible output (see 5.3.4).

5.6.1.3 The objective measures used to measure work performance should be specified using the following:

a) accomplishment of an activity should be expressed in terms of the budgetary value or earned value of the activity;

b) objective measures of performance to quantify the degree of completion of activities;

c) earned value of a completed activity equating to the amount budgeted for the activity, planned value or budgeted cost of work scheduled;

d) objective measures of performance agreed upon before the start of each work package and not changed once work has started;

e) objective measures of performance planned in the same manner in which they are to be assessed and assessed in the same manner in which they are planned;

f) objective measures of performance established in such a manner that value is earned and actuals accumulated in a consistent manner and in the same time frame;

g) one objective measure of performance or earned value technique only used per work package[6].

Objective measures of performance should be established to determine accomplishment of in-progress activities. The selection of the measure should depend on activity content, size and duration. The measuring of earned value should be calculated using the same method, as stated in the approved earned value management system documentation or plans. The resulting metric is referred to as the earned value.

Objective measures should allow work achievement to be measured in a clear and unequivocal way. Setting the objective measures in advance should enhance accountability and objectivity.

Performance can be measured in terms of currency, labour hours or other measurable units. The performance measurement indicators, such as milestones, should be scheduled with sufficient frequency to provide a basis for accurate performance measurement. Additionally, performance measurement should occur consistently within documented time intervals.

5.6.2 Earned value techniques — Description, advantages and disadvantages

5.6.2.1 General

Table 3 summarises the suggested earned value techniques.

Table 3 — Summary of the earned value techniques and their applicability

<table>
<tr><th rowspan="2">Output</th><th colspan="3">Earned value techniques for</th></tr>
<tr><th>one reporting period or less</th><th>two reporting periods</th><th>three reporting periods or longer</th></tr>
<tr><td>Measurable units</td><td rowspan="3">0/100</td><td colspan="2">Units complete (equivalent units)
Production (earned standards)
Formula method</td></tr>
<tr><td>Direct interim outputs or milestone</td><td colspan="2">Milestones</td></tr>
<tr><td>Product or achievement but no discrete units or interim milestones identified</td><td>Start/finish
50/50, 60/40, 20/80</td><td>Estimate
(% complete)</td></tr>
<tr><td>No product or achievement</td><td colspan="3">Level of effort</td></tr>
<tr><td>Proportional to progress on related work packages/discrete tasks</td><td colspan="3">Apportioned effort</td></tr>
</table>

5.6.2.2 0/100 method

5.6.2.2.1 General

No value or progress should be earned until the activity or work package is complete. This technique can be seen as another variation on the use of milestones as a progress measure.

5.6.2.2.2 Advantages

This technique can be easy to use and no additional work is required to the schedule to accommodate it.

5.6.2.2.3 Disadvantages

This technique can be suitable for short duration activities of less than one reporting period. The technique can provide distorted performance indices by not taking work in progress into account.

5.6.2.3 Units complete or equivalent units

5.6.2.3.1 General

This method should be based on measuring the number of units or items that have been completed and comparing the result with the total number of units or items that are to be completed in the approved baseline. This technique should normally be used in manufacturing sectors, where earned value is measured as the number of units produced. An equal amount should be earned for each unit completed.

5.6.2.3.2 Advantages

This technique can be easy to achieve and implement. It can help with the production of other productivity graphs, such as line of balance. This technique can be useful when a large number of repetitive items are being made, such as mass production of components: cabling or pipelines.

5.6.2.3.3 Disadvantages

This technique should only be applied to the activities that have a repetitive element. If applied to a more complicated activity, this technique can be inaccurate. Care should also be taken to allocate the time phasing of production at the start and end of a specific production run.

If 1 000 m of pipe are to be laid over a four-month period, one should be careful in using the average of 250 metres each month for measuring progress. Given the issues and challenges around production mobilisation, equipment, hiring, procurement and labour allocation, it is prudent to allocate less progress in months 1 and 4 200 m can be a better estimate for month 1. This technique also assumes that higher production rates are achievable in months 2 and 3.

5.6.2.4 Earned standards

5.6.2.4.1 General

This technique is a variation on units complete. The technique uses a number of known activity-cycle times, analysed from previous similar activities to set the standard work time for an operation. When the operation is complete, the standard value should be earned.

5.6.2.4.2 Advantages

This technique should be used for production processes that are well-defined and can be easily analysed to produce the production standards. This technique can help to identify areas for continuous improvement and aligns well with approaches for manufacturing.

5.6.2.4.3 Disadvantages

Unless development activities can be measured and assigned standard times and costs, the technique should not be used. The technique can have the potential to be inaccurate, if applied to more complicated activities.

5.6.2.5 Formula method

5.6.2.5.1 General

The formula method, should be used where performance for low-value, non-critical material and other direct cost categories can be earned on the basis of actual cost, multiplied by the relationship of the budget at completion to the estimate at completion:

$$EV = AC \times \frac{BAC}{EAC}$$

where

EV is the earned value;

AC is the actual cost;

BAC is the budget at completion;

EAC is the estimate at completion.

Table 4 provides a view of earned value after applying the formula method based on a budget at completion value of 1 000 units.

Table 4 — Earned value calculations based on the formula method

	Month				
	1	2	3	4	5
AC	200	400	700	1 000	1 400
BAC	1 000	1 000	1 000	1 000	1 000
EAC	1 000	1 000	1 200	1 300	1 400
EV	200	400	583	769	1 000

5.6.2.5.2 Advantages

This technique should rely on monthly updates of the estimate at completion to be accurate. It can be useful in situations where progress can be directly related to spend, such as, consumables and direct line feed.

5.6.2.5.3 Disadvantages

This technique should be avoided for complex activities and high-value items being either procured or manufactured.

5.6.2.6 Milestones complete

5.6.2.6.1 General

Achievement of the work package should be measured by the achievement of milestones. Each milestone should be assigned a proportion of the budget, and when the milestone is achieved, that proportion of the budget should have been earned. Earned value should only be taken on milestone completion.

5.6.2.6.2 Advantages

This technique of calculating earned value should be applied when there are a large number of frequent milestones.

5.6.2.6.3 Disadvantages

The method should not reflect the schedule and the work scope. Achievement should not be directly related to a specific milestone. Milestones chosen should not be directly on the critical path. If work in progress is considered, it can make the schedule performance index and cost performance index worse than the actual. If the number of milestones is low, then the measuring process should become coarse and can prove to be no longer useful.

5.6.2.7 Start/finish method

5.6.2.7.1 General

A set percentage of the value should be earned at the start of the activity or work package. The rest of the value should be earned upon completion. The starting percentage should be 20 % or higher depending upon the governance or plan for the use of this technique. The method should be used when the activity or work package has duration between one and two reporting periods.

5.6.2.7.2 Advantages

When used for a specific activity or work package type, stakeholders can agree to the set percentages for the reporting periods.

5.6.2.7.3 Disadvantages

Care should be taken where the duration is more than two accounting periods. No value can be earned at either the start or the finish. This accounting can bias the schedule performance index, cost performance index calculations and the estimate to completion. The method can represent work in progress over or under what is claimed, thus affecting the schedule performance index and cost performance index values.

5.6.2.8 Estimate or percentage complete

5.6.2.8.1 General

In using the estimate or percentage complete technique, earned value should be determined by a subjective assessment of the total work completed. Granularity in the schedule, activity details should provide the objectivity.

5.6.2.8.2 Advantages

No additional schedule changes or preparation should be needed. This technique can be applied to activities with duration spanning three or more reporting periods and where an objective basis exists for determining percentage complete for the work package.

5.6.2.8.3 Disadvantages

The method can be misapplied, if the schedule granularity is not achieved or maintained as planning packages are turned into work defined. Clarity of the activity or work package entry and exit criteria can help packages. The method application can also be seen as subjective if the output or deliverable is not visible or clearly stated.

5.6.2.9 Level of effort

5.6.2.9.1 General

Technique is easily used to draw value for work activities that do not produce deliverables, are not on the critical path and cannot be late. Level of effort should be kept to a minimum to avoid masking performance variances. Other uses for level of effort can be quality assurance and configuration management, which should use the apportioned effort, earned value technique.

Level of effort work packages are those work packages that should be used for necessary work efforts for the project to be successful, but that do not have a specific end deliverable or outcome represented by them in whole or in part.

NOTE Activities can include some aspects of project or programme management and contract administration or other consultations related to the management of the project or programme, where such activities are not covered by overhead costs.

5.6.2.9.2 Disadvantages

This method should only be used for this type of activity. Since level of effort earned value is measured by the passage of time, it is important to provide that the time-phased budget distribution is representative of the baseline schedule. As a result, earned value should be set equal to the budgeted schedule of work planned, even if the work package has not started. This technique should mean schedule variances never occur; thus, level of effort tasks does not allow meaningful earned value schedule analysis to be done.

However, level of effort work packages can generate a cost variance and recorded actual cost can still be compared to the earned value. Level of effort work packages should be separately defined from other work packages to avoid issues with any earned value analysis. The level of effort technique should be used only for those activities where no recovery action would be taken if the work were not undertaken.

5.6.2.10 Apportioned effort

Apportioned effort should be work that is not readily divisible into discrete work packages, but the work should be directly related and dependent upon measurable progress within another work package or another deliverable or outcome.

Apportioned effort should normally be used for tasks, such as inspection, configuration management, and quality control and assurance.

The link between an apportioned account and a base account should be a schedule link. This linkage should mean that the schedule in the apportioned account is derived by analogy to the work schedule of the base account and the earnings in the apportioned account are derived by analogy to the work accomplished in the base account.

Earned value should be determined by an apportioned factor calculated from the budget at completion for the apportioned and reference work package.

$$apportioned\ EV = EV_{\text{reference work package}} \times AF$$

where

EV is the earned value;

$EV_{\text{reference work package}}$ is the earned value of the reference work package;

AF is the apportioned factor.

There should be no similar apportionment of actual cost of work-performed values for apportioned effort work packages. Actual costs should be directly recorded and reported against the work package, resulting in the generation of cost variances where variances exist.

The control account manager of the apportioned account should still control the assignment of budget to the account, but the time phasing of that budget and the percentage of earnings should be directed by the base account. See Table 5 for an example of calculations of an apportioned work package based on an apportioned factor of 0,333.

Table 5 — Example of an apportioned work package calculations based on AF of 0,333

		Month				
		0	**1**	**2**	**3**	**4**
Reference work package	PV	0	60	120	210	
	EV	0	0	60	120	210
	AC	0	30	70	120	250
Apportioned work package AF, 0,333	PV	0	20	40	70	
	EV	0	0	20	40	70
	AC	0	10	40	50	65

5.6.2.11 Earned value types for material items

Earned value measurement for material should be measured like any other element of cost. It is intended to permit assessment of events that reflect progress in performance, not measurement of administrative or financial events, such as booking of actual costs or invoice payment. Therefore, planned value should normally be scheduled according to an event, such as material or equipment delivery or receipt, and earned value should be earned when the event occurs. Administrative or financial events can be used as indicators for contract events when such indicators occur in the same reporting period as the contract events.

5.7 Step 6: Set the performance measurement baseline

5.7.1 Overview

The performance measurement baseline should provide the reference against which the actual outcome should be compared in order to measure, assess and diagnose performance, and devise management action, as appropriate to direct the project or programme towards its objectives.

Setting the performance measurement baseline should necessitate that each previous planning step has been developed by addressing the following elements:

a) scope definition and baselining based on the work breakdown structure;

b) responsibility assignment based on control accounts and responsibility assignment matrix;

c) development of the project schedule;

d) development of the time-phased budget, incorporating resource planning, and the undistributed budget;

e) establishment of objective measures of performance for work packages (see 9.1.4.4).

The development of the schedule and the time-phased budget should incorporate risk treatment actions and can include schedule buffers.

The performance measurement baseline should integrate each of these elements into a single integrated project baseline. The performance measurement baseline should not include the management reserve, over which the project or programme management team should have no authority (see 9.1.4.8).

5.7.2 Management responsibility

The performance measurement baseline should be the basis for the assignment of management responsibility for performance to the project or programme management team.

Management responsibility should include measuring and reporting performance, diagnosing and explaining the causes of performance, and devising appropriate management actions to direct performance towards the planning targets.

Besides the project or programme manager's responsibility for the overall performance, the primary level at which responsibility should be delegated is at the control account level, where control accounts should be assigned a control account manager. If progressive elaboration and change control take place, some control account managers should be assigned at the beginning of the project or programme, while other control account managers should be assigned as progressive elaboration and change control take place. Further delegation of management responsibility can be established at the lower work package level within each cost account, as agreed by the control account manager and the project or programme management team members involved in the scope assigned to each cost account.

Negotiation and review of the previous project or programme planning elements should take place, as part of setting the final performance measurement baseline, which should be subjected to a formal acceptance process. This formal approval process can lead to the need to renegotiate contractual agreements resulting in changes to arrangements between and among the project or programme organization and the suppliers, client and sponsors. These changes should reflect how responsibility was negotiated and agreed-upon among the relevant stakeholders.

Another important aspect of management responsibility should be the feasibility of the performance targets because unrealistic and poorly documented estimates can lead to the loss of the initial commitment. The performance measurement baseline, therefore, should include a complete documented basis of estimate and schedule basis, as the foundation for the following:

a) feasible performance targets;

b) estimates and actual results being traceable and auditable;

c) performance variance being diagnosed and assigned to specific causes.

5.7.3 Control period

If necessary, the actual project or programme results should be compared against the performance measurement baseline as the basis to assess performance and take management action. The control period should be established to use in the different phases and stages and possibly in different control accounts or work packages. The establishment of an adequate control period can depend on a number of factors (see 5.9.2).

5.8 Step 7: Authorize and perform the work

5.8.1 A work authorization system process should be used because it can facilitate the implementation of earned value management.

The existence of a formal process to authorize the commencement of the work should be used to achieve the consistency and validity of the data and information entered and produced by an earned value management system.

When work is authorized to commence, the resources planned in the baseline should be made available for implementation. Actual resource use in kind, quantity and cost should start being recorded together with work progress, actual schedule dates, and performance information. Data and information regarding the scope, cost and time should be aligned and consistent, and the work authorization system should meet earned value management guidelines.

5.8.2 The elements of a work authorization should include the following:

a) work scope: what is to be done;

b) responsibility: who is responsible for the various aspects of work performance, in particular who is accountable;

c) schedule: when and in what sequence is the work to be done;

d) resources: in kind and quantity, and when to be employed;

e) budget: the cost budget available to perform the work;

f) quality elements: standards, methods, metrics and other elements aimed at enabling the work to be performed within the project or programme quality requirements;

g) entry criteria or constraints: conditions that should be met, verified and monitored for the physical execution of the work.

5.8.3 For work to be authorized, the following items should be part of the overall project or programme management process:

a) who is responsible to authorize the work should be established beforehand and communicated to the project team;

b) who is responsible to receive the authorization according to the communications planning;

c) work should be planned at the adequate level of detail prior to implementation and the baseline refined;

d) steps necessary to implement the earned value management objective measures of performance should be in place, including data collection and information gathering tools, methods and resources.

The work authorization process should be implemented in a top-down fashion, starting with the authorization of the project or programme through a charter and the assignment of a project or programme manager. These process steps should be followed by the authorization of control accounts and assignment of control account managers, as well as work packages and schedule activities. The levels of detail at which a work authorization is to be performed should be established in the planning and should sustain the guidelines

of the earned value management system regarding consistency of the data and information throughout the project or programme.

5.9 Step 8: Accumulate and report performance data

5.9.1 Overview

During implementation, performance indices should be periodically collected and accumulated to produce performance analysis metrics and indices that measure performance. These metrics and indices should serve as the basis for identification and diagnoses of variances, identification and assignment of causes and determining if management action should be taken.

The process of collecting and accumulating performance indices should repeat at every reporting period, as established in the project or programme planning, or ad hoc specific points in time.

Performance indices should be collected and accumulated in the three dimensions of scope, cost and time and occur at the work package or schedule activity levels within each control account that has been authorized for implementation.

5.9.2 Control periods

5.9.2.1 If needed, control points should be established for the control accounts and work packages.

The establishment of a reporting period should depend on several factors, including:

a) duration of the project or programme, phase, cost account or work package;

b) type, nature and complexity of the work being performed;

c) feasibility that takes into account constraints, in particular resource needs and availabilities;

d) cost of data collection and cost-benefit analysis of the data collection process;

e) management items imposed by stakeholders and organizational governance.

5.9.2.2 The control period should be established to enable:

a) sufficient time elapses so the accumulation of performance indices is meaningful, which can depend on the characteristics of the work and requests for an extended time period;

b) early detection of variances so management actions can be implemented, which indicate a need for a shorter control period;

c) reliable process to deliver the quality data and predictability;

d) each piece of the performance indices collected is properly synchronized to a common moment in time;

e) stakeholders' expectations and needs are addressed.

5.9.3 Scope performance indices

Scope performance indices should relate to measuring the degree of scope realization, which should be primarily dependent on the measures of performance established in planning. This data should include the following:

a) physical measure of scope;

b) scope related events or milestones;

c) quantities of resources consumed;

d) time elapsed.

5.9.4 Schedule performance indices

Schedule performance indices should relate to measuring status of the schedule activities regarding their actual realization and planned future. This data should include the following:

a) actual start and actual finish dates;

b) updated forecast start and forecast dates.

c) activity percent complete according to agreed methods of measurement;

d) estimate to completion.

5.9.5 Cost performance indices

Cost performance indices should relate to the actual value of the resources consumed to perform the work. The collection and accumulation of the cost data should be consistent with the guideline criteria, where the actual resource use should be understood to be the accountability for the cost actually incurred using those resources.

EXAMPLE During implementation when the video-projector was acquired in the first day of the project, it resulted an actual price of $ 1 200 as opposed to the budgeted value of $ 1 000, but with the same expected book value (i.e. $ 400) at the end of the project (see 5.5.2.1 EXAMPLE). In the implementation of the first training session, activity A, the hours of video-projector consumed were 50 h as opposed to 40 h, and it is now planned that in activity C only 10 h will be consumed, keeping video-projector use total budget constant at 60 h. The cost data accumulated for activity A for the resource video projector would be $(\$1200 - \$400) \times \frac{50}{60} = \$666,67$ versus the original cost estimate of $ 400 allocated to the video-projector use for activity A.

The higher cost of the video-projector against the budget together with the excess hours of its use led to an unfavourable cost variance of –$ 266,67 at the end of activity A due to this resource (i.e. $ 400 – $ 666,67 = $ 266,67).

Performance cost data should be mapped at the schedule activity level and include the following:

a) actual unit cost of each resource consumed;

b) actual quantities of each resource consumed;

c) updated unit cost of each resource planned to be consumed in the future;

d) updated quantities of each resource planned to be consumed in the future.

5.9.6 Performance analysis data points

The data points of planned value, earned value and actual cost should be calculated starting with data accumulated from the schedule at the work package level, if available in the work breakdown structure and eventually from its calculation at the schedule activity level. These data points are rolled-up through the work breakdown structure to the project or programme total. Earned schedule and actual time should be calculated in a similar way for each activity or scope element in the work breakdown structure. Budget at completion and schedule at completion should be calculated at the cost account level and above that level. Eventually, this effort should be done at other work package levels in the work breakdown structure within cost accounts, where responsibility for performance has been assigned.

5.10 Step 9: Analyse performance data

5.10.1 Overview

An earned value management system should quantify cost, schedule and technical performance. This quantification provides a sound and objective basis for considering corrective and preventive actions.

Analysis of deviations from plan for both cost and schedule should provide project or programme management with the ability to implement corrective actions to accomplish the objectives. Analysis of earned value management data can also provide a forecast of final cost and schedule outcomes. It can also result in the identification or update of risks and issues, as well as treatments actions.

5.10.2 Key questions

The primary questions project or programme personnel should ask are:

a) What is the earned value relative to the planned value?

b) What is the earned value relative to the actual costs?

c) What is the root cause of these variances?

d) What corrective or preventive actions should be put into place in regard to the variances?

5.10.3 Timeliness of information

Timeliness in finalising and communicating the earned value management information among control account managers and the project or programme manager at the close of each reporting period should be considered critical.

Cost and schedule variances are lagging indicators of performance. The usefulness of these lagging indicators of performance should be in indicating the plan is or is not being achieved and to respond to this information, particularly if these indications are supported by other metrics early enough to affect a change.

The predictive value in forecasting of schedule and cost can often be understated. More often than not, independent estimates at completion can be more accurate than forecasts of control account or the overall project or programme. This calculation can be used to assess the reasonableness of the contract estimates or recommend the continuation of the project or programme to the sponsor or senior management (see Annex A[6]).

5.10.4 Data analysis steps

Earned value management data analysis can be broken into the following steps:

a) earned value management data validity checks;

b) review of variances;

c) analysis of trend data;

d) review of comparative data.

5.10.5 Data validity checks

5.10.5.1 Conducting some basic checks should provide earned value management data that are of sufficient quality and completeness to facilitate analysis to validate the data.

5.10.5.2 These validity checks should be conducted:

a) planned value, earned value, actual cost, budget at completion and estimate at completion data should total correctly from control account level to project level;

b) budget at completion of the reporting elements should equal the performance measurement baseline.

5.10.5.3 For any reporting element, one should carry out the following actions:

a) calculate the current period values by subtracting the cumulative data provided last period from that provided in the current period, and if any negative values are generated, it can be evidence of a retroactive change;

b) ensure that the actual cost should not exceed the estimate at completion, but if it does, it is an indication that the estimate at completion has not been revised;

c) calculate estimate at completion which should equal actual cost, if 100 % complete, since all costs should have been booked to that particular reporting element;

d) demonstrate that the value of the work planned, work achieved and the total budget, if 100 % complete, should be equal;

e) provide an explanation for a budget at completion or estimate at completion that has a significant change as determined by the project management team.

Customer or management directed changes should be checked for accurate incorporation into the baseline.

An indication of systemic problems with the earned value management system can be problems with the earned value management data quality. The project or programme manager should consider conducting an assurance review on the application of the earned value management system (see Clause 6).

5.10.6 Review variances and analyse trend data

5.10.6.1 Project or programme status can be expressed in terms of cost and schedule variances using earned value management data. Variances can arise from a number of different causes that are often interrelated, such as inadequate planning, incorrect bases of estimates, technical problems, or unforeseen labour and material rate changes. Correcting a performance problem should necessitate the identification of the root causes for the performance problem through the analysis and team review of the performance measures.

5.10.6.2 Variances are defined by two categories:

a) current variances: variances incurred in a given reporting period;

b) cumulative variances: sum of the variances incurred in the total reporting periods to date.

5.10.6.3 Management action should be required when either the cumulative cost variance or cumulative schedule variance is greater than the defined threshold, as defined by project or programme governance, organizational governance or contract.

One should identify reporting elements that have significant cost or schedule variances, with significant being defined as exceeding the variance reporting threshold. One should also identify elements with the largest variances and the largest budget.

Additional selection criteria should include, but not be limited to, those reporting elements that:

a) reside in the risk register;

b) sit on the critical path;

c) have follow-up being conducted from the previous reporting period.

5.10.6.4 For those reporting elements identified as significant, one should graph and analyse the trends for performance indicators, such as:

a) schedule variance;

b) cost variance;

c) variance at completion;

d) schedule performance index;

e) cost performance index.

5.10.6.5 Control account managers should analyse their variance trends and perform variance analyses to describe the cause of cost and schedule variances, as well as impacts to the project or programme[6].

Possible causes of cost variances can include the following:

a) changes in labour and overhead rates;

b) changes in material costs;

c) incorrect planning assumptions, i.e. basis of cost estimates;

d) lower productivity than expected due to insufficient skills;

e) no learning curve allowance for tasks where experience is low;

f) expensive resources used on simpler tasks;

g) unnecessary activities being performed.

5.10.6.6 Possible causes of schedule variances include the following:

a) poor schedule baseline that does not reflect the way work is being performed;

b) incorrect planning assumptions, in other words, basis of schedule estimates;

c) insufficient resources;

d) volatility of scope;

e) work stoppages;

f) identified key staff absences;

g) non-sequential work performed;

h) unnecessary activities being performed.

If the trends for the reporting element are worsening, new or recurring risks should be identified, and the risk and issue registers or similar documents should be updated respectively. Variances can also be positive or favourable. Positive variances can present opportunities for the project or programme management team and should be analysed. A positive variance should be analysed for issues with cost or schedule estimating, such as work activities that have not been undertaken, and training or other activities not taken that were part of a work package to enhance the team performing.

The project or programme manager and control account managers should also look at the performance indices for trends and future cost and schedule outcomes that predict and indicate whether there is sufficient management reserve to cover any forecasted overruns.

5.10.7 Review comparative data

5.10.7.1 Project or programme personnel should look to other performance measures to:

a) determine whether the earned value management data reported reflects the project or programme status;

b) help improve the accuracy of the variance analysis;

c) assess the impacts to the project or programme.

A source of comparative data should be the schedule. A consideration should be whether the schedule variances reported in the earned value management data can affect the critical path, thus the overall schedule. The reported schedule should reflect the schedule delays and impacts to subsequent activities. Additionally, members of the project or programme management team should provide input on the technical details of identified problem items, as gathered from the team members. An understanding by the project and programme management team of emerging technical problems can provide an early indicator of future cost and schedule performance. Only where the three major areas of cost, schedule and technical scope, along with their associated risks, are examined can the management team attain an overall view of the project or programme.

5.10.7.2 Supporting information should be examined, including:

a) progress reports and meeting minutes;

b) schedule;

c) technical metric reports;

d) documents reporting contract status;

e) risk and issue registers;

f) advice from relevant controls and technical leads.

5.10.7.3 The following considerations should be addressed, including:

a) forecast dates in the schedule agree with the information derived from earned value management reports;

b) explanations provided by the control account managers agree with the latest understanding of problem areas;

c) corrective actions proposed are assessed as adequate to address the problem;

d) consistent negative trends have been explained adequately;

e) schedule and cost forecasts are reflective of the trends;

f) known problems that have not been identified in the performance indices;

g) known adverse impacts to milestones that have not been identified in the data.

5.11 Step 10: Take management action

5.11.1 General

Management action can occur at any of the levels of responsibility and accountability defined by the organizational, project or programme governance or contract terms.

Management action should be auditable, traceable and involve future project or programme activities.

Taking management action can occur at different levels of responsibility within the established managerial boundaries according to the escalation procedures and processes within the governance, project or programme management plan or contract terms and conditions.

5.11.2 Types of management actions

5.11.2.1 Management action for projects or programmes fall into two categories:

a) re-planning and changing the performance measurement baseline;

b) re-planning the future without changing the performance measurement baseline.

5.11.2.2 The decision to change the baseline should result from the project or programme management team and relevant stakeholders recognizing that the current performance management baseline no longer portrays a feasible future. The change can be done for the following reasons:

a) significant overperformance to date that creates a need to review for risks;

b) severe underperformance to date that makes it impossible to recover from negative variances and to meet the performance measurement baseline targets;

c) risk treatment actions no longer achieve the residual risk position, and new or revised risk treatment actions are needed;

d) changes have been approved and planning documents should be updated per the approved changes.

The changed performance measurement baseline should be able to be used to demonstrate the ability to achieve the deliverables or outcomes and benefits stated in the planning documents.

Changing the planning documents without changing the baseline occurs when presented with observed actual past variance or a projected potential future variance. The objective is to set outcome back to the baseline in a relatively short-term period. This action often takes the form of developing a recovery or adjustment plan that differs from the baseline in the short-term, but in the longer-term the project or programme manager maintains the baseline plan as the planned way to continue performing the project or programme work.

The actions described in the prior paragraph should only be undertaken if the organizational, project or programme governance, or terms and conditions of the contract allow for such actions.

5.11.3 Decision-making

Earned value performance analysis should produce information and data for the management team to make decisions. An understanding of potential risk and uncertainty can be included to allow the management team to make risk-based decisions.

This decision process should provide an understanding of how the integrated elements of the project or programme are performing. This information can support a diagnosis of the root causes and, information to develop potential management actions and assess the impacts of those actions. Situational awareness can also be an important factor in decision-making. Various environmental factors both internal and external can be integrated into the decision-making of the management team, such as changes in commodity markets, transportation costs and re-organization.

EXAMPLE A project or programme is significantly behind schedule but shows considerable cost savings. The management team note that human resources effort is driving performance: a group of programmers is delivering a software development work package. From past experience, the observed performance can result from an under-resourced project or programme plan. In this case, savings from cuts in quality control activities, such as code reviews have generated rework. The programmers are running out of time, and the future schedule performance index needed to complete on time is high. Adding extra new resources cannot be effective, whereas extending the schedule combined with continued allocation of the existing resources can prove an effective decision.

5.11.4 Lessons learned

The use of earned value management can enhance the development and use of lessons learned for the following reasons:

a) it widens the range and in-depth visibility of project or programme performance;

b) it provides for the diagnosis of causes of performance with greater objectivity and traceability; and

c) it provides for the development of objective and quantified “what-if” analysis models regarding the project or programme future.

The rigor, the objectivity, the traceability and the wide range of scenario analysis provided by the use of earned value management can provide the material for a useful lessons learned process.

5.12 Step 11: Maintain the baseline

5.12.1 General

Maintain the baseline is the process by which recognition of changes to the baseline plan due to scope changes, resource constraints or reallocation is accomplished (see 5.12[6]). This process should be aligned with the earned value management system to define applicable conditions for changing the baseline. This process should be done to protect the integrity of the scope, the schedule and the cost. The process for maintaining the baseline should document and mange changes to the baseline documents from the original baseline through previously approved changes. This step should be accomplished through the process of identifying the controlling authority with the application of thresholds or duties for the change of the baseline.

Four guidelines should be followed for the introduction of approved changes; any change not approved is a forecast until approved, unless superseded by events, such as change in scope to which the change can apply, or the change needed is different than what is forecasted. The guidelines that should be followed are:

a) approved changes on scope of work, schedule or budget;

b) changes should be documented and traceable;

c) risk budget transferred out of management reserve should be equal to that transferred into the baseline to cover risk treatment actions;

d) retroactive changes to baseline schedule, cost or scope should not be made, but documented in regard to the variance.

NOTE Changes to the baseline can occur due to risk changing, being realized, or no longer being considered a risk. In this case, approved risk treatment actions can be transferred into or out of the baseline. This baseline change should be aligned with the risk management system to protect the integrity of the management reserve.

5.12.2 Context

When there are internal and external changes that occur, the maintenance of the baseline should be accomplished through the respective category of the change. Maintaining the baseline should be based upon establishing a process involving:

a) identification of potential change;

b) documentation of the potential change;

c) evaluation of the potential change;

d) approval of the potential change;

e) incorporation of the approved change order.

5.12.3 Baseline plan

The baseline of the plan should be established through review and approval processes (see 5.12[6]). Once the baseline is approved, it should be considered as a controlled plan, thus the baseline can only be changed through approved change orders. The performance measurement baseline should be the original baseline plus approved changes.

5.12.4 Change order process for maintenance of baseline

5.12.4.1 General

The maintenance of the baseline should have a process flow, as shown in Figure 3.

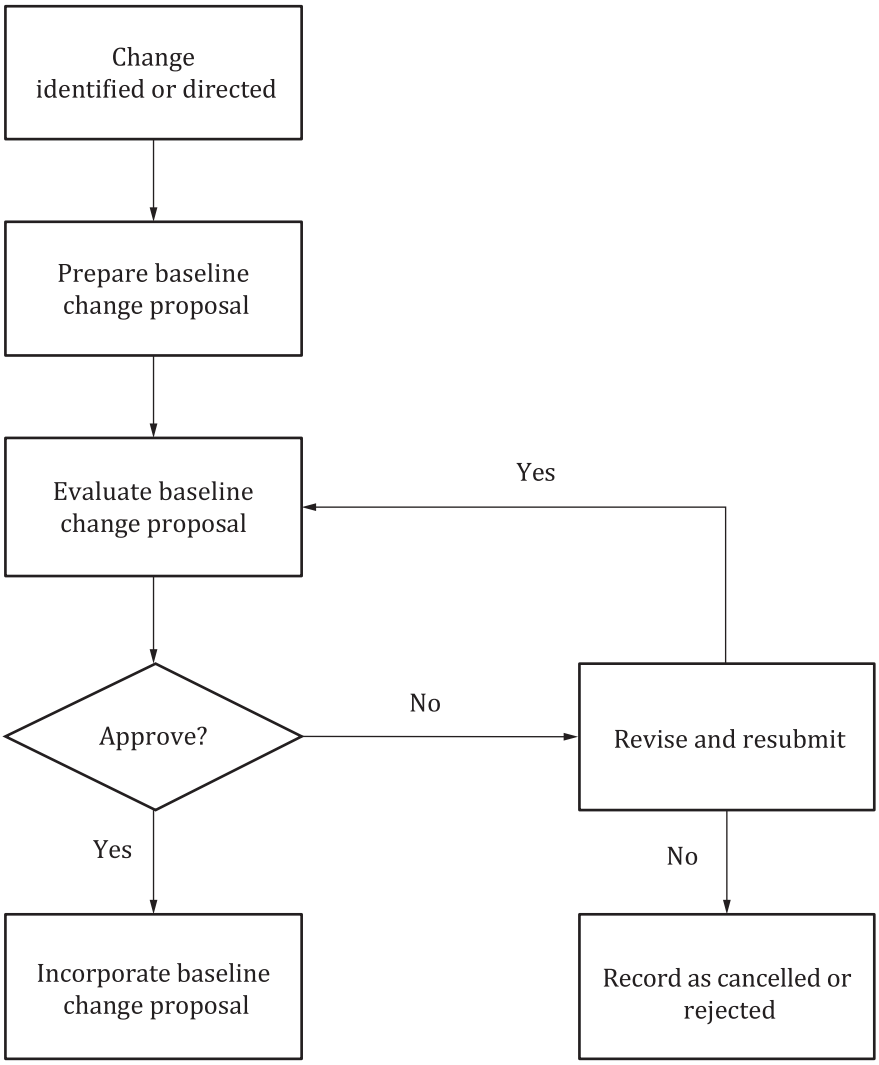


Figure 3 — Process flow for maintenance the baseline

5.12.4.2 Change identification

A potential change can be identified by any project or programme team member, but the change should only be placed before the decision-makers for determination to enter the change control process by the following roles: the project or programme management team or manager, project or programme steering committee, sponsor, or customer.

5.12.4.3 Documentation

Documentation for change control, including presentations or other communication supporting the potential change, should be produced using the governance procedures and processes for project and programme management. The documentation should be reviewed for scope, schedule, cost and risk changes. The information should then be recorded in the baseline change proposal.

5.12.4.4 Evaluation

The baseline change proposal should be reviewed by the project or programme management team for approval by the responsible manager, per the planning documentation or as stated in the governance documents. Proposals should be evaluated in reference to the remaining budget, schedule, scope and identified remaining risk, as well as any pending preventive or correction actions that are awaiting implementation. Once this portion of the evaluation is accomplished, evaluation analysis by the customer and sponsor should be reviewed and a plan to implement any approved change should be developed.

5.12.4.5 Approval

The baseline change proposal should be approved or rejected by the project or programme manager, change control board or other person, or organizational structure identified for that purpose in the governance documentation or contract. Approvals should be logged and submitted by the management team for incorporation in the baseline.

5.12.4.6 Rejected baseline change proposals

Depending upon the governance procedures and processes, rejected baseline change proposals can be reviewed, potentially revised and resubmitted for the process. Cancelled baseline change proposals should be recorded in the project log.

5.12.4.7 Incorporation

Approved baseline change orders should be incorporated into the baseline in the period for which the change was approved. If the approval has retroactive scope, schedule or budget, it should be incorporated into the current period and the variance explained, no changes to the project or programme to date can be acceptable.

6 Implementation of earned value management system reviews

6.1 Overview

Once an earned value management system has been established, the system should be reviewed. This review should establish whether or not the earned value management system is being operated properly and complies with recognised standards. The customer can request these reviews or in some instances, organizations can operate an internal review process against the recognised standards.

Reviews of an earned value management system can assist with the confirmation that the project or programme management processes for managing scope, schedule, cost, risk, change and reporting are in place. The review can also confirm the team and structure to manage delivery in a controlled manner.

The benefits of conducting a review of the earned value management system can include:

a) confirming that an integrated project management system exists;

b) indicating when specific gates or phases are to be completed;

c) supporting verification and validation of data, preventing decisions being made using unsound data through reviews that are pre-planned checkpoints;

d) helping to reduce project implementation risks;

e) supporting and encouraging the use of historic experience and data from previous projects or programmes, where appropriate;

f) supporting the implementation of earned value.

Earned value management system reviews take one of three forms: integrated baseline review, demonstration review or surveillance review. Of these review forms, the integrated baseline review can take the most time and effort to organise, conduct and report the findings (see Annex B).

Demonstration and surveillance reviews should be conducted by organizations using earned value management. Such reviews should serve to validate systems and to provide information to the project and programme management teams for system improvements. Integrated baseline reviews appear in Annex B. These reviews are commonly conducted by governmental organizations as part of their due diligence in regard to governmental funding.

6.2 Demonstration review

Once a new project or programme management system or earned value management system has been implemented, a demonstration review can be held. This review differs from an integrated baseline review in that the demonstration review focusses on the earned value management system to validate the system.[6] The earned value management system should be checked for compliance against the earned value criteria. An integrated baseline review can consider only one reporting cycle. A demonstration review should be held after sufficient periodic reports have been reviewed and issued to provide trends and forecasts for managerial analysis and corrective actions.[6] The demonstration review should also be able to draw upon a larger amount of data relating to management of risks and treatment strategies actions.

The same process used for conducting an integrated baseline review can be used. The demonstration review report should be written in much the same way as an integrated baseline review report and should be based on the following guideline groups:

a) organization;

b) planning, scheduling and budgeting;

c) risk;

d) accounting;

e) analysis and management reports;

f) revisions and data maintenance;

g) team behaviours;

h) senior management support.

The demonstration review should assess the earned value management system against the earned value management governance, standards or guidelines, as specified by the organization or contract. Particular attention should be paid to scheduling interviews with other senior managers or heads of functions, including commercial, legal and financial. These actions should help in understanding how the earned value management system integrates with and supports other functions within the organization.

6.3 Surveillance review

6.3.1 In order to confirm that an earned value management system governance, standards or guidelines are being maintained, periodic surveillance should be conducted throughout the remaining duration.

There is the possibility that the project or programme organization has changed considerably since the last baseline review, as to the following:

a) contract clauses;

b) governance and working practices;

c) software and office locations;

d) legislation, including health, safety and environment;

e) supply chains, including company acquisitions, mergers and demergers.

6.3.2 Surveillance reviews should provide that the earned value management system:

a) provides timely and reliable cost, schedule and technical performance information directly summarised internal management system;

b) complies with the earned value management governance, guidelines or standards employed in the project or programme plan or contract;

c) provides timely indications of risks or issues that can affect project delivery;

d) maintains baseline integrity;

e) provides accurate and timely information on performance trends and forecasts;

f) provides comprehensive variance analysis at the relevant level, including proposed and chosen corrective actions and how the corrective actions can affect scope, schedule, cost, risk, change control and overall performance reporting.

7 Cost and schedule performance measurement analysis using earned value management data

7.1 Overview

The project or programme management team should evaluate variances and metrics at each work breakdown structure level: work breakdown structure element, control account and work package. See Table 6 for an example of a hierarchical work breakdown structure defining a system with two electronic sub-systems. Each sub-system comprises hardware and software components to be developed, integrated and tested.

Table 6 — Example of a WBS integrated with EVM level and BAC values

WBS level	WBS number	EVM level	WBS item	BAC
1	1	WBS	System	$ 52 500
2	1.1	CA	Electronic component 1	$ 12 250
3	1.1.1	WP	Hardware 1 development	$ 3 000
3	1.1.2	WP	Software 1 development	$ 3 750
3	1.1.3	WP	Integration and test 1	$ 5 500
2	1.2	CA	Electronic component 2	$ 14 000
3	1.2.1	WP	Hardware 2 development	$ 4 000
3	1.2.2	WP	Software 2 development	$ 4 000
3	1.2.3	WP	Integration and test 2	$ 6 000
2	1.3	CA	Program management	$ 5 250
2	1.4	CA	Systems engineering	$ 10 500
2	1.5	CA	Integration and test	$ 10 500

Cumulative and current month or established period of review variances should be collected at the work package or lowest level. Control account and work breakdown structure values should be calculated by summing the lower-level values.

Reviewing and analysing earned value management measures and metrics at every level of the work breakdown structure should allow the management team to understand how each part of the project or programme is performing. This insight should help the team identify problem areas and implement preventive and corrective actions at the level where the issues exist to keep the project or programme on cost and schedule.

7.2 Performance measurement indicators and predictors

Performance measurement analysis should begin with understanding the earned value management measures and metrics. Table 7 summarizes the earned value cost performance indicators, predictors and associated benefits.

Table 7 — Purpose and benefit of earned value management metrics

Key indicator	Benefit of earned value management metric
Cost variance	The benefit of this measure should include enabling understanding of the cost performance relative to the progress achieved as measured by earned value and the actual costs incurred to the status date. The cost variance should be calculated using the earned value unit of measure such as money or labour hours. A negative cost variance indicates that the project or programme is over budget or underperforming. A positive cost variance can indicate that the project or programme is under budget and exceeding the cost performance planned or overperforming.
Schedule variance	The benefit of this measure should include understanding where the project or programme is relative to the time-phased budget. The schedule variances should also be calculated using the earned value unit of measure, such as of money or labour hours. A negative schedule variance can indicate that the project or programme is not achieving progress as measured by earned value at the rate planned or underperforming, which can indicate that the project is behind schedule. A positive schedule variance should indicate the project or programme is achieving progress as measured by earned value more rapidly than planned or overperforming, which can indicate the project or programme is ahead of schedule.
Cost performance index	The cost performance index should also enable understanding of cost performance relative to the progress achieved as measured by earned value. The index can provide an early warning into whether a project or programme is on track, over or under budget relative to the progress achieved. An important use of this index can be as a performance factor in the independent estimate at completion prediction calculation. The following scenarios describe the assessment of the cost performance index: a) equal to one, indicates that to date, cost performance is progressing as planned; b) less than one, indicates that to date, progress is being achieved at a greater cost than planned, which implies the project or programme has a cost overrun; c) greater than one, indicates that to date progress is being achieved at less cost than planned which implies the project is under budget. Cost performance index can also be used to evaluate trends and as performance factor for calculating independent estimates at completion.
Schedule performance index	The schedule performance index should also provide early warning into whether the progress is on track, ahead of or behind the planned spend profile. The following scenarios describe the assessment of performance from the schedule performance index: a) equal to one indicates that to date, the schedule performance is progressing as planned; b) less than one indicates that to date, the project's progress achieved is behind the time-phased plan, which can indicate a schedule slip; c) greater than one indicates that to date, the project or programme progress achieved is ahead of the time-phased plan, which can indicate the project or programme is ahead of schedule. Schedule performance index can also be used to evaluate trends and as performance factor for calculating independent estimates at completion.
Variance at completion	Variance at completion is the delta between the budget at completion and the estimate at completion. If this variance is negative, the project or programme is over budget. If the variance is positive, the project or programme is under budget. A benefit of this measure can be quantifying the difference between the budget at completion and the project or programme manager's estimate at completion. Another benefit can be providing an alert that the feasibility and affordability of completion should be investigated.
To complete cost performance index	The to complete cost performance index measures the expected cost efficiency needed to meet the approved budget at completion or the estimate at completion. The benefit of this metric can be to allow the assessment of the feasibility of achieving either the budget at completion or the estimated cost at completion. If the expected efficiency is determined to be significantly different from the historical efficiency achieved, the project or programme management team should re-evaluate critical assumptions and risks, as well as consider updating the planning documentation.
Independent estimate at completion	The independent estimate at completion should use the historical cost, schedule or a combination to determine the performance efficiency achieved to date to calculate estimated completion costs. These estimates can be used to check the feasibility of achieving the bottoms-up ETC and EAC.
NOTE ISO 21508:2018, Table A.1 provides further information on these key indicators and predictors, including abbreviations and formulae used to calculate them.	

The cost and schedule variances and indices should result from the earned value process. Project and programme managers should expect variances throughout the lifecycle and should use the variances to

understand project and programme status, opportunities and identify problem areas needing further attention.

The benefit of earned value management metrics should be achieved by analysing the areas with the largest variances to understand the root cause of the problem and develop corrective and preventive actions (see 7.4).

The four potential scenarios are:

a) negative cost and negative schedule variance;

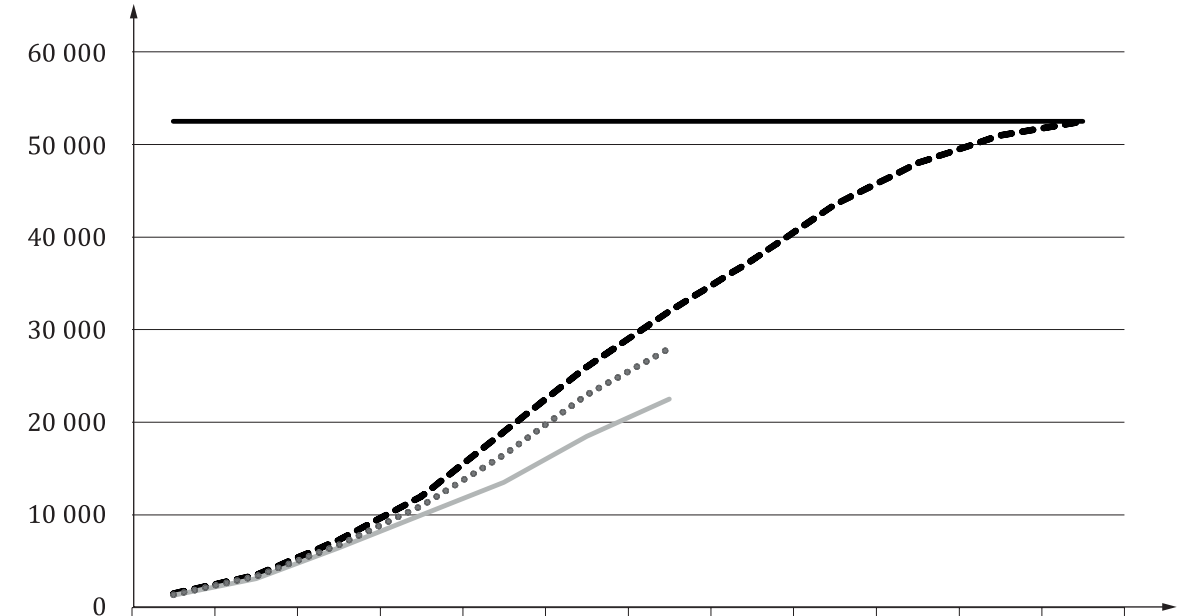
b) negative cost and positive schedule variance;

c) positive cost and negative schedule variance;

d) positive cost and positive schedule variance.

However, one should recognize that these calculations and associated analysis should also occur using the current monthly data and at all levels of the work breakdown structure.

7.3 Cost and schedule performance measurement scenarios



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BAC	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500
PV	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	48 000	51 000	52 500
EV	1 300	3 100	6 400	10 000	13 500	18 500	22 500					
AC	1 400	3 400	6 800	11 000	16 500	23 000	28 000					

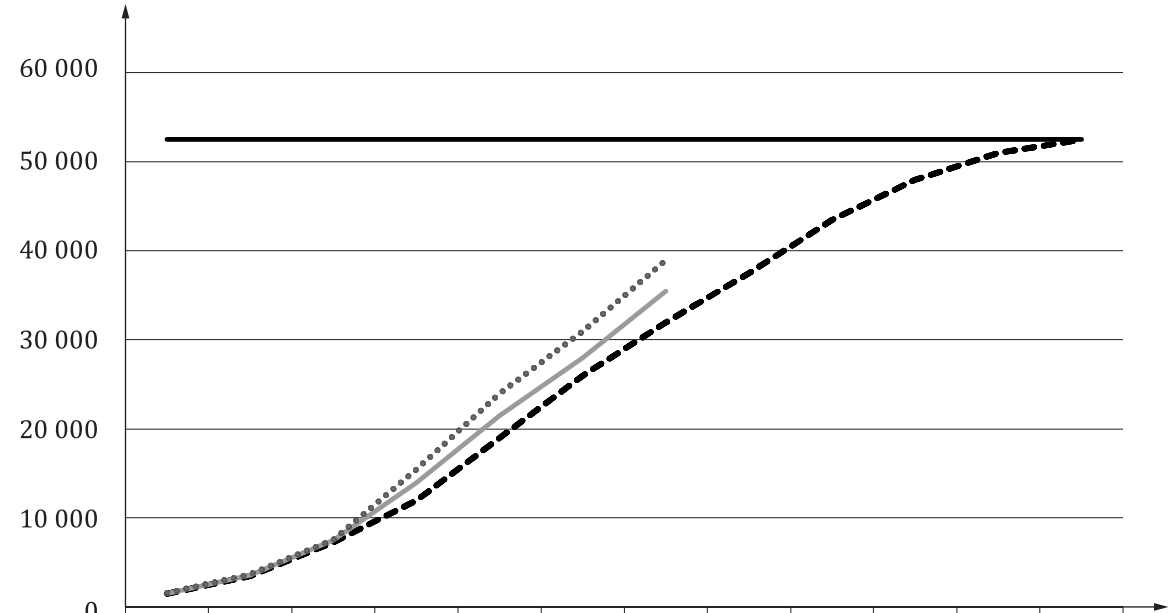
Figure 4 — Example of a negative cost and schedule variance

Figure 4 shows an example where both the cost and the schedule variances are negative:

a) cost variance is indicated by the distance between the actual cost line and the earned value line;

b) schedule variance is indicated by the distance between the planned value line and the earned value line.

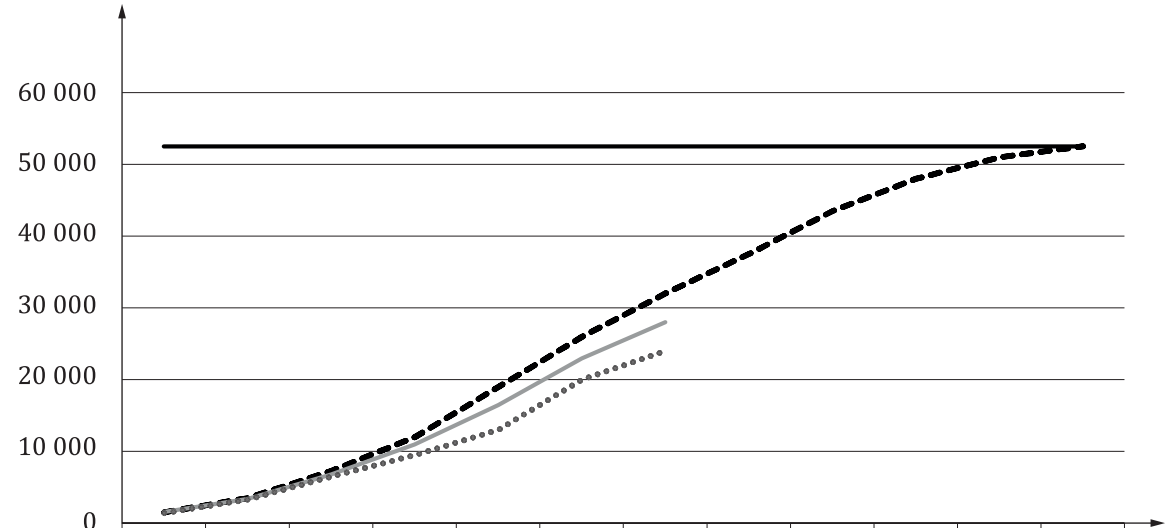
The cumulative cost variance is calculated to be –8 000, and the cumulative schedule variance is calculated to be –4 000, which means that the project or programme is spending more and taking longer to accomplish the work than planned. Therefore, when the data reflects a negative variance, the respective index is less than one: CPI is 0,778, and SPI is 0,875.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BAC	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500
PV	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	48 000	51 000	52 500
EV	1 500	3 550	7 500	14 000	21 500	28 000	35 500					
AC	1 600	3 700	7 600	15 500	24 000	31 000	39 000					

Figure 5 — Example of a negative cost and positive schedule variance

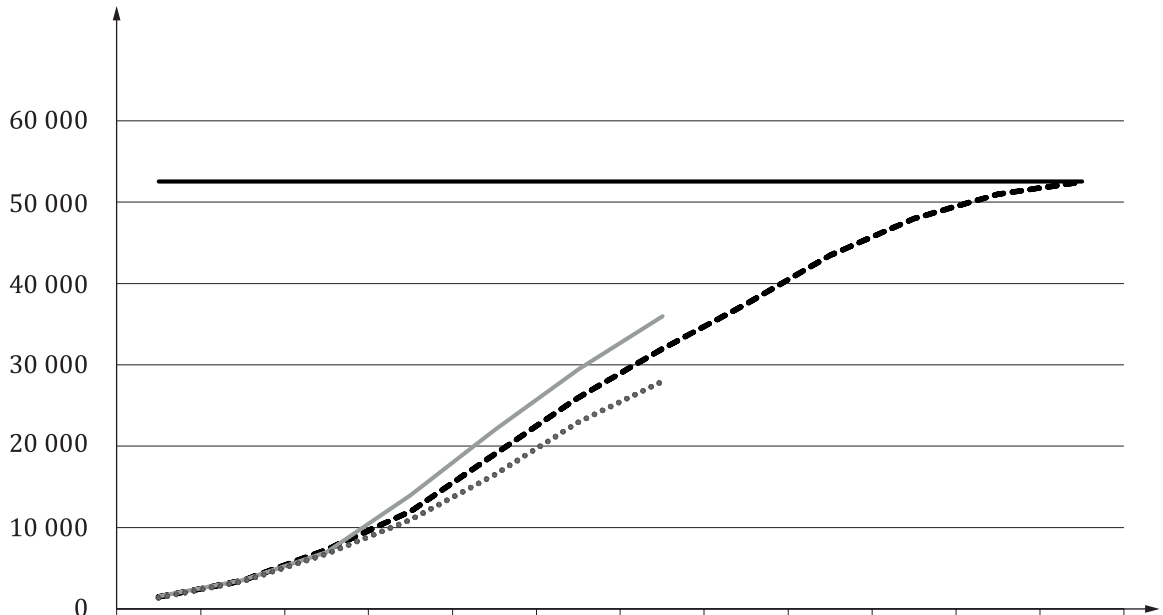
Figure 5 shows an example where the cost variance is negative and the schedule variance is positive. The schedule variance is indicated by the distance between the planned value line and the earned value line. The cumulative cost variance is calculated to be –3 500, and the cumulative schedule variance is calculated to be +3 500. These variances demonstrate that the project or programme is spending more to accomplish the work than planned and completing the work faster than planned. When the data reflects a negative variance, the respective index is less than one: CPI is 0,778. Conversely, when the variance is positive, the respective index is greater than one: SPI is 1,109.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BAC	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500
PV	1 550	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	48 000	51 000	52 500
EV	1 400	3 400	6 800	11 000	16 500	23 000	28 000					
AC	1 400	3 400	6 500	9 500	13 000	20 000	24 000					

Figure 6 — Example of a positive cost and negative schedule variance

Figure 6 shows an example where the cost variance is positive and the schedule variance is negative. The cumulative cost variance is calculated to be +4 000, and the cumulative schedule variance is calculated to be −4 000, which means that the project or programme is spending less to accomplish the work than was planned and is completing the work more slowly than was intended. Notice when the cost variance is positive, the cost performance index is greater than one: CPI is 1,167, and when the schedule variance is negative, the schedule performance index is less than one: SPI is 0,875.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BAC	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500
PV	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	48 000	51 000	52 500
EV	1 550	3 600	7 000	14 000	22 000	29 500	36 000					
AC	1 400	3 400	6 800	11 000	16 500	23 000	28 000					

Figure 7 — Example of a positive cost and schedule variance

Figure 7 shows an example where the cost variance and schedule variance is positive. The cumulative cost variance is calculated to be +8 000, and the cumulative schedule variance is calculated to be +4 000, which means that the project or programme is spending less to accomplish the work than planned and is performing the work faster than planned. When the data reflects a positive cost variance, the cost performance index is greater than one: CPI is 1,286, and the schedule variance is positive, the schedule performance index is greater than one: SPI is 1,125.

7.4 Benefits of performance measurement analysis

7.4.1 General

Earned value management should provide a structured framework for planning and implementation. Earned value management should provide data to support the project and programme team's decision-making process. One of the primary benefits of earned value management should be using the measures and metrics to develop actionable updates to the technical plan.

This benefit of earned value should come from the use of accurate data. Therefore, periodically conducting a data quality review should help provide that each month's variances are an accurate reflection of status. Data quality checks can include:

a) the work breakdown structure elements, the integrated master schedule, and the cost report allowing earned value measures to be calculated at all work breakdown structure levels;

b) the sum of all work package budgets plus planning package budgets within control accounts, which equals the budgets authorized for those control accounts;

c) the sum of the planned values of control accounts, which equals the budget at completion;

d) the sum of all control accounts' earned value and actual cost, which equals the cumulative value of earned value and actual cost at the top level of the work breakdown structure;

e) changes to the budget at completion or estimate at completion from the prior report, explained.

7.4.2 Variance analysis

Variances, both small and large, can occur during the project or programme performance. Small or less significant variances should achieve balance over time and should not require immediate attention. Large or more significant variances should be an indication that management attention can be needed to minimize the impact on the project or programme.

To differentiate between small variances and large variances, projects or programmes should identify variance thresholds. Variances below the threshold should be evaluated as part of the analysis process, but these variances should not automatically invoke management attention. Variances above the threshold should initiate a root cause analysis. A preventive or corrective action or change control can result from the root cause analysis.

Thresholds to establish variances to be considered significant should be defined at the beginning and can be unique to that project or programme. However, a good practice can be to use a threshold of ±10 %.

Once the significant variances have been identified using the thresholds, the variances should be prioritized allowing the management team or project or programme management office to address the highest priority issues first.

The variance analysis process should be defined at the beginning of the project or programme and should include organizational and customer stakeholders, as well as the consideration of the various risks. Variance analysis should be done by the project or programme management team member or members responsible for the area of the issue or risk.

Once the root cause and recommended course of action have been established and approved, the team should update the planning documents. Updates to the planning documents should result in new forecast dates, updated estimates to complete, and an updated risk or issue register.

The variance analysis process should be done at every work breakdown structure level and consider both current and cumulative variances.

7.4.3 Estimate at completion

Evaluation of the variances and respective updates to the technical plan should inform the update to the estimate at completion. The manager's estimate at completion should be developed by evaluating the earned value management performance to date and estimating the cost to complete the remaining work. To calculate the estimate to complete the remaining work, the project or programme management team should review the updated plan, assess current risks, external factors and inputs from stakeholders. Based upon this review, the project or programme manager should develop a best case, a worst case and a most likely case. The difference among these estimates should primarily be the management team's assumptions about the risk. The project or programme manager should provide an updated estimate at completion at least annually, based on internal organizational governance or at an interval that assist in project control.

EXAMPLE In addition to the PM's EAC, teams can also calculate an IEAC using the formulae described in ISO 21508:2018, Table A.1 where PF is either CPI or SPI or a combination of both.

$$IEAC = \frac{BAC}{CPI}$$

where

IEAC is the independent estimate at completion;

BAC is the budget at completion;

CPI is the cost performance index.

or, $IEAC = \frac{AC + (BAC - EV)}{PF}$

where

IEAC is the independent estimate at completion;

AC is the actual cost;

BAC is the budget at completion;

EV is the earned value;

PF planned finish date.

The calculated values of IEAC, using the data from the scenario described in Table 6 are:

— $IEAC = \frac{BAC}{CPI} = \frac{52\,500}{0{,}778} = 67\,481$

— $IEAC = AC + \frac{(BAC - EV)}{CPI} = 36\,000 + \frac{(52\,500 - 32\,000)}{0{,}778} = 62\,350$

— $IEAC = AC + \frac{(BAC - EV)}{SPI} = 36\,000 + \frac{(52\,500 - 32\,000)}{0{,}875} = 59\,429$

— $IEAC = AC + \frac{(BAC - EV)}{CPI \times SPI} = 36\,000 + \frac{(52\,500 - 32\,000)}{0{,}778 \times 0{,}875} = 66\,114$

Calculating a range of values for estimate at completion should help the project or programme manager assess the probability of achieving the objectives against the current planning documents, as well as the related cost and schedule estimates to complete.

7.4.4 Using the to complete cost performance index to assess the feasibility of the project or programme plan

The to complete cost performance index should be calculated against the latest budget at completion and estimate at completion values.

EXAMPLE Using the data from the scenario described in Table 6:

— $TCPI(BAC) = \frac{(BAC - EV)}{(BAC - AC)} = \frac{(52\,500 - 32\,000)}{(52\,500 - 36\,000)} = 1{,}242$

where

TCPI is the to complete performance index;

BAC is the budget at completion;

EV is the earned value;

AC is the actual cost.

The TCPI value indicates that in order for the programme to achieve the current BAC, the programme will have to perform with a cost efficiency of 1,242 for the remainder of the programme. Given that the cost efficiency to date is 0,778, it is improbable that the programme will achieve a cost index of 1,242. Therefore, this indicates the current BAC is incorrect, and the PM should develop a more realistic EAC.

— TCPI calculations can also be done against the IEAC, in this case, as IEAC equals to 67 481, the TCPI is:

$TCPI = \frac{(BAC - EV)}{(IEAC - AC)} = \frac{(52\,500 - 32\,000)}{(67\,481 - 36\,000)} = 0{,}651$

where

TCPI is the to complete performance index;

BAC is the budget at completion;

EV is the earned value;

IEAC is the independent estimate at completion;

AC is the actual cost;

indicating that a cost efficiency of 0,651 is necessary for the remainder of the project or programme to achieve the IEAC. Since the expected cost performance index is less than the current cost performance efficiency, the programme has a good chance of meeting the programme objectives with the IEAC of 6 7481.

7.4.5 Evaluation of trends

7.4.5.1 The earned value management metrics should provide a view of the historical cost and schedule performance for the current reporting period and cumulative performance to date. In addition, the evaluation of trend data should allow the manager, management team, or project or programme management office to evaluate the probability of achieving the contracted cost outcomes.

7.4.5.2 There can be a variety of ways to calculate trend data, as indicated by the following:

a) Cumulative moving average: The cumulative moving average trend should be calculated by adding the monthly cost variances and dividing this sum by the total number of reporting periods. See Figure 8. This measure should flatten out variances to provide an overall view of the project or programme. However, the measure can have the disadvantage of not allowing early insight into short-term changes in the status.

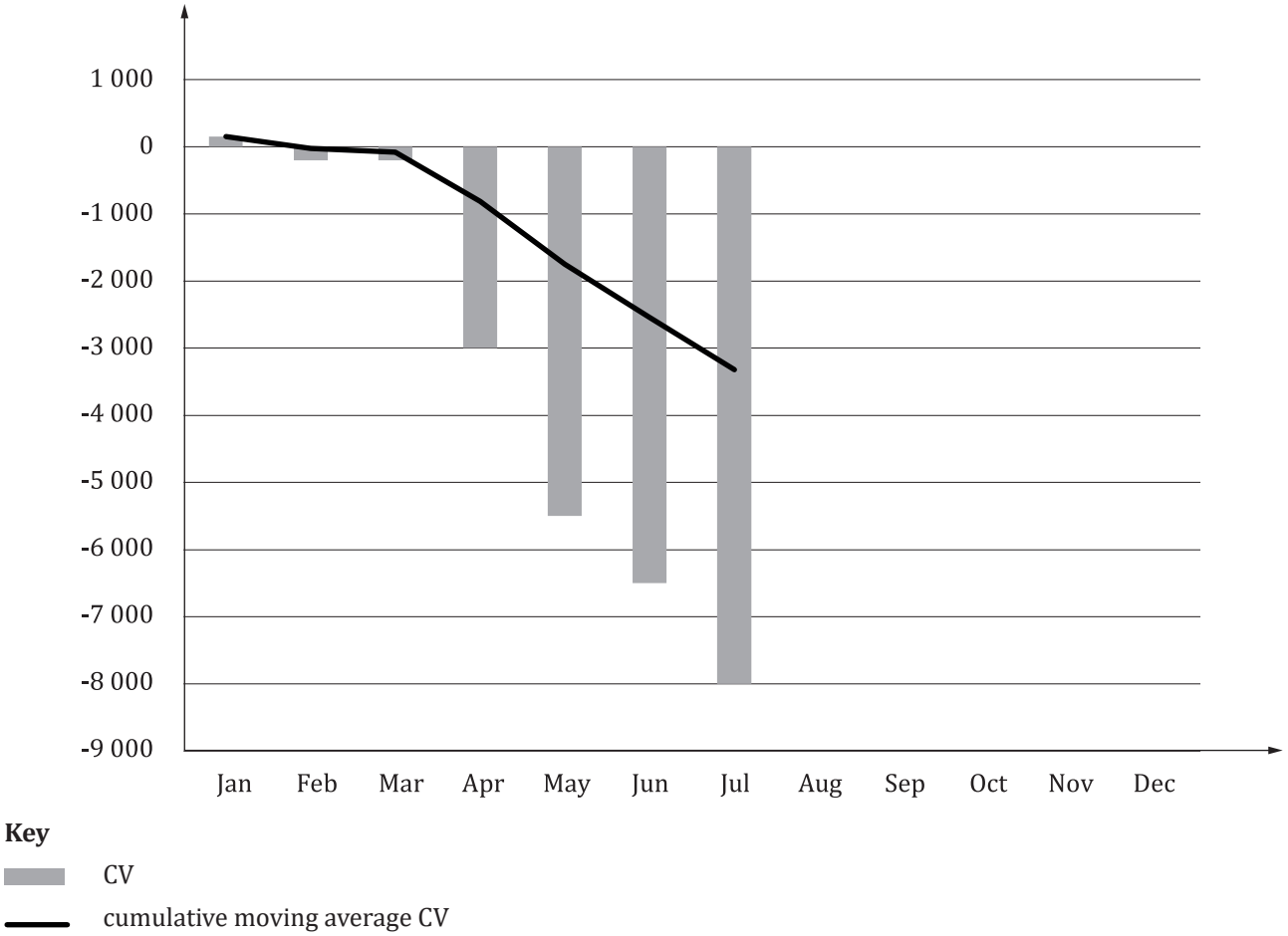


Figure 8 — Cumulative moving cost variance average

b) Sliding window moving average: The sliding window moving average should be done using a fixed historical value window and a set of selected data points to calculate a monthly average. This measure should provide early insight into emerging trends and allow the project or programme manager to understand sudden changes to the health and status, which can indicate an emerging problem. See Figure 9, using the same data as in Figure 8, one can see the three-month moving average of cost variance has a more significant downward trend than seen in Figure 8.

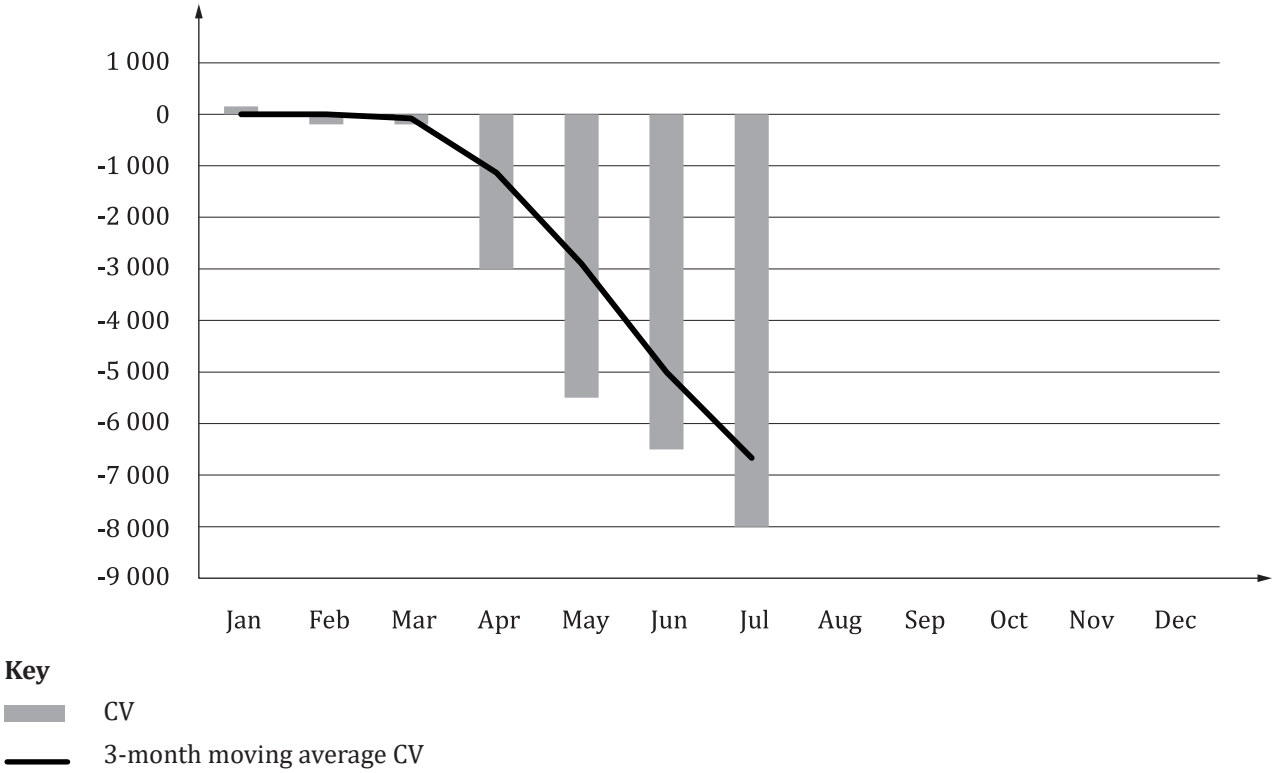


Figure 9 — Three-month moving average cumulative cost variance

7.4.5.3 In addition to trend data, the project or programme management team should conduct a comparative analysis among the earned value data, the integrated master schedule, the register of residual risks and any technical metrics. In general, the measures and metrics across these domains should be consistent. A project or programme with significant negative schedule variances can manifest as:

a) integrated master schedule with forecasted finish dates later than the original baseline dates;

b) risks not being addressed as planned;

c) technical metrics not maturing as quickly as initially planned.

7.4.5.4 The following reviews should be part of the earned value analysis:

a) changes to the performance measurement baseline. Changes to the performance measurement baseline can happen as part of the natural progressing. A constantly changing performance measurement baseline can indicate the project or programme team is struggling to resolve critical issues or has a changing functional baseline;

b) staffing report as compared to the resources needed by the technical plan to project resource overages or shortfalls;

c) lessons learned database for any applicable lessons that can be applied to the earned value analysis.

The earned value analysis should result in a management report discussing the significant variances, preventive or corrective actions, changes to the integrated master schedule, updates to the risk management plan, changes to the performance measurement baseline and updating the resource planning documentation.

8 Earned schedule implementation

8.1 Overview

Earned schedule measurements can be made throughout the lifecycle. The measurements should apply equally well to projects and programmes that are early, late or on-schedule.

For projects or programmes that are on schedule, there should be no variance in the measurements. For projects or programmes that are early or late, there should be variance in measurements of past performance and in estimates of future performance.

The variances should be able to be calculated, interpreted and communicated.

Earned schedule measurements should be collected at the lowest level of detail in the schedule. Variances can then be summed up as a whole or for parts of the schedule, such as the critical path, milestones or control accounts.

Analysis of the different parts of the schedule should help the management team identify problem areas. Where problems exist, the team can implement preventive and corrective actions to keep on schedule.

Earned schedule measurements can be used with network schedule analysis, risk analysis and root-cause analysis.

8.2 Performance measurement metrics, indicators and predictors

Implementation of earned schedule performance analysis should start with an understanding of its basic metrics, indicators and predictors (see Table 8).

Table 8 — Earned schedule measurement type, term and description

ES measurement type	Term	Description
Metrics	ES measure	The number of periods in the performance measurement baseline in which the earned value is greater than the planned value.
	AT	The number of time periods between the planned start date and the date on which the project data is reported.
	PD	Time span from the project or programme planned start to the planned finish, measured in any selected unit of accrual for earned value, such as day, week or month.
	ED	Time span from the project or programme planned start to the estimated finish, measured in any selected unit of accrual for earned value, such as day, week or month.
Indicators	SV(t)	Schedule variance (time) is the difference between the earned schedule and actual time. One benefit is that it quantifies in time units, the variance between earned schedule and actual time. A negative variance indicates the project or programme can be behind schedule. A positive variance indicates the project or programme can be ahead of schedule. A variance of zero indicates the project or program can be one time. The schedule variance (time) can be used to assess the feasibility of achieving the planned duration.
	SPI(t)	Schedule performance index (time) quantifies the schedule efficiency achieved as a ratio. The time-based efficiency at which earned value is accrued by the project or programme enables an understanding of past schedule performance and enables estimates of future outcomes. The following scenarios describe the assessment of project or programme performance from the schedule performance index (time): a) equal to one, indicates that to date, schedule performance in time-based units is progressing as planned; b) less than one, indicates that to date, schedule progress is being achieved slower than planned, which implies behind schedule; c) greater than one, indicates that to date, schedule progress is being achieved faster than planned, which implies ahead of schedule. Schedule performance index (time) can also be used to evaluate trends and as a performance factor for calculating the independent estimates at completion (time) and the independent estimate of the completion date.

Table 8 *(continued)*

ES measurement type	Term	Description
	VAC(t)	The variance at completion (time) is the difference between the planned duration and the estimated duration. If this variance is negative, the project or programme is behind schedule. If the variance is positive, the project or programme is ahead of schedule. A benefit of this measure is quantifying the difference between the planned duration and project managers estimated duration. Another benefit is providing an alert that the feasibility of achieving the planned duration can need investigation.
	ES burndown	The burndown should give insight into actual schedule performance relative to planned accomplishment. Burndown can be useful for communication within the project or programme team and with stakeholders. If earned schedule is less than the difference between planned finish and planned start, the project or programme is behind schedule. If earned schedule is greater than the difference between planned finish and planned start, the project or programme is ahead of schedule. If earned schedule equals the difference between planned finish and planned start, the project or programme is on schedule.
Predictors	TSPI	To complete schedule performance index is the ratio between the amount of duration objective achieved and the amount of duration objective that should have been achieved. Benefits of this index include its use to not only assess the future efficiency required to achieve time-based targets, but also to assess the project manager's estimated duration. The future schedule performance efficiency required to meet these targets can be compared to the efficiency achieved to date as measured by schedule performance index (time). This comparison can enable the feasibility of achieving the planned duration or estimated duration to be assessed. Additional benefits can include: a) enabling an assessment of the feasibility of recovery from poor performance to achieve the target objectives of planned duration and estimated duration; b) comparing a threshold value to invoke project or programme attention.
	IEAC(t)	The independent estimate at completion (time) uses historical schedule performance, performance factors to calculate an estimate of project or programme duration. The use of schedule performance index (time) as the performance factor assumes that future schedule performance will be comparable to schedule performance to date. Differences between the independent estimate at completion (time) and the planned duration and the project managers estimated duration can be used to assess the feasibility of achieving either outcome. Differences between the estimated and planned duration can be compared to threshold values to cause project or programme attention.
	IECD	The independent estimate at completion date equals the start date plus the estimated duration. The purpose of independent estimate of completion date is to express duration as a date rather than as a time increment. This metric can enable schedule performance impacts to be easier to understand and communicate and can also enable a direct comparison of the critical path calculated completion date.

Project and programme managers should expect variances throughout the lifecycle (see 7.2). The earned schedule indicators and predictors should be used to understand, document and communicate schedule status. Once problem areas are identified and root cause analysis performed, if determined one is needed, preventive or corrective action steps can be developed.

8.3 Earned schedule performance measurement scenarios

8.3.1 General

The following scenarios present examples of indicators and predictors shown in Table 8.

Each scenario includes reference to those specific indicators and predictors shown in Table 8. In some cases, there can be multiple indicators and predictors needed for the evaluation presented in the scenario.

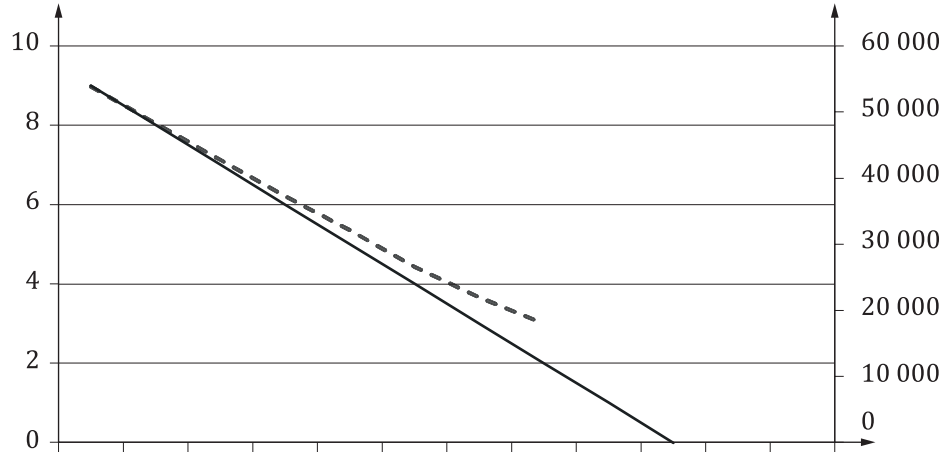
The sequence of the example scenarios follows the sequence of indicators and predictors in 8.2, except for the variance at completion time. This metric is included in the independent estimate at completion time scenario and the independent estimate of completion date used in each scenario. The scenarios also vary by start point, finish point, and whether the points occur early, on time or late. A selection of on time and late scenarios are used, but there are no early start scenarios, as earned schedule measurements can be generated only in relation to the performance measurement baseline.

8.3.2 Earned schedule burndown with on time start, late finish

The earned schedule metric can be used as an indicator. The earned schedule metric should be compared with the amount of schedule planned to be earned.

If earned schedule is less than planned duration, the project or programme is behind schedule. If earned schedule is greater than planned duration, the project or programme is ahead of schedule. If earned schedule equals planned duration, the project or programme is on schedule.

The comparison can be represented visually in a burndown chart of planned versus earned schedule, as shown in Figure 10.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Earned schedule burndown	8,975	8,05	7,132	6,213	5,357	4,429	3,667	3				
Planned burndown	9	8	7	6	5	4	3	2	1	0		
Planned value	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	52 500		
Earned value	1 550	3 400	6 800	11 000	16 500	23 000	28 000	32 000				

Figure 10 — Earned schedule burndown

In Figure 10, the vertical axis represents the total number of time periods planned for the project or programme. The horizontal axis represents the estimated duration. The estimate of completion date can be used in place of numerical periods.

The planned burndown line should represent the time in the performance measurement baseline. One period should be used for each period planned. The line should start from when the schedule is first earned and extend to the last scheduled period.

The earned burndown line should show how much time has actually been earned. It should be calculated by decrementing the total remaining time by the amount of schedule that has been earned. The line should start from the point at which schedule is first earned and extend to the last scheduled period.

If the earned burndown line is above the planned burndown line, the project or programme is behind schedule. If the earned schedule burndown line is below the planned burndown line, the project or programme is ahead of schedule.

In the example, the chart shows in August, or period 8, that the programme is behind schedule and the variance is widening. It appears likely that the finish will occur later than planned. Therefore, the estimated duration is greater than ten periods.

The earned schedule should continue to be calculated based on the performance measurement baseline, in which planned duration remains at ten. If earned value continues to increase, the earned schedule ultimately reaches ten, but only does so once the period exceeds ten. A negative schedule variance (time) should indicate the project or programme is behind schedule.

The results of the implementation of earned schedule calculations and analysis should further aid in the decision-making process. The results of calculation and analysis should be applied to decision-making.

The content, media and timing of communication for the purpose of decision-making should be in a communication plan. The project or programme manager should be responsible for the formulation of the plan, and the management team should be responsible for approving it.

The plan should identify the types of communication, such as Figure 10, and measurements that should be used to assess their effectiveness as described or stated in the organizational governance documents for projects or programmes. Communications should express schedule performance in units meaningful to decision-makers.

The burndown chart should be used to visually communicate to the management team and stakeholders that the project or programme is or is not on schedule.

8.3.3 Schedule variance (time) with on time start, early finish

Schedule variance (time) is the difference between the earned schedule and the actual time. Schedule variance (time) quantifies the variance between earned schedule and actual time.

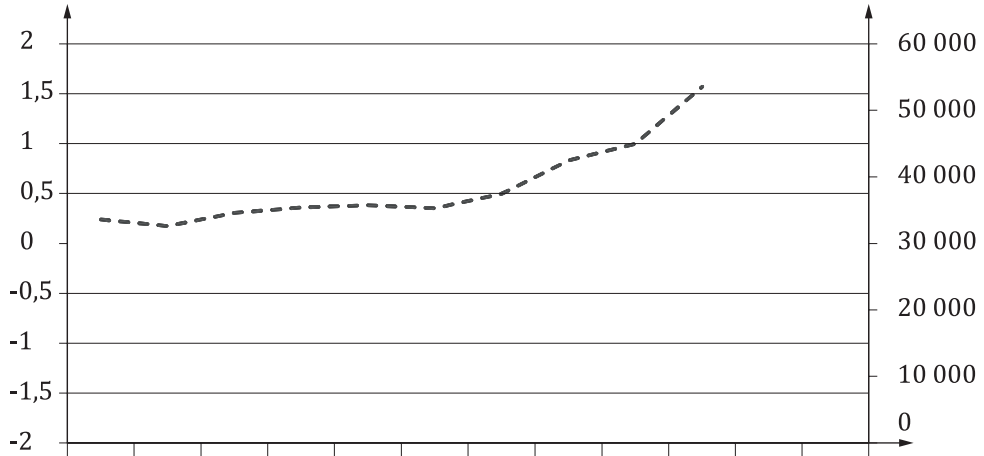
Schedule variance (time) that is negative should indicate the project or programme is behind schedule. Positive variance should indicate the project or programme is ahead of schedule.

The amount of schedule variance (time) can be compared with a threshold value, which should enable the management team to understand how efficiently the schedule is performing (see 8.4).

The schedule variance (time) should be accurate across a lifecycle. If a project or programme finishes ahead of schedule, the schedule variance (time) ends above the nominal value of 0,0. If a project or programme finishes behind schedule, the schedule variance (time) ends below the nominal value 0,0. The amount of the schedule variance (time) should indicate the number of periods or partial periods the project or programme is ahead or behind schedule.

Finally, as a numerical measurement, the schedule variance (time) should provide a structured framework for planning and a data point for detailed problem identification and analysis.

Schedule variance (time) can be represented visually in a chart, as shown in Figure 11.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Schedule variance (time)	0,243	0,176	0,31	0,364	0,385	0,355	0,5	0,833	1	1,571		
Nominal	0	0	0	0	0	0	0	0	0	0	0	0
Planned value	1 550	3 400	6 800	11 000	16 500	23 000	28 000	35 000	41 000	46 000	49 000	52 500
Earned value	2 000	4 000	8 100	13 000	19 000	24 775	31 500	40 000	46 000	51 000		

Figure 11 — Schedule variance (time)

The vertical axis represents the schedule variance. It starts at 0 and increases to the highest observed positive value, if any. At the same time, it decreases to the lowest observed negative value, if any. The horizontal axis, which is usually set at the estimated duration, can be set at the planned duration to maintain the visibility of the original timeline. The estimate at completion date can be used in place of numerical periods.

The nominal value should be represented as a straight line at a value of 0. The line should extend from the first period to the last period. The schedule variance (time) should be represented as a series of values between the highest and lowest values. The schedule variance (time) line should extend from the first period in which value is earned to the actual time.

In Figure 11, the project starts on time and at a higher level of efficiency than planned. The efficiency continues to improve as the project proceeds. The improvement can be assessed against thresholds to determine if variance analysis and management attention are needed.

Halfway through the planned duration, efficiency continues to improve. This trend should be analysed (see 8.5).

With schedule variance at time equal to 1,571 and actual time at ten or October, the decision to shorten the schedule can be made following discussions with the performing organizations, the project or programme management team along with a review of any relevant past projects or programmes. In the example, if one period is removed, the estimated duration equals 11, which is not shown.

The earned schedule should continue to be calculated based on the performance measurement baseline, in which planned duration is 12. Assuming value is earned at the same rate, earned schedule is 12 at one period before the planned finish, which is not shown, and the schedule variance at time finishes at 1,0, which is not shown, indicating that the project finished one period ahead of schedule.

The schedule variance (time) should allow the quantification of schedule performance efficiency throughout a project or programme lifecycle. It should inform detailed analysis and decision-making within a structured framework.

8.3.4 Schedule performance index (time) with late start, late finish

The schedule performance index (time) should indicate whether or not time is being used according to plan and how well or poorly time is being used.

If time is being used according to plan, the schedule performance index (time) should be at a nominal level of 1,0. If the project or programme is behind schedule, the schedule performance index (time) should be below 1,0. If the project or programme is ahead of schedule, the schedule performance index (time) should be above 1,0.

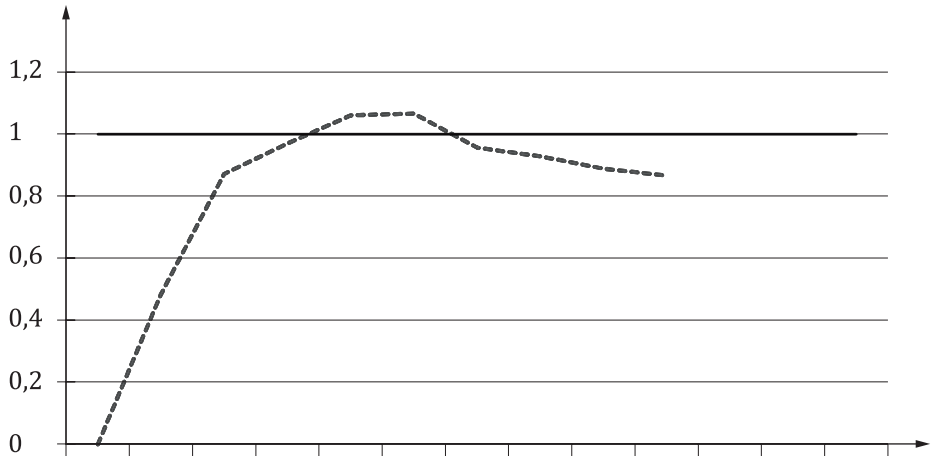
To assess schedule performance against time, the schedule performance index (time) can be compared with a threshold value. Threshold values can be located in a governance document, plan or contract. Variance can be used to understand how efficiently the schedule is performing (8.4).

The schedule performance index (time) is a ratio. One of the benefits of its use should be that it applies to projects or programmes of varying size. For the same reason, it should apply when diverse project or programme management approaches are used. The schedule performance index (time) should be accurate across a lifecycle.

If a project or programme finishes behind schedule, the schedule performance index (time) ends below 1,0, rather than at 1,0. If a project or programme finishes ahead of schedule, the schedule performance index (time) ends above the nominal value of 1,0.

Finally, the schedule performance index (time) should be used to quantify schedule efficiency. Numerical measurements should provide a structured framework for planning and data for detailed problem identification and analysis.

The schedule performance index (time) can be represented visually in a chart (see Figure 12).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Schedule performance index (time)	0	0,484	0,873	0,97	1,062	1,067	0,957	0,929	0,889	0,867			
Nominal	1	1	1	1	1	1	1	1	1	1	1	1	1
Planned value	1 500	3 400	6 800	11 000	16 500	23 000	28 000	35 000	41 000	46 000	49 000	52 500	52 500
Earned value	0	1 500	5 500	10 500	18 500	25 000	26 500	31 000	35 000	39 000			

Figure 12 — Schedule performance index (time)

The vertical axis represents the index value. It starts at 0 and increases to the maximum observed value. The horizontal axis represents the estimated duration. The estimate of completion date can be used in place of numerical periods.

The nominal value is represented as a straight line at a value of 1,0. The line extends from the first period to the last period. Schedule performance index (time) is represented as a series of values between 0 and the maximum value. The line for schedule performance index (time) should extend from the first period in which value is earned to the actual time.

In Figure 12, the project experienced a late start. Earned schedule calculations should account for the deviation. The earned schedule is 0 for period 1, or January, and as a result, schedule performance index (time) is 0 for that period.

In spite of a slow start, the schedule efficiency improves rapidly. Within three periods, the schedule recovers to the nominal value and continues to improve. Mid-way through the project, however, efficiency begins to decline, eventually dropping below the nominal level.

Schedule performance index (time) is 0,867 for period 10. The planned duration is at risk. A decision can be taken to add a period (see 8.4).

In Figure 12, if one period is added, the estimated duration is 13, which is not shown. However, the earned schedule continues to be calculated based on the performance measurement baseline, in which planned duration is 12. Assuming value is earned at a similar rate, schedule performance index (time) is 0,923 at one period after the planned finish, which is not shown.

Measures of schedule efficiency express how well the quantity of value delivery matches the planned quantity. Measures of schedule adherence express how well the planned sequence of deliverables is being followed.

Schedule efficiency can be above, below or on plan. It is not sensitive to which deliverables are completed, as long as they meet the planned quantity. By contrast, schedule adherence is either on plan or off plan. Schedule adherence is sensitive to the sequence in which deliverables are completed.

Earned schedule should measure schedule efficiency with indicators such as schedule performance index (time). Earned schedule should measure schedule adherence with indicators such as p-factor.

In Figure 12, the schedule performance index (time) increases rapidly. One disadvantage of the increase is that tasks can be done out of sequence. Such tasks can need rework, when more information becomes available.

The problem is indicated by the p-factor. During the first few periods of the schedule in Figure 12, the p-factor is 0,688, 0,837, 0,879. The variance from the nominal value of 1,000 indicates that rework can be incurred.

The schedule performance index (time) should quantify schedule performance efficiency throughout the lifecycle. The schedule performance index (time) supports detailed analysis and decision-making within a structured framework, and it applies equally to projects or programmes of varying size and management approach.

8.3.5 Independent estimate at completion (time) and variances with late start, on time finish

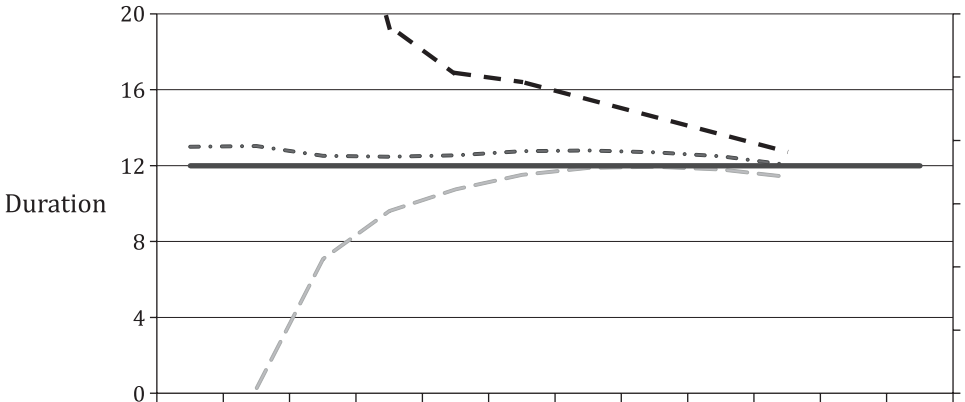
The independent estimate at completion (time) should estimate the duration that can be needed to complete the project or programme. It assumes that future schedule performance can be comparable to previous performance.

The independent estimate at completion (time) is an estimate based solely on previous performance and not on other factors. The independent estimate at completion (time) should be placed within a variance of possible values.

The high and low boundaries of the variance of possible values can be set by the manager's estimate (see 8.4.4) or by performing statistical analysis of past performance.

The independent estimate at completion (time) and variance can be used to assess the feasibility of the planned duration. Differences between the estimate and the planned duration can be compared to thresholds to cause project or programme management attention (see 8.4).

The independent estimate at completion (time) and variance can be represented visually in a chart (see Figure 13).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Variance high		1991,75	29,878	19,270	16,842	16,427	15,429	14,519	13,672	12,738		
Estimate at complete (time)	13,000	13,032	12,529	12,476	12,545	12,769	12,800	12,714	12,500	12,050		
Variance low		0,309	7,106	9,629	10,772	11,534	11,897	11,958	11,808	11,418		
Planned duration	12	12	12	12	12	12	12	12	12	12	12	12
Planned value	1 550	3 400	6 800	11 000	16 500	23 000	28 000	35 000	41 000	46 000	49 000	52 500
Earned value	0	1 500	5 000	9 000	13 500	18 000	24 000	30 000	38 000	45 750		

Figure 13 — Independent estimate at completion (time) and variances

On Figure 13, the vertical axis represents duration in time periods. It starts at 0 and increases to the planned duration, estimated duration, or variance, whichever is greatest. The horizontal axis represents the estimated duration. The estimate of completion date can be used in place of numerical periods.

The nominal value is the planned duration. It is represented as a straight line at the number of planned periods. The line extends from the first period to the last period. The independent estimate at completion (time) and variance are represented as a series of values starting at the first period in which value is earned and ending at the actual time.

In Figure 13, the project experienced a late start. Earned schedule calculations account for the deviation. The earned schedule is 0, and the independent estimate at completion (time) is 0 for period 1, January.

For period 1, January, if,

$$IEAC(t) = AT + \left(\frac{(PD - ES)}{PF} \right)$$

where

$IEAC(t)$ is the independent estimate at completion (time);

AT is the actual time;

PD is the planned duration;

ES is the earned schedule;

PF is the planned finished date.

when PF is 1,0, then $IEAC(t)$ is 13, as shown. If

$$IEAC(t) = \frac{PD}{SPI(t)}$$

where

IEAC(*t*) is the independent estimate at completion (time);

PD is the planned duration;

SPI(*t*) is the schedule performance index (time);

then SPI(t) is 0, and no value is available for IEAC(t). In both cases, the period has no statistical variance. For period 1, the IEAC(t) does not provide a sound basis for decision-making.

In Figure 14, after a late start, the increase in earned value is gradual. As a result, duration estimates improve but do so slowly. The steady convergence on the planned duration by both the independent estimate at completion (time) and variance make an on-time finish feasible.

Further evidence for this conclusion comes from the variance at completion (time). The variance at completion for time is the difference between the independent estimate at completion (time) and the planned duration. The variance at completion (time) offers a numerical representation of convergence.

In Table 9, from period 2, February, through period 4, April, the variance decreases, but mid-way through the timeline, the variance begins to increase.

Table 9 — Example of variance at completion (time)

	Month									
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**
VAC(t)	−1,00	−1,03	−0,53	−0,48	−0,55	−0,77	−0,80	−0,71	−0,50	−0,05

There is a steady rise until period 7, July. At that point, the variance decreases rapidly, ending just above zero (0). Convergence on zero (0) variance supports the conclusion that the project or programme will finish on time. The independent estimate at completion (time) and variance should enable the project or programme management team to assess the feasibility of the planned completion date. The quantitative measurements can be compared to thresholds to indicate the need for management attention.

8.3.6 To complete schedule performance index with on time start, late finish

Some earned schedule measurements, such as schedule performance index (time), are descriptive. Other earned schedule measurements, such as independent estimate at completion (time), are predictive. By contrast, to complete schedule performance index is prescriptive. It prescribes the future performance level needed to achieve the desired duration.

To complete schedule performance index is a ratio between two differences: the difference between the planned duration and the earned schedule and the difference between a total duration and the actual time.

In the context of the plan, the total duration is given by the planned duration, and the formula is:

$$Total\ \ duration = \frac{PD - ES}{PD - AT}$$

where

PD is the planned duration;

ES is the earned schedule;

AT is the actual time.

In the context of estimates, the total duration is given by the estimated duration and the formula is:

$$Total\ duration = \frac{PD - ES}{ED - AT}$$

where

PD is the planned duration;

ES is the earned schedule;

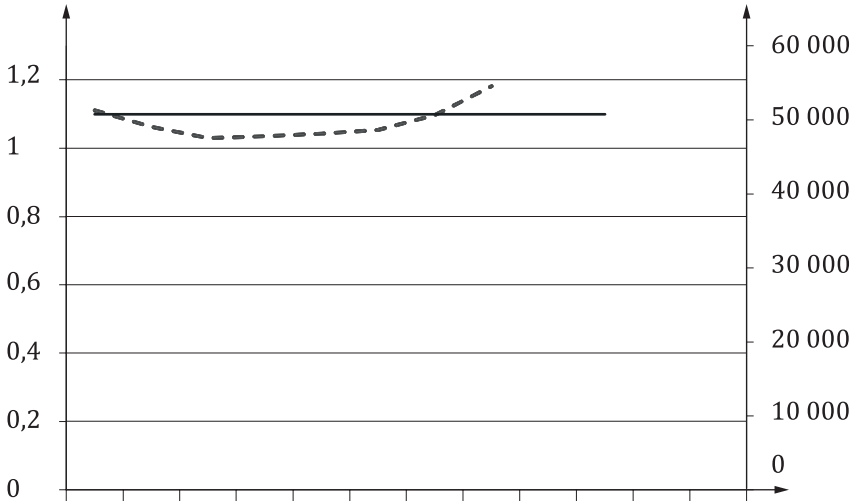
ED Is the estimated duration;

AT is the actual time.

The estimated duration can be based on analysis of past performance or on other factors. An example of the former is statistical analysis of past schedule performance (see 8.3.3). An example of the latter is the manager's estimate (see 8.4.4).

To complete schedule performance index can be used to assess the feasibility of the planned or estimated duration. For this purpose, to complete schedule performance index should be compared with a specific threshold value of 1,10. Once the threshold is breached, the duration can be regarded as unrecoverable. (see 8.4).

To complete schedule performance index can be represented in a chart, as shown in Figure 14.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
To complete schedule performance index	1,111	1,063	1,03	1,035	1,043	1,054	1,097	1,182				
Threshold	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1		
Planned value	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	52 500		
Earned value	0	2 500	6 500	11 000	17 500	24 500	30 250	35 500				

Figure 14 — To complete schedule performance index

In Figure 14, the vertical axis represents the index value. It starts at 0 and increases to the maximum observed value or to the threshold value, whichever is greater. The horizontal axis is set at the estimated duration. The estimate of completion date can be used in place of numerical periods.

The threshold is represented as a straight line at 1,10. The line extends from the first period to the last period. To complete schedule performance index is represented as a series of values between zero and the maximum value. The line for to complete schedule performance index extends from the first period in which value is earned to the actual time.

In Figure 14, the project experienced a late start. The deviation is part of the earned schedule calculations. With no earned value in period 1, January, the amount of earned schedule is zero.

If the formula for to complete schedule performance index uses planned duration, the value of the index is 1,111. The threshold is immediately breached.

If the formula for to complete schedule performance index uses estimated duration, the value of the index varies, which is not shown, depending on the type of estimate that is used.

For period 1, neither formula can provide a sound basis for decision-making because of the absence of earned value.

After period 1, the earned value increases but does not fully recover. A shortfall grows, and to complete schedule performance index climbs toward the threshold. Before reaching 1,10, individual values of to complete schedule performance index can be compared to threshold values to assess the need for management attention. The trend of to complete schedule performance index values should also be considered (see 8.5).

In period 8, August, to complete schedule performance index passes the 1,10 threshold. Project management attention should be given to the project. If the project finishes, it can be after the planned duration.

To complete schedule performance index should help the management team identify the performance level needed to achieve the desired duration. By comparing the needed level of performance to threshold values, the team can assess the need for management attention.

8.4 Benefits of schedule performance measurement analysis

8.4.1 General

The use of earned schedule can provide benefits as part of a structured framework that can be useful in the identification of problems. Related benefits include providing data for root-cause analysis, remediation planning and support for actionable responses.

These benefits can be maximized through variance analysis against thresholds, suitable organizational design and data quality assurance.

8.4.2 Variance analysis

Variances, both large and small, can occur during the performance of the project or programme. Small variances should balance out over time and do not need immediate management attention. However, significant variances indicate that management action should be taken to minimize the impact and improve performance (see Table 10).

To differentiate between small variances and large variances, the organization, management team or contract should specify variance thresholds (see 7.4.1).

Table 10 — Earned schedule measurement, practice threshold and description

Earned schedule measurement	Practice threshold	Description
Schedule variance (time)	Upper bound: +10 % Lower bound: −10 %	Schedule variance is greater than or less than 10 % or the agreed threshold from one period to the next. SV(t) is 0,355 in period 6 and SV(t) is 0,500 in period 7 for a variance of −40,8 %.
Schedule performance index (time)	Upper bound: +10 % Lower bound: −10 %	Variance in index is greater than or less than 10 % or the agreed threshold from one period to the next. Schedule performance index (time) is 1,067 in period 6 and schedule performance index (time) is 0,957 in period 7 for a variance of 10,3 %.
Independent estimate at completion (time)	Upper bound: >10 % of planned duration Lower bound: <10 % of planned duration	Estimated duration is greater than 10 % of planned duration or less than 10 % of planned duration or agreed upon threshold. Planned duration is twelve periods, and independent estimate at completion (time) is thirteen periods. The estimate is less than 13,2 and greater than 10,8. Achieving the planned duration can be feasible.
To complete schedule performance index	Upper bound: >1,10 Lower bound: <0,99	Variance in index greater than 1,10 or agreed upon threshold indicates the planned duration could be unrecoverable. To complete schedule performance index is 1,182. Once the variance exceeds 0,99, management should monitor the situation. Once the variance exceeds 1,10, the planned duration could be unrecoverable.
Earned schedule burndown rate accomplished	Planned duration	The planned duration is the threshold value. Analysis is based on the shape and orientation of any gap between the planned duration and the earned schedule.

Variances that do not breach thresholds can be evaluated as part of the response to variance, but such variances should not automatically invoke management attention.

Individual variances that breach threshold values can cause management attention. Overuse of individual threshold breaches, however, can undermine the usefulness of variance analysis. To avoid overuse, individual variances can be used in conjunction with trend analysis (see 8.5).

Once a problem has been identified, it should be prioritized. This identification should allow the management team to address the problems identified as highest priority first.

For the highest priority problems, the next steps should be root cause analysis, remediation planning and communication with the management team. If the team approves the remediation plan, it should be implemented.

NOTE The remediation action plan can also be known as the corrective action plan.

Implementation of the remediation plan should include updates to the plan, forecasts and risk register. It also should include preventive and corrective actions.

Results of preventive actions should be monitored to track whether the preventive actions have prevented the variance from recurring. Preventive actions should be entered into the lessons learned database.

Results of corrective actions should be monitored, leading to either the closure of the issue or back to the start of the process. In either case, results should be communicated to the management team.

8.4.3 Organizational design

The organizational structure that supports variance analysis should be defined and approved at the beginning of the project or programme. The structure can vary from organization to organization, but each should align with the organizational governance documentation.

The roles and responsibilities for variance analysis can be defined as:

a) project and programme managers should be responsible for enabling the variance analysis process to be defined, approved by the management team, and communicated to the team and other stakeholders;

b) project and programme managers or their delegates should be responsible for calculating earned schedule metrics, indicators and predictors;

c) project or programme management team or their delegates should be responsible for identifying variances, determining whether management attention is needed and communicating such variances to the team and other stakeholders;

d) project or programme management team should be responsible for understanding and approving the variance analysis process;

e) project or programme management team should be responsible for prioritizing problems once they are identified by variance analysis;

f) project or programme management team should approve remediation plans and enable problems to be resolved.

The variance analysis process should be performed by a member or members of the management team. Evidence of variance can occur remotely from its cause. The team member or members responsible should be from the area or areas causing variance, rather than areas where the evidence appears.

8.4.4 Data quality assurance

The benefit of variance analysis is dependent on the use of accurate data. Periodic data quality reviews should enable the variances to accurately reflect status and provide a sound basis for analysis, judgment and action.

Earned schedule measurements should be collected at the lowest level of detail in the schedule. Variances can then be summed up for the schedule as a whole or for parts of the schedule, such as the critical path, milestones or control accounts. The data should be traceable between the whole and its parts.

The cumulative planned value should be greater than 0. The effect of this action is that the start should coincide with the first occurrence of planned value. No initial periods of 0 planned value should be allowed. Therefore, no early starts in which activity occurs but no value is planned should be allowed.

The cumulative planned value cannot decrease from one period to the next. The cumulative earned value cannot decrease from one period to the next. The effect of this action should be that if a new baseline is set, calculations do not simply continue as if the old baseline is extended. Instead, calculations start as if the project or programme is new.

The cumulative earned value should not be greater than the maximum planned value, regardless of the period in which the maximum is reached.

In the final period, the earned value should equal the planned value. It is possible for the project or programme to be terminated before this point is reached but earned schedule measurements should not indicate completion.

The number of periods in the baseline can differ from the number of periods in the current plan. Calculations should be performed as of a certain period. The period should occur between the earliest date in the baseline plan and the latest date in either the baseline plan or current plan, whichever is later.

8.4.5 Variance analysis, and project or programme manager's estimate at completion (time)

The project or programme manager’s estimate should set variance limits for the estimate at completion (time).

The manager’s estimate should be developed by evaluating similar historical plans, risks (see 9.1) and external factors, and by eliciting input from stakeholders. The estimate should include a best case, worst case and most likely case.

The manager’s estimate should be reviewed at least annually or according to the organizational, project or programme governance or contract guidelines.

In addition to the manager’s estimate, project or programme teams should also calculate the independent estimate at completion (time) using a formula referenced in Table 11.

Table 11 — Formula and rule for calculating independent estimate at completion (time)

Formula	Rule for calculating estimate at completion (time)
$IEAC(t) = \frac{PD}{SPI(t)}$	This formula should be used when the SPI(t) is assessed as most likely to represent future schedule efficiency and where the variation in SPI(t) across periods is stable.
$IEAC(t) = AT + \left(\frac{PD - ES}{PF} \right)$	This formula should be used when alternative performance factors are assessed to be more likely to represent future schedule efficiency. Examples include: a) the assessment that future schedule efficiency should be according to plan in spite of the past schedule performance; b) cumulative measures of schedule performance index (time): 1) moving average; 2) sliding window moving average; 3) prior period three month or selected other periods such as a six month or nine month moving average; c) other performance factors that can be assessed as likely to represent future schedule efficiency.

The independent estimate to completion (time) should be used in conjunction with its variance. The variance can be set by the manager's best case and worst case estimates, or by statistical analysis of historical schedule efficiency.

The independent estimate to completion (time) and variance can then be used with the thresholds referenced in Table 10 to assess the probability of achieving the objectives as represented in the plan.

8.4.6 Assessment of the indicators and predictors against thresholds

8.4.6.1 Earned schedule burndown rate accomplished

The earned schedule burndown rate accomplished (see 8.3.1) should be used to communicate whether the project or programme is behind, on or ahead of schedule. A widening gap between the planned duration and earned schedule can imply schedule performance is worsening. If the gap is above the planned duration line, the project or programme could be lagging behind schedule. If the gap is below the planned duration line, the project or programme could be proceeding ahead of schedule.

8.4.6.2 Schedule variance (time) and schedule performance index (time)

Variance analysis of schedule variance (time) (see 8.3.2) and schedule performance index (time) (see 8.3.3) should be used to assess and communicate whether the project or programme is or is not on schedule. The metrics should also indicate how well or poorly the schedule is performing.

If there is no threshold breach, the project or programme should be considered to be performing well. If there is a threshold breach, the project or programme can be considered to be performing poorly and therefore, can require project or programme management attention. The attention should involve a root cause analysis, remediation planning and implementation, and communication.

Inferences about future effects on finish date should be made cautiously, as there are indicators and predictors specifically for future effects.

8.4.6.3 Independent estimate at completion (time)

The independent estimate at completion (time) and its variance (see 8.3.4) should be used to assess the feasibility of finish date. If the independent estimate at completion (time) and its variance are within 10 % of the planned duration, the planned duration should be feasible.

If the independent estimate at completion (time) or its variance are ±10 % or the threshold stated in the governance documents of the planned duration or the value set by the organization, project or programme governance, or contract, there is a threshold breach. The breach can indicate that the planned duration is not feasible. The breach should cause a detailed analysis to be made and the attention of the project or programme management. The detailed analysis should entail root cause analysis, remediation planning and implementation, and communication.

If risk analysis (see 9.1) has been performed, the project or programme should use schedule buffers as thresholds for independent estimate at completion (time). The lower bound should be set by the duration of the performance measurement baseline and the upper bound by the duration of the performance measurement baseline plus schedule reserve.

The independent estimate at completion (time) and its variance can be used in conjunction with trend analysis (see 8.5), risk analysis (see 9.1) and indicators, such as schedule performance index (time) (see 8.3.3) and to complete schedule performance index (see 8.3.5) in making judgments and communicating estimates related to finish date.

8.4.6.4 To complete schedule performance index

Once the independent estimate at completion (time) and its variance (see 8.3.4) are in place, the project or programme manager can assess the schedule performance efficiency needed to meet the finish date. The needed efficiency can be calculated against the planned duration or the estimated duration.

As long as the to complete schedule performance index (see 8.3.5) is less than the upper threshold value of 1,10 or the threshold value in the governance documents, the project or programme can be recoverable from any delay it has experienced.

Before the 1,10 or the governance stated threshold is exceeded, the to complete schedule performance index can indicate the need for detailed analysis and management attention. Individual measurements of to complete schedule performance index that are greater than 0,99 or the governance stated threshold should cause detailed analysis and management attention. Each threshold metrics can also depend upon the guidance for such actions in the organizational project or programme governance or contract terms and conditions.

Trends in measurements of the to complete schedule performance index should also be assessed to determine if escalation is needed (see 8.5).

The to complete schedule performance index (see 8.3.5) can be used in conjunction with the independent estimate at completion (time) and its variance (see 8.3.4) to assess the feasibility of meeting the estimated finish. The independent estimate at completion (time) and its variance can be used to set the objective, and the to complete schedule performance index can be used to gauge its achievability.

8.4.6.5 Variance use: Separate or together

Earned schedule indicators and predictors can be used separately or together. Individual measurements should be used separately, only if they breach thresholds by more than 20 % depending on organizational, project or programme governance or contract. Otherwise, the measurements should be used together.

8.5 Trend analysis

8.5.1 General

From one period to the next, there is natural variance in schedule performance. If that variance happens to cross a threshold value, it can signal a need for management attention. Although such cases should have variance analysis by the project or programme manager, the decision can be not to escalate to the management team.

Trends should be comprised of three or more consecutive earned schedule measurements. Trends should have two properties: direction and magnitude.

Direction is the period-to-period rise or fall in a measurement relative to a target value. Magnitude is the period-to-period percentage change in a measurement. Both properties should be used in trend analysis.

To merit analysis, the direction of the consecutive measurements should diverge from or converge on a nominal value or in the case of the to complete schedule performance index (see 8.4.5), the threshold value of 1,10 or a value that can be set forth by the organizational, project or programme governance or contract.

If there is no divergence or convergence, there can be no breach. The risk of a breach is in the movement of the trend in a specific direction.

A trend that crosses the nominal value of a measurement or crosses thresholds that bound the nominal value should cause management attention.

Apart from the direction of a trend, there is another property that can be used to cause project or programme management attention: the magnitude of the trend.

If all percentage changes in a trend cross the threshold, the trend should receive project or programme management team attention, but management attention can be invoked, if only one of the changes is across the threshold.

It is also possible for each percentage change in the trend to stay within the threshold, but the trend as whole to breach the threshold. A calculation should be performed on the largest and the smallest changes in the trend. If that percentage change crosses the threshold, the trend should cause management attention.

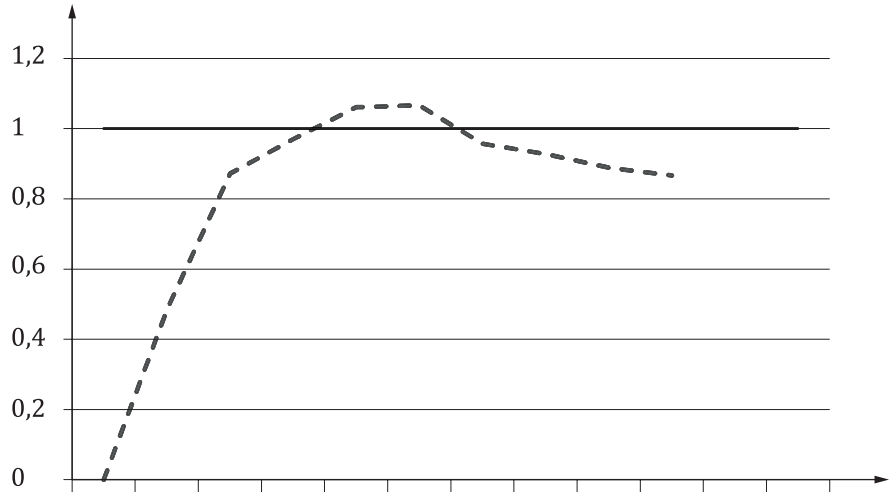
A trend in earned schedule burndown rate accomplished (see 8.3.1) does not automatically require project or programme management attention. It should be used to communicate the need for management attention if trends in other measurements breach thresholds.

8.5.2 Magnitude of trend and threshold

The magnitude of change in schedule performance index (time) should be assessed against the ±10 % threshold or the threshold stated in organizational, project or programme governance or contract. The magnitude of change in periodic schedule performance index (time) should be represented by a percent difference.

For percent differences, negative values can imply percentage increase, and positive values can imply percentage decrease.

In Figure 15, during the first half of the year, schedule performance recovers from a delayed start. For period 3, March, and period 4, April, the percent difference crosses the threshold of –10 %. Project or programme management attention should be sought, if it was not already in place due to the absence of percent differences for period 1, January, and period 2, February.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Schedule performance index (time)	0	0,484	0,873	0,97	1,062	1,067	0,957	0,929	0,889	0,867		
Nominal	1	1	1	1	1	1	1	1	1	1	1	1
Start-finish	0	-0,484	-0,389	-0,098	-0,091	-0,005	0,11	0,029	0,04	0,022		
(Start-finish)/start	0	0	-0,803	-0,112	-0,094	-0,005	0,103	0,03	0,043	0,025		
Percent difference	0	0	-80,3	-11,2	-9,4	-0,5	10,3	3	4,3	2,5		

Figure 15 — Magnitude of trend and threshold

The percent difference for May and June runs below the 10 % threshold, thus it can reduce the need for a detailed variance analysis and management attention.

In July, the percent difference swings from repeated increases to a decrease. The percentage change from June to July breaches the good practice of a 10 % threshold that the organization is using.

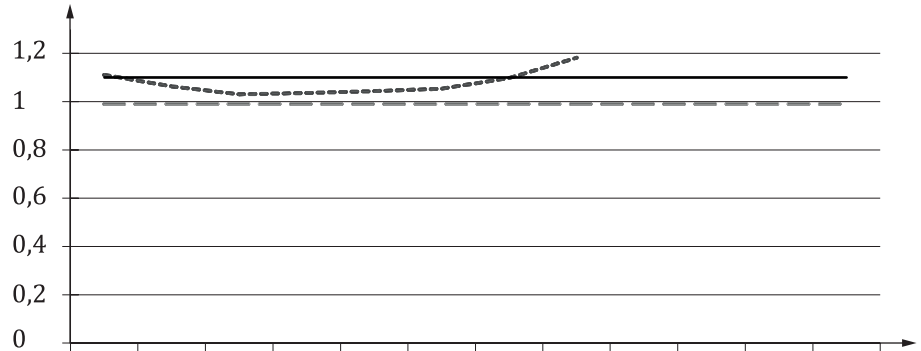
Before invoking project or programme management attention, the context of the observation should be considered. Schedule efficiency has consistently improved for five preceding periods, almost fully recovering to the planned level. The question should be whether the measurement in period 7, July, is a one-time anomaly or is it an inflection point, the first indication of declining efficiency.

In Figure 15, following July, four measurements diverge from the nominal value of 1,0, which can identify a trend that needs analysis. The percent difference for the periods July-August, August-September and September-October are consistently below the 10 % threshold. If the analysis stopped there, further investigation and project management attention should not be required.

A final check should be done by calculating the percent difference between the highest and lowest changes in the trend. The difference, which is not shown, is 75,7 %. The trend breaches the threshold. The observation in July is an inflection point. Detailed variance analysis and management attention should be done.

8.5.3 Direction of the trend and threshold with the to complete schedule performance index

In Figure 16, the trend breaches the threshold value of 1,10 used for this example in period 8, August, which should trigger a request for the attention of project or programme management.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
To complete schedule performance index	1,111	1,063	1,03	1,035	1,043	1,054	1,097	1,182				
Upper threshold	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
Lower threshold	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99	0,99

Figure 16 — Direction of the trend and the threshold

Before that point, the direction of the trend indicates a problem. From period 2, February, through period 6, June, the to complete schedule performance index is above the lower threshold value of 0,99 used for this example. The observation in period 1, January, is excluded because it is a result of calculation with earned value of 0.

Any part of the trend between period 2, February, and period 6, June, can invoke escalation because they breach the 0,99 threshold. The consideration before doing so is that the to complete schedule performance index is not rising rapidly. It hovers below the 1,10 threshold, leaving open the possibility that the project can finish on time.

Other earned schedule measurements can help decide the issue. At period 7, July, the independent estimate at completion (time) is 10,292 with a variance of 11,516 for the high and 9,455 for the low, which are not shown.

The variance high of 11,516 crosses the predictor's upper threshold of 11 periods, which can signal a need for the attention of project management.

The to complete schedule performance index can indicate whether a project or programme is recoverable. The measurement can lead to other questions.

— What is the probability that it will recover?

— What is the window of opportunity for recovery?

— What level of performance is required in each recovery period?

Figure 16 should be considered before the threshold is breached. In period 7, July, there are additional earned schedule measurements.

The window for improvement is 0,006. The schedule performance index (time) improvement required is 29 %.

Table 12 — Schedule performance index (time) improvement profile

	Recovery period		
	August	**September**	**October**
Required schedule performance index (time)	1,051	1,144	1,236

Table 13 — Schedule performance index (time) past performance

	Month						
	January	**February**	**March**	**April**	**May**	**June**	**July**
Schedule performance index (time)	0,000	0,750	0,930	0,947	0,957	0,964	0,958

The probability of recovery is 51 %.

The window of opportunity for improvement is narrow. At 0,006, there is little time remaining. Significant improvement in efficiency should be made. Historical efficiency rates in periods 1 through 7, January through July, are lower than the required rates in periods 8 through 10, August through October. The probability of recovery can be low.

Even before the threshold is breached, there is reason to doubt the project can be recoverable. Action by the project management team should start immediately.

Using other earned schedule measurements, the need to cause management attention can be established before the to complete schedule performance index breaches the threshold used.

9 Integrating other project or programme management practices

9.1 Integration of risk management

9.1.1 Overview

The integration of earned value management with risk management should enable uncertainties and risks to be identified, assessed and treated according to the governance for the project or programme or contract.

Uncertainties and risks should be addressed using the risk management process. Management reserve should be established outside of the performance measurement baseline, with a suitable mechanism for transfer into the baseline.

9.1.2 Project or programme risk context

Risk management activities should have commenced during the business case or other similar process development and acceptance. Risks that have an impact on the organizational business case objectives should be identified and treatment actions considered, dependent on the risk tolerance of the organization.

The project or programme context should be recorded, including the objectives, needs and scope, budget and schedule targets, any assumptions that have been made, and any potential trade-offs that can be made.

Risk tolerance should be determined to establish how much risk the project or programme can accommodate. This determination can include:

a) level of confidence to be used to establish baseline items and milestones;

b) how much risk can be held within the risk register;

c) what risk exposure can be covered by management reserve;

d) level of risk occurrence that can trigger a management review.

This information should be documented and can be used to inform management decisions.

The organization should select a tool for their risk management system that allows for formal, controlled changes, approvals, authorized users and procedures. An initial risk register for the project or programme should be created during the business case development or similar documentation.

Risk should inform each step leading up to and including the creation of the performance measurement baseline, and the subsequent integrated baseline review. During implementation, the focus of risk should

change to governance in support of management action to maintain confidence that the project or programme should be able to deliver against the organizational business case objectives.

Risk management activities performed during the lifecycle should address the uncertainties and risks found in the various elements of the project or programme, such as cost, schedule and scope.

Risk management should be performed iteratively throughout the earned value management steps.

9.1.3 Intersections between risk management and earned value management processes

Used together, earned value management and risk management can support enhanced forward planning and decision-making to increase the likelihood of achievement of deliverables, outcomes and benefits.

Intersection between risk management and earned value management occurs throughout the lifecycle, including:

a) risks and assumptions identified in the business case or a similar document should be entered into the risk register and should inform the activities associated with decomposing the scope and assigning the responsibility for these activities;

b) a Monte Carlo simulation can provide early warning of potential high-risk areas of the work breakdown structure that can be managed during the decompose the scope and schedule the work activities;

c) risk tolerance should inform the inclusion of risk treatment actions during schedule the work, develop time-phased budget and maintain the baseline activities to establish management reserve that covers residual risk;

d) earned value performance data can provide feedback on whether treatment actions can deliver the residual risk position to inform further risk management activities and support the objective measurement of management reserve for unknown risks;

e) risk analysis cost and schedule confidence measures can inform management action to replan the performance measurement baseline, as well as to increase or release management reserve based on an updated risk register.

Risk management and earned value management steps are non-linear and feedback loops should be considered when establishing the intersection of activities. For example, earned value variances can trigger the identification of emergent risk that can then trigger new risk treatment actions to be transferred into the baseline, which can then create further risk and variances. In order to recommend appropriate management action, risk and earned value practitioners should understand these feedback loops.

Demonstration and surveillance reviews of the earned value management system should provide formal opportunities to re-assess not only risks and associated management reserve, but also to review the risk management process.

9.1.4 Risk management during project or programme planning

9.1.4.1 General

During steps 1 to 6 of the earned value process, risk management focus should be on risk assurance (see Clause 5).

9.1.4.2 Step 1: Decompose the project or programme scope

During scope breakdown, any assumptions relating to the scope can be identified and recorded as risks in the risk management system. These risks should be identified against work breakdown structure elements at the level most suited to understanding the potential risk impact.

A high-level work breakdown structure can provide a useful framework for risk analysis, risk reporting and decision-making. Risks should be identified top down to maintain a focus on the objectives of the project or programme. Where problem areas are discovered, further detailed risks can be identified by drilling

down into the work breakdown structure at a lower level of decomposition. Systemic risks, common across multiple projects should be managed collectively at the programme or organizational level.

9.1.4.3 Step 2: Assign responsibility

Assignment of responsibility should consider accountability for risk management activities. This assignment approach can include defining responsibility for approving risk treatment actions, transfer and release of management reserve, and risk reporting (see 5.3.1 and 5.3.2).

9.1.4.4 Step 3: Schedule the work

A schedule check can be performed to provide feedback that the schedule is robust. This schedule check should include reviewing that each task is properly logic linked, only necessary lags, leads and constraints are used, and merge bias is avoided.

NOTE Merge bias is the effect of increasing risk by scheduling multiple near-critical paths in parallel. It is common for one of those near-critical paths to overrun, causing a larger than expected project overrun.

Any risk treatment actions approved in the risk management system should be included as scheduled work. Traceability of those actions to their risks should be available to allow the risks to be monitored and updated based on the continued assessment of whether those actions will be completed successfully and in time to treat the risk.

Schedule buffers can be included to cover expected schedule slippage based on residual risk being managed in the risk management system. Such schedule buffers should be based on an approved estimation or calculation of necessary schedule reserve.

Where suitable data exists, schedule buffers can be calculated by running a Monte Carlo simulation on a schedule-checked risk schedule with approved risk treatment actions, residual risks included, and level of effort tasks excluded. The analysis should be carried out with a minimum of constraints applied to the schedule to allow both negative and positive variance to inform milestone confidence results.

A Monte Carlo simulation can inform the schedule risk analyst of critical and near-critical paths. Any available schedule float should be utilised to cover risk occurrence during the Monte Carlo simulation, up to the point where float is exhausted. At this point the sequence of tasks becomes critical and an overrun is recorded. The likelihood and size of overrun is calculated for each milestone and schedule buffers should be inserted at the milestones most influencing the overrun. Monte Carlo simulation can demonstrate an acceptable project outcome at a chosen confidence level, that covers both overrun and any necessary task constraints.

9.1.4.5 Step 4: Develop the time-phased budget

Progressive elaboration should include reviewing and addressing known risks to meet organizational, project or programme governance, or contract needs. This progressive elaboration can include repeated analysis and re-assessment of risk and uncertainty following adjustments to the phasing of work.

NOTE A Monte Carlo simulation can be used to calculate a combined schedule and cost risk analysis, which can include the testing of scenarios by systematically including and excluding risks and their associated treatment actions. A cost benefit analysis can be used to calculate the return on investment in treatment actions, to decide whether to treat, accept or transfer individual threat risks or to exploit, enhance or share individual opportunity risks.

Risk treatment actions included in the schedule should be assigned appropriate resources and budget to implement those actions.

Any adjustment to the schedule that results in risk treatment actions being moved should cause the revisiting of any associated risks and overall risk exposure, to ensure the adjustments continue to achieve the desired residual risk position.

Some organizations can allocate extra budget to the baseline in the form of contingency reserve. This practice can be carried out where the mechanism for authorising release of management reserve is held at a much higher management level than the project or programme. If used, release of the contingency reserve

should be operated in the same way as release of management reserve, whereby the reserve is allocated to risk treatment actions related to specific risks in the risk management system. The reserves should be placed as buffers after the scope to which the addressed risks refer.

There can be contingency reserves at various levels of detail, including the work package and activity levels. The contingency reserves should be either converted into planned scope or when not used, released to fund risk treatment actions in other parts of the project or programme.

Allocation of contingency reserves into the performance measurement baseline should be avoided where possible. Such budget should be held as management reserve at the project or programme level, where permitted per organizational, project or programme governance, or contract, and a mechanism for its release against identified risks should be established.

9.1.4.6 Step 5: Assign objective performance measures of performance

Schedule risk analysis can be used to inform ongoing confidence in achieving a project's or programme's milestones. If schedule buffers are included in the baseline, a measure of their use can be used to establish whether sufficient buffer remains to cover schedule slippage.

The success rate of risk treatment actions can be measured by comparing the amount of actual and expected risk reduction for completed and ongoing actions. A mechanism for reporting variance to expected management reserve by comparing it with actual use of management reserve for cost and schedule can be needed for governance purposes.

9.1.4.7 Step 6: Set the performance measurement baseline

The performance measurement baseline should only include work which is planned to be done. Management reserve should not be included in the performance measurement baseline because it provides budget for risk treatment actions that can be transferred into the baseline in response to emerging or materializing risks.

The performance measurement baseline should include risk treatment actions needed to achieve the residual risk position in the risk management system.

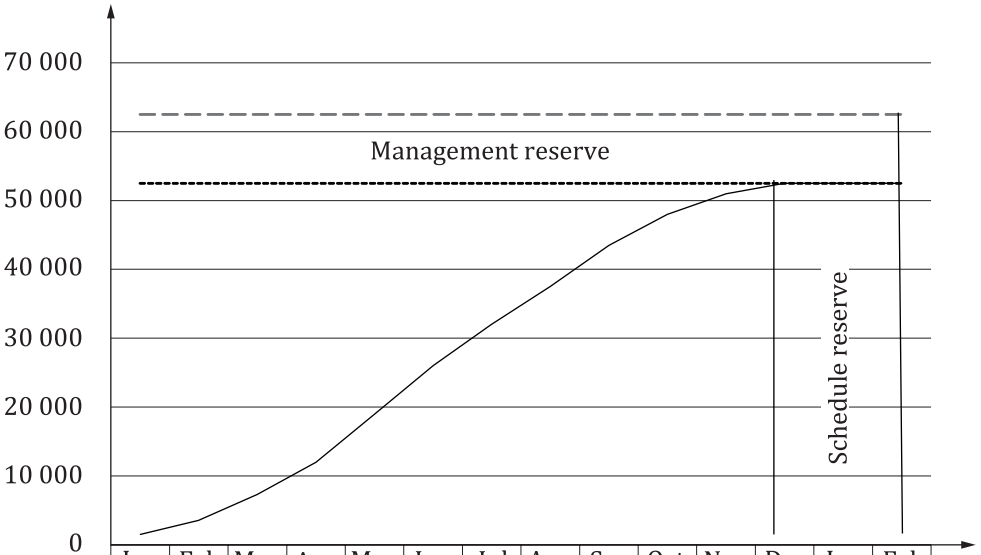
9.1.4.8 Step 6a: Set management reserve

When set the performance measurement baseline is completed (see 5.7), the management reserve should also be calculated.

The management reserve should be calculated using risk analysis methods, based on residual risks recorded in the risk management system. A pre-requisite for establishing the management reserve should be that approved risk treatment actions are included in the performance measurement baseline and are resourced and scheduled in a timely manner to achieve the residual risk position.

Schedule buffers can be included at key milestones in the schedule, to allow for residual schedule risk occurrence.

An allowance can be included for emergent risks based on criteria that adhere to governance policies. Management reserve budget should be based on risk tolerance and approved according to organizational, project or programme governance or contract terms (see Figure 17).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
PV	1 500	3 500	7 300	12 000	19 000	26 000	32 000	37 500	43 500	48 000	51 000	52 500	52 500	52 500
BAC	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500	52 500
total project cost	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500	62 500

Figure 17 — Total project cost

This action can be based on a pre-determined risk tolerance, the capacity of the project or programme to manage risk or other agreed criteria. This process should include a final assessment of the risks, checking that management responsibility is established.

9.1.4.9 Step 8: Accumulate and report performance data

Risk performance indices can relate to measuring the success of risk treatment actions to date and the amount of residual risk and uncertainty. The data can include the following:

a) actual risk reduction from risk treatment actions;

b) amount of emergent residual risk;

c) confidence of completing on-budget based on uncertainty and risks;

d) confidence of completing on-time based on uncertainty and schedule risks;

e) updated status of management reserve.

Management reserve should be re-calculated at every reporting period. This value should be based on up-to-date progress of risk treatment actions included in the performance measurement baseline and latest information on potential risk impacts in the risk management system.

The difference in value between the current and re-calculated value of management reserve can be released to or taken from margin. This action should only be done when there is sufficient evidence of project or programme performance, for example, on the completion of a milestone.

When risk does not materialize, releasing budget to margin on a risk-by-risk basis should not be done. Budget should only be released to margin following re-calculation of management reserve at a milestone, or when a large variance or a significant event triggers management action, according to the organization, project's or programme's governance process or the contract.

9.1.4.10 Step 9: Analyse performance data

9.1.4.10.1 Risk performance indices can be useful when presented as trends because risk is probabilistic and therefore, relative measures can be more useful than absolute calculated values.

9.1.4.10.2 Trend analysis can be useful to assess:

a) management reserve usage and forecast to understand the likelihood the project or programme will run out of budget to cover the residual risk recorded in the risk management system;

b) amount and source of emergent risk, to inform the trajectory of future risk exposure;

c) timeliness and success of treatment actions needed to achieve the residual risk position, to inform review of the untreated position and the need for additional actions;

d) use of schedule reserve buffers, to inform future dependent tasks that can require re-scheduling in time to minimise unplanned costs and penalties;

e) confidence of completing to budget and on-time based on remaining durations, outstanding work and residual risk position.

9.1.4.10.3 Risk analysis can be useful to perform:

a) uncertainty analysis of the estimate to completion, to understand the confidence of completing on-time and on-budget;

b) what-if scenario analysis to provide recommendations on any new risk treatment actions, work reallocation or schedule restructuring that can deliver improved outcomes.

9.1.4.10.4 Causes of cost or schedule variances can include the following:

a) failure to manage risks;

b) risk amplified by scheduling too many activities in parallel.

9.1.4.10.5 A data validity check should be performed to verify the management reserve budget spent equals the budget allocated to approved risk treatment actions during the current period.

A key question that project or programme and risk personnel should ask is: do we have enough management reserve to cover the residual risk?

The budget at completion should be reviewed to provide a projection of overall affordability of the project or programme.

9.1.4.11 Step 10: Take management action

Risk information should be included in regular management reviews and decision-making in order to agree upon preventive or corrective actions.

The risk management system should be used as an early warning system to identify potential problems and put risk treatment actions in place before the risks materialise. If the risks do materialise, then the risk management system should record outcomes, actions and decisions made. This approach should provide an audit trail in the event that future inquiries or lessons learned exercises are carried out.

At periodic reviews, intolerable and emergent risks should be assessed based on risk tolerance, and risk treatment actions should be put in place to reduce those risks to a less adverse residual value. Risk treatment action expenditure should be approved based on governance.

Management action can involve release of management reserve into the baseline to cover the actions needed to address unacceptable levels of risk. However, management reserve should not be used to fund scope change or reduce variances.

Finally, a review of the high-level risks to the objectives can be undertaken. If the project or programme management team is no longer able to meet the objectives for a set of identified metrics, management should establish a major review to establish the project's or programme's ongoing viability.

9.1.4.12 Step 11: Maintain the baseline and management reserve

Risk treatment actions, including mitigation, exploitation, fall back and recovery, should cause a baseline change. When the risk treatment actions are approved, they should be translated into work and associated budget allocated to the baseline. This baseline change should be a formal process that aligns governance with the earned value management and risk management systems. This process should protect the integrity of the scope, schedule and budget.

Earned value performance and risk management status reports should be aligned to enable decision-making to be accountable for factors identified in both areas of reporting. Similarly, performance variance fluctuations can be indicators of underlying issues or risks. Therefore, stakeholder communication should provide that earned value performance metrics and information about risks are consistent and presented alongside each other to enable stakeholder decision-making.

After a final review of risks, the management reserve should be re-calculated based on the residual risks in the risk management system.

9.2 Integrating earned schedule with the critical path

9.2.1 General

Connection of earned schedule (see 8.2) and earned value management and integrating earned schedule with critical path should be established. The approach should be to use earned schedule on the critical path through the project or programme, as progress is recorded in each reporting period (see Figure 18).

Comparisons should be made among and between the critical path, schedule variance (time) (see 8.3.2), total float erosion, the independent estimate at completion (time) (see 8.3.4), schedule performance index (time) (see 8.3.3), and the original critical path length. The critical path length index should also be plotted to show the change in efficiency needed to complete the project to the original critical path duration (see Figure 20).

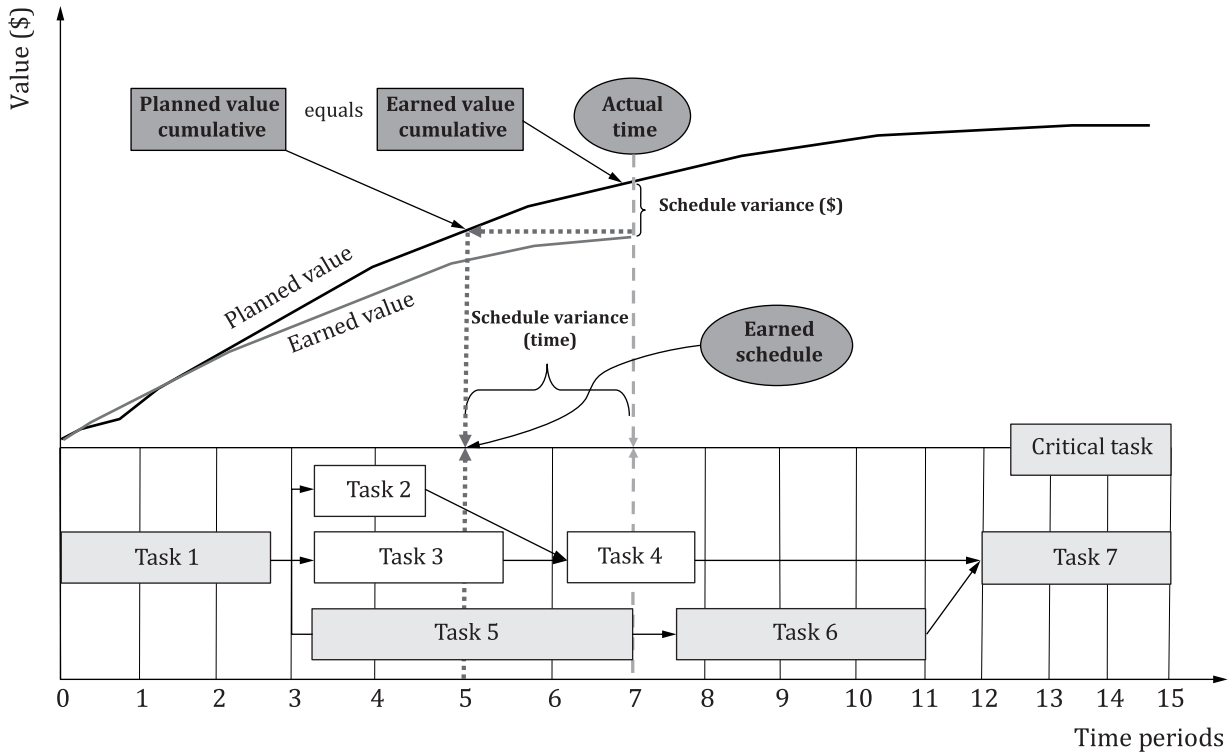


Figure 18 — Connecting earned schedule to the critical path[19]

There should be a direct correlation among total float erosion, schedule performance index (time) and schedule variance (time). This correlation can be used as an early warning technique to help the project or programme manager select preventive or corrective actions, and prioritise those actions.

9.2.2 Process steps

The process steps which should be followed are:

a) create the schedule and identify the critical path;

b) identify any other schedule paths that need to be monitored in terms of total float;

c) record earned value and actual costs;

d) calculate

- earned schedule (see 8.2),
- schedule variance (time) (see 8.3.2),
- schedule performance index (time) (see 8.3.3), and
- independent estimate at completion (time) in a period (see 8.3.4) and cumulative for the critical path and other schedule network paths, as needed;

e) plot the values for

- schedule performance index (time) and the schedule variance (time),
- total float versus the cumulative schedule performance index (time), and
- independent estimate at completion (time) versus the original critical path and cumulative earned schedule across the same period of performance.

The graphs should be analysed for determination of the health of the project or programme by identifying trends, patterns and forecasts

9.2.3 Cyclical process

9.2.3.1 General

A cyclical process can be used for analysis. The time frame for the cyclical analysis review should be established using a stated timed cycle and quasi-static variables, such as activities and other time series data.

9.2.3.2 Set the project baseline and identify critical path

Figure 19 provides network schedule data which is used to demonstrate the integration of the earned schedule with the critical path. Figure 19 shows a network schedule of seven tasks with tasks connected using a finish-to-start logic. The critical path runs through tasks 1, 5, 6 and 7 where the total float is zero.

Table 14 provides the notional earned schedule and critical path length index data for the entire project and the critical path used to demonstrate the integration of the earned schedule with the critical path.

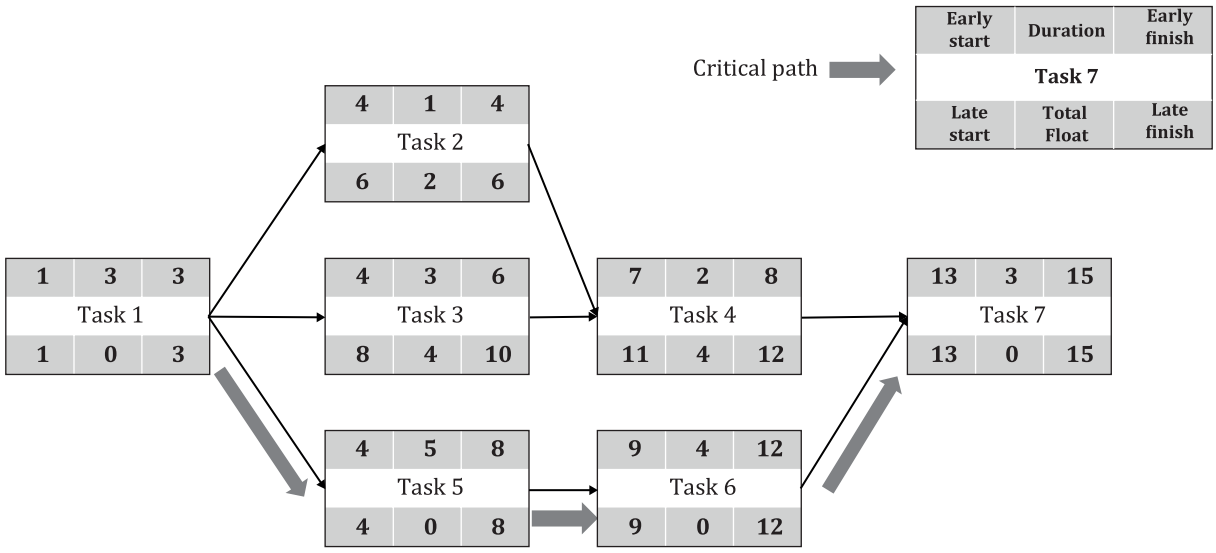


Figure 19 — Example of a project network

Table 14 — Analysis table for critical and secondary paths

Task no.	Indicator	Performance period										
		0	1	2	3	4	5	6	7	8	9	10
Critical path 1-5-6-7	SPI(p)	—	1,00	0,80	1,00	0,60	1,60	0,80	1,00	0,90	1,30	1,00
	SPI(c)	—	1,00	0,90	0,93	0,74	0,93	0,90	0,93	0,92	0,95	0,96
	SPI(t)(p)	—	0,80	1,00	0,60	1,40	1,00	0,80	1,00	0,90	0,80	0,40
	SPI(t)(c)	—	0,80	0,90	0,80	0,95	0,96	0,93	0,94	0,94	0,92	0,87
	SV(t)(p)	—	−0,20	0,00	−0,40	0,40	0,00	−0,20	0,00	−0,10	−0,20	−0,60
	SV(t)(c)	—	−0,20	−0,20	−0,60	−0,20	−0,20	−0,40	−0,40	−0,50	−0,70	−1,30
	ES(p)	—	0,80	1,00	0,60	1,40	1,00	0,80	1,00	0,90	0,80	0,40
	ES(c)	—	0,80	1,80	2,40	3,80	4,80	5,60	6,60	7,50	8,30	8,70
	CPLI(c)	—	0,99	0,98	0,95	0,98	0,98	0,96	0,95	0,93	0,90	0,79
	IEAC(t)	15,00	18,75	16,67	18,75	17,14	15,31	15,70	15,67	15,48	16,27	17,24
Secondary path 1-3-4	SPI(p)	—	1,00	0,80	1,00	1,60	0,80	0,50	1,20	0,90		
	SPI(c)	—	1,00	0,90	0,93	1,10	1,04	0,89	0,96	0,95		
	SPI(t)(p)	—	0,80	1,00	0,60	1,80	1,10	0,50	1,00	0,80		
	SPI(t)(c)	—	0,80	0,90	0,80	1,05	1,06	0,97	0,97	0,95		
	SV(t)(p)	—	−0,20	0,00	−0,40	0,80	0,10	−0,50	0,00	−0,20		
	SV(t)(c)	—	−0,20	−0,20	−0,60	0,20	0,30	−0,20	−0,20	−0,40		
	ES(p)	—	0,80	1,00	0,60	1,80	1,10	0,50	1,00	0,80		
	ES(c)	—	0,80	1,80	2,40	4,20	5,30	5,80	6,80	7,60		
	CPLI(c)	—	0,97	0,97	0,89	1,05	1,11	0,91	0,83	0,00		
	Total float	4,00	3,80	3,80	3,40	4,20	4,30	3,80	3,80	3,60		
	IEAC(t)	8,00	10,00	8,89	10,00	7,62	7,55	8,28	8,24	8,42		

The critical path runs through tasks 1, 5, 6, and 7 as shown in Figure 19.

Both the critical path and the secondary path, which is nearest in length, are treated as separate networks. The values for planned value, earned value and actual costs should be captured for both, as shown in Figure 19.

The schedule network shows the task duration in performance periods. These performance periods can be weeks, months or four-week periods depending on governance documentation and any contract terms. Total float in the network runs through tasks 1, 3 and 4 and is a total of four periods.

There is no additional schedule margin shown as allocated to the critical path.

The longest path is also the critical path which is a total duration of 15 periods.

9.2.4 Collect periodic performance data

The analysis should include the following steps:

a) calculate values for the latest period and cumulative;

b) schedule performance index (time) (see 8.3.3) and schedule variance (time) (see 8.3.2);

c) determine critical path length index;

d) compare independent estimate at completion (time) (see 8.3.4) for the critical path with the independent estimate at completion (time) for the entire project;

e) review independent estimate of completion date (see 8.2) for the critical path and the entire project;

f) compare the total float to the schedule performance index (time) with the schedule variance (time) values.

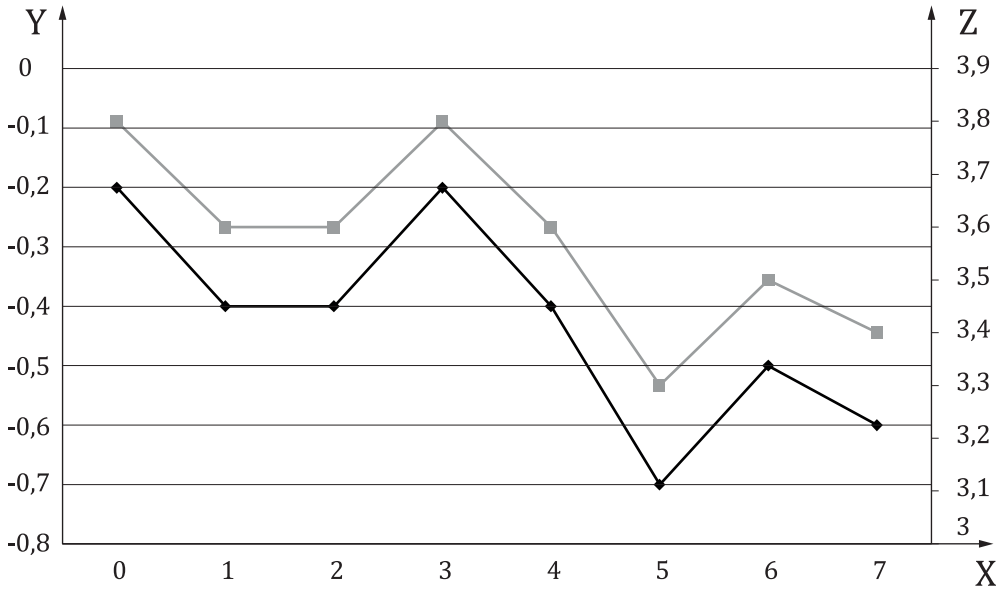
The values for schedule variance (time), independent estimate at completion (time) and independent estimate of completion date should be reviewed.

The determination for independent estimate at completion (time) and independent estimate of completion date should be checked against the critical path predicted completion date.

If there are divergences among these calculations, this determination should be used as a trigger to conduct a more detailed variance analysis. The causes of a variance should be reviewed and understood by the project and programme management team. The team should also understand the actual project status, as well as whether the critical path has changed.

By superimposing the schedule variance (time) and schedule performance index (time) with an independent estimate at completion (time) and earned schedule, it can be seen that the performance on the critical path is worsening. Both the schedule variance (time) and schedule performance index (time) are clear indicators that if performance does not change, the remaining work on the critical path will take longer. In summary, recovery action is needed now to try to keep the project or programme on track.

Figure 20 shows that the schedule variance is the same as the total float position. This situation is true because there is no additional schedule margin allocated.



Key

X performance period

Y schedule variance (time) cumulative

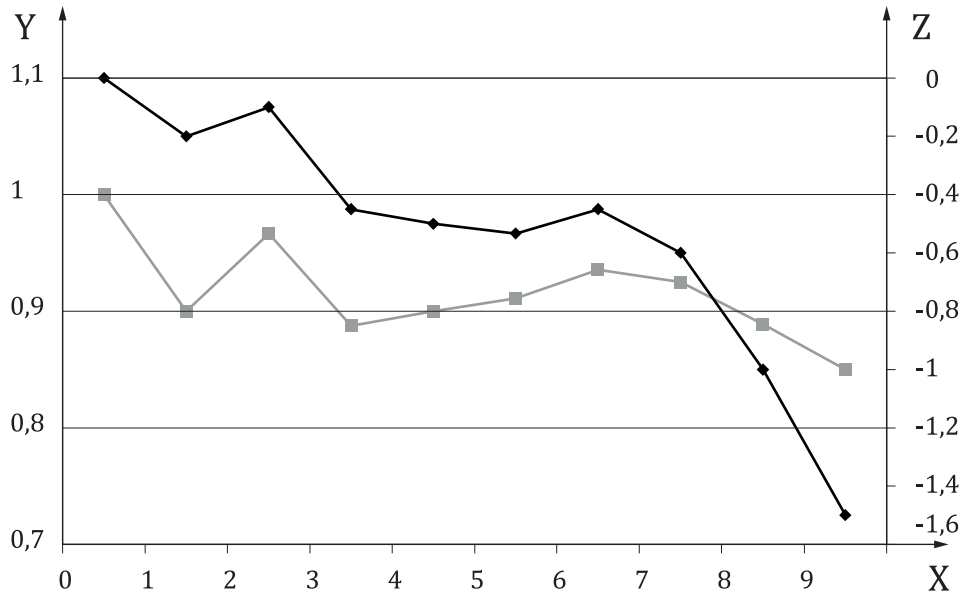
Z total float

schedule variance (time) cumulative

total float

Figure 20 — Comparison of schedule variance (time) and total float values path 1, 5, 6 and 7

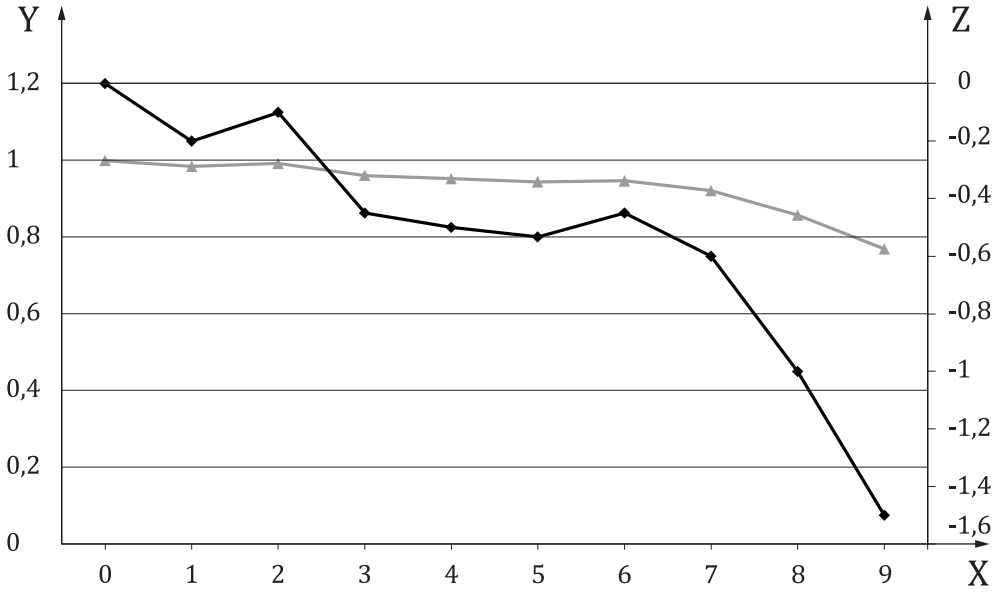
Figure 21 shows that schedule performance index (time) and schedule variance (time) cumulative values are trending in the same direction. Both are trending negatively. This analysis is reinforced by Figure 22 where the critical path length index and schedule variance (time) are also trending negatively.



Key

X	performance period	■—	schedule performance index (time) cumulative
Y	schedule performance index (time)	◆—	schedule variance (time) cumulative
Z	schedule variance (time)		

Figure 21 — Schedule performance index (time) versus schedule variance (time) cumulative values for path 1, 5, 6 and 7



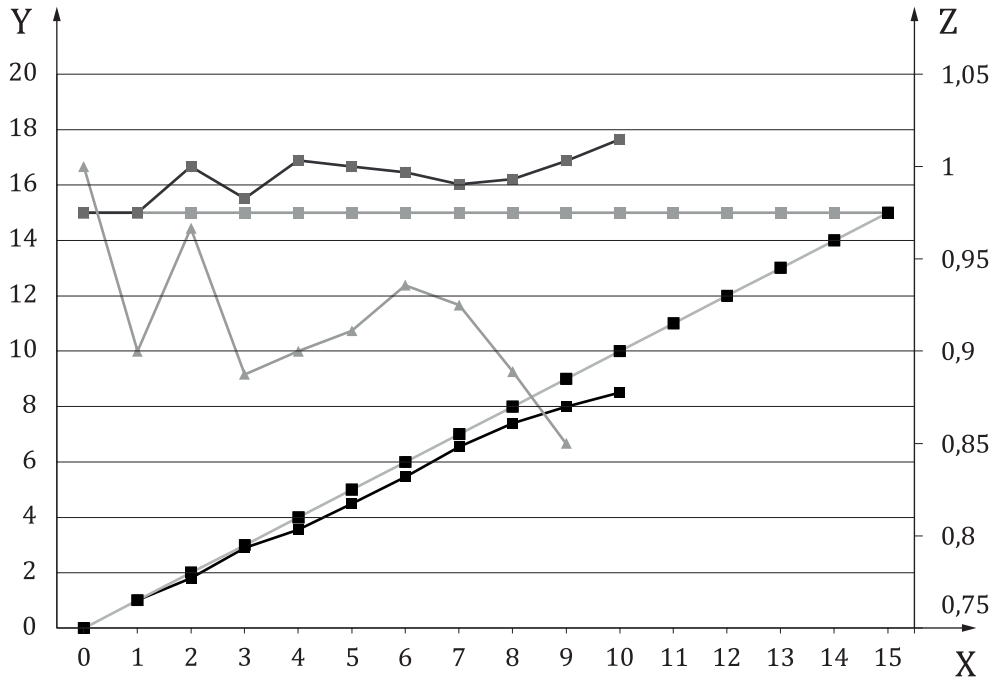
Key

X	performance period	▲—	critical path length index (cumulative)
Y	schedule variance (time) cumulative	◆—	schedule variance (time) (cumulative)
Z	critical path length index		

Figure 22 — Comparison of cumulative values for schedule variance (time) against critical path length index for path 1, 5, 6 and 7

Further evidence of poor performance can be seen in Figure 23 and Figure 24. A worsening earned schedule is matched by an increasing total duration from the independent estimate at completion (time).

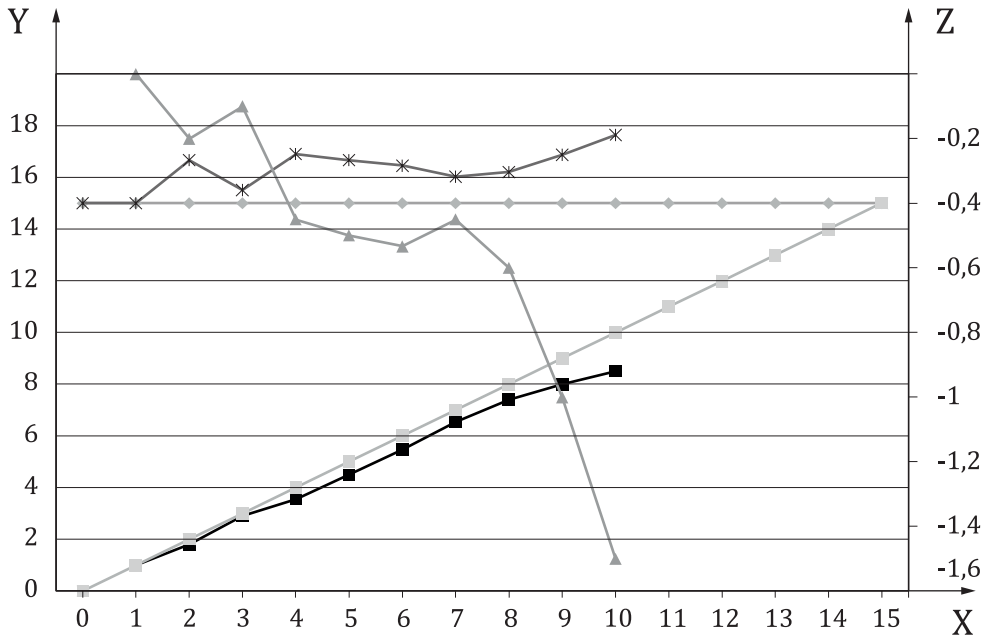
By comparing the schedule variance (time) and schedule performance index (time) values with independent estimate at completion (time) and earned schedule, the performance on the critical path is worsening, and both the schedule variance (time) and the schedule performance index (time) are clear indicators that if performance does not change, the remaining work on the critical path can take longer. Thus, the metrics indicate a recovery action is needed to return the project or programme performing to plan. An analysis for the management actions needed to achieve this should be done.



Key

X	performance period	—■—	earned schedule (cumulative)
Y	time	—■—	independent estimate at completion (time)
Z	schedule performance index (time)	—▲—	schedule performance index (time) (cumulative)
—■—	original critical path	—■—	performance period

Figure 23 — Graph of independent estimate at completion (time) versus earned schedule and schedule performance index (time) for path 1, 5, 6 and 7



Key

X	performance period		earned schedule (cumulative)
Y	time		independent estimate at completion (time)
Z	schedule performance index (time)		schedule performance index (time) (cumulative)
	original critical path		performance period

Figure 24 — Comparison of independent estimate at completion (time) and schedule variance (time) for path 1, 5, 6 and 7

9.2.5 Proposed recovery action for the critical path

Trends, patterns and forecasts on the critical path can be shown by using the following queries and actions.

a) How are schedule variance (time) (see 8.3.2) and schedule performance index (time) (see 8.3.3) trending on the critical path when compared with the rest of the project or programme?

b) Is the value of the independent estimate at completion (time) (see 8.3.4) versus the deterministic critical path duration increasing or decreasing?

c) Are the values for critical path length index with schedule variance (time) trending in the same direction? Are these metrics trending in the same direction as the to-complete schedule performance index for the critical path?

d) Are the number of critical and near-critical activities staying the same or are the number increasing? Are there any identifiable trends or patterns emerging that can help with the recovery action?

The options to control the project or programme's period and cumulative performances should be analysed and reviewed. If there is an increase or decrease overtime, the following activities should be taken:

a) activities should be prioritised;

b) project or programme assignments should be adjusted;

c) project or programme should be renegotiated;

d) critical path duration should be determined;

e) determinations regarding use of schedule reserve, treatment of risks and use contingency should be done.

If change control is needed and this action affects the schedule and the critical path, such change should be implemented before the next period, otherwise calculations, analysis and decisions can be adversely affected.

9.3 Integrating critical chain scheduling

9.3.1 General

Critical chain scheduling should combine both activity and resource constraints to develop a plan that demonstrates how the project or programme can be completed on time or sooner.

The five-step process using the theory of constraints should be:

a) identify the system constraint;

b) decide how to exploit the constraint, such as increase productivity or increase capacity;

c) subordinate everything else to the previous decision, such as make changes not to overburden the constraint;

d) elevate the constraint, such as change the way the constraint is used;

e) examine the impact of the change on other parts of the process and check if there is a new constraint that limits system performance and return to first step.

Different types of constraints should be identified (see Table 15).

Table 15 — Constraints types

Constraint type	Internal/external	Description
Market	External	Exists when there is a deficit of capacity or productivity related to the market needs
Resources	Internal	Includes production bottlenecks, long lead times, rework, quality and human resource availability
Material	External	Includes internal resource bottlenecks as: imposed activity time constraints, activity rework and decision process requirements, activity technological, manpower missing availability or time fix deliverables or milestones
Supplier	External	Exists when unreliable suppliers, such as unacceptable product or service quality, delivery issues, or insolvency problems impacts project activities
Financial	Internal	Exists when there is insufficient money to meet project short-term commitments as, for example, activity development or deliverable accomplishment
Knowledge/ competence	Internal	Exists when missing knowledge or competencies occurs in order to develop project activities needed to support project deliverables typically found in research and development projects
Policy	Internal	Exists when team, project's or programme's or organization's policies, such as industrial practices, supplier or personnel selection, or project management plans imposes limited action to the project or programme activities and development

The constraints in projects or programmes can be the allocation and use of resources. These constraints can be activity time, people, hardware, software, facilities, machinery, equipment or money.

9.3.2 Benefits of adopting and integrated critical chain project management and earned value management approach

The integration and alignment of the earned value associated with performance control and estimate indicators within the critical chain buffer management practices should advance project or programme performance control. The critical chain time risk management, the linking of scope and time management to risk management should be enhanced by the earned value management change control techniques

considering the critical chain risk protection buffers, costs and potential time, and cost change impacts during implementation. The critical chain project or programme network process can enable:

a) improved chances of project success;

b) reduced project duration and costs;

c) reduced confusion arising from multitasking;

d) increased ability to focus on one activity at a time;

e) reduced focus on and reduced numbers of common-cause risks;

f) increased focus on special-cause risks;

g) reduced numbers of changes;

h) reduced amounts of rework;

i) reduced insertion of new priority tasks;

j) reduced complexity of project measurement;

k) reporting buffer to help define decisions;

l) conducting measurements to support decisions about resource priorities and whether to plan or act;

m) reduced delays due to resource conflicts.

9.3.3 Critical chain scheduling process

9.3.3.1 General

During the earned value step 3, schedule the work, critical chain scheduling should:

a) create an as late as possible project or programme network;

b) identify the resource constraints, working backwards from the end date;

c) identify the critical chain;

d) subordinate other activities, resources and network paths to the critical chain;

e) analyse times and costs associated with the implementation of post-impact risk recovery actions;

f) add time and cost buffers within the chain.

9.3.3.2 Step 1: Create the as late as possible project or programme network

This process step should involve integrating protective feeding buffers and a buffer in the schedule to support risk treatment actions, which should be provided and added to the network, as new activities from the work breakdown structure element.

In addition, activity duration estimates should be provided by using defined target durations within the desired confidence level to be met, typically percentile 50 or other management option, such as the mode or most frequent duration, or the expected mean or average duration, based on the available information about the activity duration behaviours considering resources working full-time on the activity, in other words, with no multi-tasking or pre-emptive behaviours.

9.3.3.3 Step 2: Identify the resource constraints

Working from the last activity in the network, one should identify the first resource constraint that needs to be resolved. This constraint can be either the resource used on an activity nearest to the completion date

or the activity that shows the highest degree of conflict or overallocation. A resource profile, breakdown and representation of a resource that can be used to assist with an activity, can be used to focus on one resource at a time. One technique to remove the resource conflict can be resequencing the resource and the associated activity earlier in the project timeline. The work and associated budget together should be moved together.

Until identified resource constraints have been resolved, one should continue to review the network.

The network as late as possible logic should not be changed, as a result of anticipating the activity for constraint resolution that should be resolved, as the activities and resources are reviewed in reverse-order sequence. New resource profiles can be created, if deemed appropriate.

9.3.3.4 Step 3: Identify the critical chain

In order to identify the longest chain of dependent activities, the resource constraints should be checked and resolved, as well as any activity resequencing that can shorten the overall duration without creating new schedule constraints.

A buffer should be added to the end of the critical chain, according to the organization, the project or programme governance, the contract, or the chosen buffer sizing method. One should frequently consider the removed activity duration variations from the chain activities. If possible, a buffer sizing method that is risk-based should be used, such as a risk analysis technique.

NOTE If a Monte Carlo simulation is not available, then, analytical methods and empirical rules can be put in place for buffer sizing.

9.3.3.5 Step 4: Subordinate other activities, resources and network paths to the critical chain

Once the critical chain has been identified, one should protect the critical chain by adding in feeding buffers at the end of the non-critical chains feeding critical chain activities. One should be aware that non-critical chains should link into the critical chain at some point in the network. If the network uses milestones to indicate the end of a phase, stage or gate, a feeding buffer should be added directly before those milestones.

The earned value management basic concepts of the project should be performed by a progress review that should be done by comparing how much was spent against how much was planned, using:

a) the schedule variance;

b) the cost variance;

c) the schedule performance index;

d) the cost performance index.

These metrics can be aligned within the critical chain buffer management perspective to estimate cost and schedule performance impacts considering the estimated buffering.

When the added feeding buffer causes the chain to become longer than the critical chain, this activity can be no longer needed. The project or programme management team should analyse the schedule and critical chain prior to determination that the feeding buffer is not needed. In this instance, the feeding buffer can be resized to enable it to remain non-critical and the buffer should be updated to address the remaining unprotected duration variation.

Where possible, one should add resources to specific activities or work breakdown structure elements to break any resource conflict deadlocks. In these cases, one should make sure that the schedule quality is not compromised.

9.3.3.6 Step 5: Baseline the project schedule and inform stakeholders

Once the preceding process steps have been completed and the stakeholders have confirmed the schedule, as constructed, the schedule should have an established baseline, approved and brought under formal

change control. In addition, the basis of schedule, the basis of estimate, the risk register, the responsibility assignment matrix and the control account plans should be updated prior to publication.

9.3.4 Critical chain and earned value management control

9.3.4.1 General

The critical chain scheduling control should integrate a buffer management approach considering the impact of the estimated buffer use in a graphical format, known as a fever chart. A fever chart presents in the X-axis the percentage of the activities of the project or programme completed based on the longest activities chain feeding the chain endpoint and in the Y-axis the percentage of the buffer consumed within the corresponding control dates, divided in three main decision support areas that can be color-coded for ease of interpretation: red for recovering action, yellow for recovering plan and green for maintaining the monitoring action.

In combining earned value management with critical chain buffer control, these steps should be followed:

a) quantify the earned value management indicators on cost and schedule of the buffers used;

b) calculate the earned value management buffer performance index schedule and cost of those buffers;

c) estimate the cost and duration impact from the end point of the chain;

d) estimate buffer cost and estimate buffer duration at end chain completion;

e) integrate results in the critical chain fever chart and analyse for next actions based upon the integration results.

For the management decision process, one should support the classical three red, yellow and green logic within an earned value management performance schedule and cost matrix (see Table 16).

Table 16 — Earned value management buffer performance

		Cost buffer variance		
		Green	**Yellow**	**Red**
Schedule buffer variance	**Green**	Keep monitoring, no action is needed	Pay increased attention to the costs and plan for corrective action	Take cost saving actions per saving the project or programme value and work speed, as much as possible
	Yellow	Check schedule more often and monitor deeper activities work and plan for corrective action	Prepare plan to speed up work and reduce cost, as much as possible	Take cost saving actions within the speed up schedule recovery plan
	Red	Take work speed up actions, while keeping cost as is, as much as possible	Take work speed up actions within plan cost recovery plan	Take all actions planned for speed up activities and cost reduction

9.3.4.2 Step 1: Quantifying the earned value management costs and schedule of the buffers

The earned value management schedule and cost indicators of the added critical chain management buffers should be computed and added to the computed earned value management indicators of the baseline without the buffered costs considering the activities target baseline durations and associated earned value management cost for activities of the associated chain. The earned value management cost buffer and schedule buffers can be calculated by choosing a desired method or one directed by organizational, project or programme governance or contract.

9.3.4.3 Step 2: Calculate the earned value management performance of the buffers

The cost status can be retrieved based upon the percentage of the cost buffer considering the work done based on cost, as well as the duration status that can be retrieved based on the percentage of the schedule

buffer and the work done on time calculated for the control point that can be add to the critical chain buffer management fever chart, in order to integrate and monitor earned value management performance schedule and cost performance. The following formulae should be used:

a) $P_C = \frac{CV}{CB}$

where

P_C is the percentage of cost buffer;

CV is the cost variance;

CB is the cost buffer;

and

$$W_C = \frac{EV}{BCAC_0}$$

where

W_C is the work done based on cost;

EV is the earned value;

$BCAC_0$ is the budget cost at completion regardless the cost buffer.

b) $P_T = \frac{SV_T}{SB}$

where

P_T is the percentage of schedule buffer;

SV_T is the schedule variance (time);

SB is the schedule buffer.

with

$$W_T = \frac{ES}{BPD_0}$$

where

W_T is the work done based on schedule;

ES is the earned schedule;

BPD_0 is the baseline duration regardless the schedule buffer.

9.3.4.4 Step 3: Estimate the earned value management performance impacts of the buffers

For the buffers estimated cost at completion and the estimated duration at completion, the following formulae can be considered:

a) $ECAC = ECAC_0 + CB_{\mathrm{A}}$

where

$ECAC$ is the estimated cost at completion;

$ECAC_0$ is the estimated cost at completion regardless the cost of the add buffer;

CB_A is the adjusted cost buffer earned schedule; CB_A is adjusted cost buffer in control considering the percentage of cost buffer, P_C, and the cost performance index.

$$CPI = \frac{EV}{AC}$$

where

CPI is the cost performance index;

EV is the earned value;

AC is the actual cost.

b) $EDAC = EDAC_0 + SB_A$

where

$EDAC$ is the estimated duration at completion;

$EDAC_0$ is the estimated duration at completion regardless the scheduled buffer;

SB_A is the adjusted schedule buffer in control considering a percentage of schedule buffer, P_T, and the schedule performance index.

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

where

$SPI\ (t)$ is the schedule performance index (time);

ES is the earned schedule;

AT is the actual time.

The earned value management performance indicators can then be added to the critical chain buffer control fever chart in order to manage the performance during implementation in an integrated way (see Table 16).

9.4 Integrating earned schedule

In the earned value management methodology, the schedule performance of a project can be analysed and measured under the two complementary perspectives of volume of work and time (see 7.3). With earned schedule analysis focus should be on the time perspective.

This focus should be on the overall time-delay or time-saved to date.

The two dimensions of work volume and time should be considered in an integrated manner for schedule variance and its causes, as well as to assess the impacts on the other performance and management dimensions of cost, technical performance, resource and risk.

9.5 Integrating agile development

9.5.1 Agile development is a set of development methods in which solutions should evolve through collaboration between and among self-organized, cross-functional teams. Agile development should focus on delivering the highest priority capability to stakeholders, as quickly and affordably as possible. Agile development methods should focus on allocating work and measuring progress in small increments (see Figure 25).

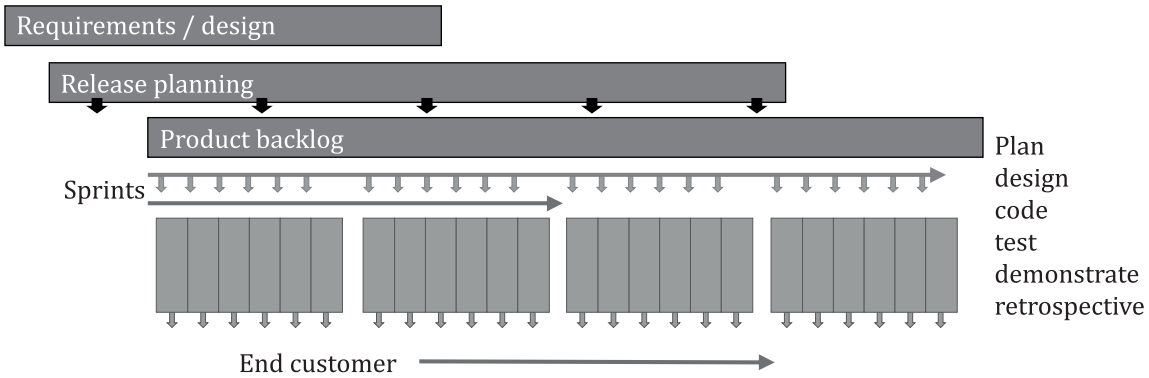


Figure 25 — Typical software agile development process showing deliveries in small increments

Agile development methods should have similar project and programme management governance and oversight as predictive project and programme implementation. The use of earned value management on agile projects and programmes should provide an ability to measure progress and forecast cost, schedule and technical performance.

9.5.2 Agile considerations for each of the eleven earned value management process steps should contain (see Clause 5):

a) agile projects decompose work into end-to-end behavioural threads that can be implemented incrementally in short timebox frames;

b) end-to-end threads should be decomposed into a hierarchy to facilitate progress.

In the agile environment, scope or contractual requirements are broken down into capabilities that are further broken down into features at which point agile implementation and earned value management progressing aligns (see Table 17).

Table 17 — Example of a sprint backlog hierarchy roll up of capabilities, features and stories

WBS	EVM level	Product item
1.1	WBS	Prime mission subsystem
1.1.1	WBS	Prime mission hardware
1.2	WBS	Prime mission software
1.1.2.1	CA	Capability A
1.1.2.1.1	WP	Feature A1
		Story A1.1
		Story A1.2
		Story A1.3
1.1.2.1.2	WP	Feature A2
		Story A2.1
		Story A2.2
		Story A2.3
		Story A2.4
1.1.2.1.3	WP	Feature A3
		Story A3.1
		Story A3.2
		Story A3.3
		Story A3.4

9.5.3 In addition:

a) specifications in an agile environment should be broken down into capabilities, which should be further decomposed into features at which point agile implementation and earned value management progress measures converge;

b) timebox frames are increments that can be three months in duration and sprints that can be two to three weeks in duration;

c) the definition of work should be prioritized and documented in a backlog.

Work should be assigned collaboratively to development teams.

9.5.4 Work should be planned and scheduled with prioritization of high priority work to be done in the near-term:

a) plan and schedule work incrementally, starting with a product roadmap that describes the notional timeframe for the implementation of objectives;

b) define and prioritize the work to be done; with higher priority, near-term, within a single sprint, a short timeboxed period;

c) work accomplished at the sprint level rolls up to the progress of features and then to capabilities;

d) feature progress is rolled into the integrated master schedule (see Figure 26).

Once progress has been put into the schedule, the earned value management cost reporting can occur per organizational, project or programme agile governance processes and procedures or contractual terms governing agile project or programme management.

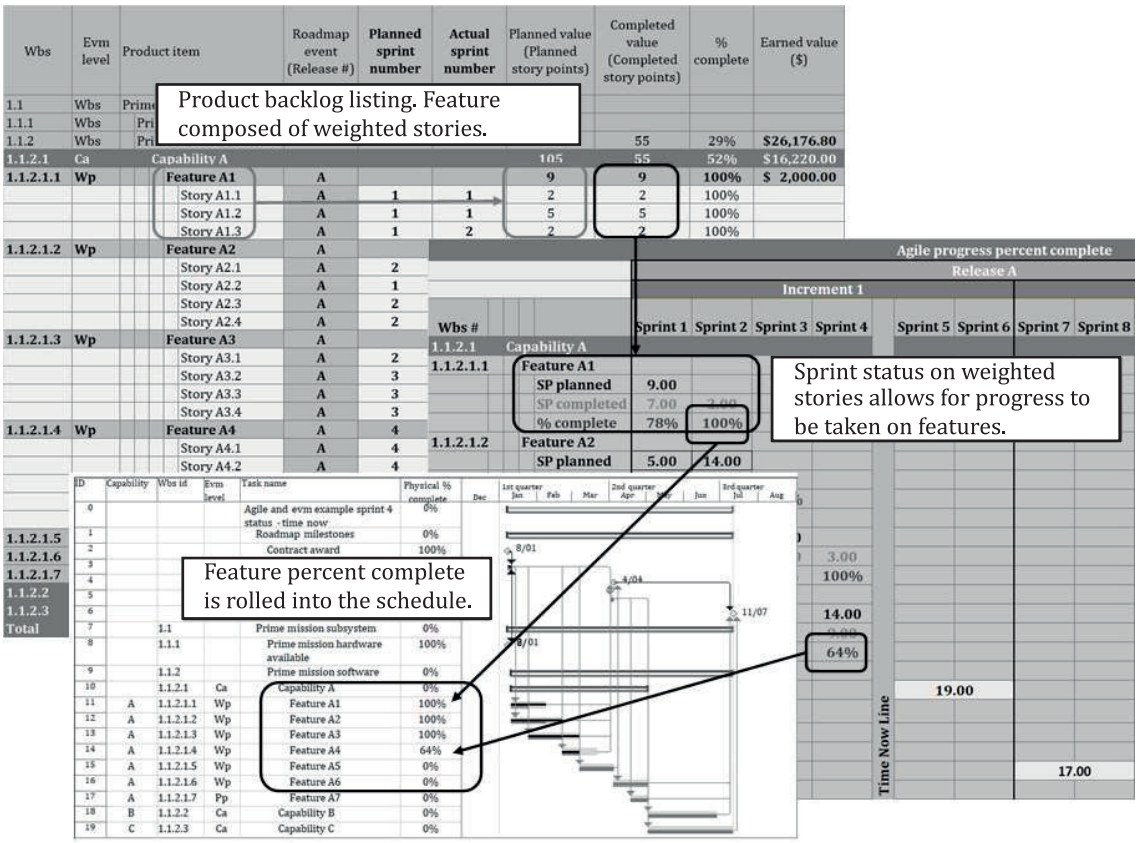


Figure 26 — Example of an integration of sprint status, product backlog and integrated schedule

To use the integrated master schedule using agile, one should understand and use the agile integrated master schedule, which can be less detailed than for predictive project or programme management.

9.5.5 A time-phased budget should be developed that should be:

a) used to track progress against a challenge;

b) managed against a cost target so that, as work is performed, variances against the plan should occur to enable the management team to manage;

c) done using broad categories, such as tee-shirt sizing and story point estimating to understand the risk, complexity and the overall effort of a piece of work;

d) related to work effort, an estimate of the cost to complete should be done but not be as rigorously as traditional cost estimates.

9.5.6 The time-phased budget should be developed that demonstrates:

a) accomplishment at every level of the implementation;

b) expression to reflect as closely as possible physical progress;

c) hierarchical physical progress rolled up into the schedule.

9.5.7 The setting of the performance measurement baseline should involve:

a) product roadmap, broadly phasing the work;

b) prioritized and decomposed work;

c) detail planned, near-term work decomposed into items that can be managed as a sprint;

d) documented decomposition of work in an agile tool for tracking progress and maintaining a view of remaining work;

e) hierarchical time-phased planning that can be integrated with the master schedule.

9.5.8 The actions that should be authorized and performed to accomplish the work are:

a) product owner should prioritize from the product backlog, which is the authorization of work;

b) team should perform by accepting work from the top of the priority list;

c) sprints should be performed; a series of sprints are performed until completion of the work as prioritized or otherwise instructed.

9.5.9 Accumulation of various progress reports and the reporting of performance indices should be:

a) provided in the form of completed stories, features and capabilities;

b) provided in increments of releases, as collected and accumulated daily in the agile tool being used, while being consistent with earned value governance.

9.5.10 In analysing the performance indices, a variety of metrics and reports should be used to help managers include:

a) velocity: team-based metric of capacity;

b) story accomplishment;

c) feature accomplishment;

d) capability accomplishment;

e) release status in percent complete.

Integrating agile performance indices should be integrated into the overall project or programme, which can include non-agile work.

9.5.11 The step of taking management action allows for:

a) management action to take place based on variances and risk at each level of performance;

b) sprint reviews and increment reviews;

c) continuous grooming of the product backlog to adjust to daily progress;

d) visibility into the progress for end-users and other stakeholders;

e) adjustment of priorities and objectives, as necessary based on overall project or programme and external influences.

9.5.12 The maintenance of the baseline should allow for the following:

a) allow the work to be baselined and maintained in the agile tool and updated during each planning event, sprint or project or programme increment;

b) start in the integrated master schedule and be maintained, as part of the integrated master schedule update process, either weekly or biweekly;

c) allow for maintaining top to bottom hierarchical traceability between the work and the integrated master schedule.

9.6 Integrating project or programme management office

9.6.1 General

Project and programme office governance should include a framework to determine the level of guidance, support and documentation to be provided to each project and programme. The governance can assist in the justification for a dedicated office. This decision is typically based on the level of delivery confidence or risk pertaining to the project or programme.

9.6.2 Activities of a project or programme management office

The activities of project and programme management offices can include:

a) developing, tailoring, championing, implementing and embedding standards, processes, procedures and templates, such as the earned value management system and its component elements;

b) selecting, implementing and supporting tools that underpin the standards, processes and procedures and provide a central repository of information, such as scheduling tools;

c) delivering education, training and mentoring to project and programme managers and team members, such as training on the techniques used within earned value management;

d) auditing and assuring the use of standards, processes, procedures, and templates, such as facilitation of the formal process of authorizing the commencement of project work through stage gates within the lifecycle;

e) gathering, validating, verifying, collating, evaluating, communicating, and disseminating data, such as regular collection and accumulation of performance indices, identification of patterns of causation in performance and communicating;

f) building and maintaining organization delivery capability and capacity to match current and future needs, such as assessing earned value management competence;

g) performing continuous improvement of project and programme management and delivery, such as implementation of actions from earned value management system reviews;

h) provisioning of resources to undertake other management activities, such as maintenance of the management action list.

9.6.3 Benefits of a project or programme management office

The overall benefits of a project or programme office to the functions and delivery of earned value management should be the following:

a) reduced costs in delivery;

b) consistent application of earned value management governance, processes and practices across the projects and programmes;

c) availability of timely and accurate decision enabling information;

d) continuous improvement of earned value management processes, procedures, guidance and reporting within the organization or contract.

9.7 Integrating continuous improvement

9.7.1 General

Earned value management can identify areas of project or programme management that need improvement.

Earned value management can have three primary uses in continuous improvement (see 9.6.2). First, promoting better management practices in project or programme delivery organizations, the standardised earned value management process model can be a foundation that reinforces good practice and matures organizational behaviour. Second, once process standardisation is in place, measurement of performance can be conducted, which not only facilitates project control but can subsequently be used as a guide to determine which processes need improvement. Third, providing performance data, which should be available to teams and executive management, so the results of continuous improvement can be measured.

9.7.2 Continuous improvement

Continuous improvement should target either incremental changes over time or improvements that are achieved through notable and immediate changes.

Continuous improvement should be identifiable, verifiable and able to be put into practice. The following criteria should be identified and addressed in a continuous improvement plan:

a) performance aspects that need to be improved;

b) current performance;

c) target performance;

d) levels of performance that should trigger change for incorporation into everyday practice;

e) data that should be targeted, gathered, collated and assessed.

Earned value management forecasting and trend analysis through the use of key performance indicators can help identify what and when to change. Improvements in cost and time can be directed into the cost and estimating systems and practices informing the earned value management system.

Improvements in behaviours and culture can be reinforced by training, governance processes and procedures or by contractual obligation.

9.7.3 Types of continuous improvement processes and methodologies

9.7.3.1 General

Organizations that implement continuous improvement have numerous methods to choose to:

a) address process flow and waste issues;

b) focus on eliminating waste using a set of standardized tools and methodologies that target organizational;

c) focus on eliminating defects and reducing variation.

Each organization is unique and should tailor their chosen methodology to their individual environment and needs. However, one common need across methodologies is for performance data. An earned value management system can provide accurate cost and schedule performance data as a valuable input to continuous improvement methodologies.

Using analysis techniques, such as root-cause analysis, can be a way to identify the drivers of performance issues. Earned value management systems can support this analysis by the ability to identify lower level elements, such as control accounts and work packages that are driving variances in planned performance. The cost and schedule performance metrics used in earned value management analysis, such as cost variance, schedule variance, schedule variance, cost performance index, schedule performance index and schedule performance index time, can also be used as thresholds to undertake root cause analysis within the work breakdown structure.

9.7.3.2 Measurable

The impact of continuous improvement can only be measured when one can quantify the results. One should understand how the process is implemented and if it is having the desired effect. This understanding should help one set the objectives for the future and enable each performance organizational unit to be working toward the same result. Earned value metrics, as well as other analysis processes provide the methods for measuring progress to highlight needed improvements.

9.7.3.3 Continuous

Continuous improvement should be a long-term activity and investment. It should be a repetitive cycle that draws upon project and programme data to highlight potential improvements. Control methods, such as earned value management, support continuous improvement and can be used to enable improvements to occur frequently and continually to increase productivity, reduce variation and remove waste. There should be a change in behaviour and culture within an organization, as well as a supportive organizational or contract environment.

9.7.4 Core continuous improvement functions aligned with earned value

The following core functions of continuous improvement can align with earned value:

a) project tracking: data on physical progress should provide valuable data for cost-benefit analysis;

b) project planning: as a part of the plan, do, check, act process, earned value can help provide a sound basis for planning by aligning needs with work and the performing organization;

c) risk management: processes for identifying risk treatment for uncertainty can become part of the continuous improvement process;

d) use of data: earned value management data can be used to produce confidence limits, forecasts, trends and learning curves. Data from project performance using physical progress can be captured and analysed to identify activities that did not perform as expected and begin the process of understanding what can be done to avoid the same events occurring in future. Analysis of the metrics from projects or programmes over time can help with the development of expectations and thresholds for similar projects or programmes in the future;

e) cost-benefit analysis: contribution of the project or programme to one or more benefits can be calculated using the project's or programme's performance data and monitored as the project or programme progresses. The return on investment can also be calculated for the project or programme as delivery progresses. When it has been identified that the return on investment value is unfavourable, corrective actions can be identified and taken.

At an organizational level, if poor project or programme outcomes are being achieved, the organization should attempt to identify the particular process steps causing the issue. Once the root cause is identified, action can be taken to re-engineer the process. If a process step is continually generating large schedule variances, it is likely causing schedule slip across all the projects or programmes of an organization. Once identified, the root cause can be examined and the proposed improvements made.

Beyond the application to controlling projects or programmes in the delivery phase, earned value management performance data can be captured in a project or programme estimates database. The historical data, aggregated over time, should not only be useful for the planning and implementation of new projects or programmes, but for analysis of improvement initiatives.

9.8 Integrating governance

Governance, whether from organizational, project or programme, or contract, should be integrated with earned value management to assist and enable the project or programme management team to achieve the identified objectives.

Project or programme governance from organizational, project or programme governance or contract should be considered to be an important enabling tool for project or programme success. The governance should be scaled and shaped to address the level of complexity of investment[5]. Governance should set an adaptable framework, using organizational gateway reviews, an analysis or evaluation done before moving to the next stage of work, which should guide project or programme success, creating transparency and confidence in decision-making, clarity of roles and responsibilities and consideration of stakeholder interests[5].

Governing bodies and other structures should recognise and assist the project or programme management team to manage risk in a way that is most likely to achieve the desired outcomes, deliverables or benefits as stated in the business case or similar documentation of the objectives.

Inadequate governance can contribute to project or programme failure[5].

A primary objective of governance should be making decisions with efficacy and transparency, as defined within the governance documentation.

Project and programme governance should be about guiding and controlling the process for the organization or external customer and delivering the anticipated outcomes, deliverables and benefits. The organizational or contract outcomes and benefits that can result should be directed to the intended beneficiaries.

Annex A

(informative)

Worked example

A.1 Scope approval

Before the 11 steps of earned value management can be implemented (see Clause 5), a project or programme should start with the definition of the scope needed to accomplish the objectives, or fulfilment of the organisational strategy. This scope should be captured in an approved business case, project plan, requirements specification or equivalent documentation.

This worked example is based on an approved business case, which describes the scope for the design and development of a new automobile.

A.2 Step 1: Decomposition of the project or programme scope

In this step, the new automobile project team defines what deliverables or outcomes are needed and captures them in a work breakdown structure (see 3.1.89 and Clause 5).

Figure A.1 shows one possible view of a work breakdown structure for the new automobile project. The work breakdown can be shown in outline form, hierarchical table or tree diagram.[6]

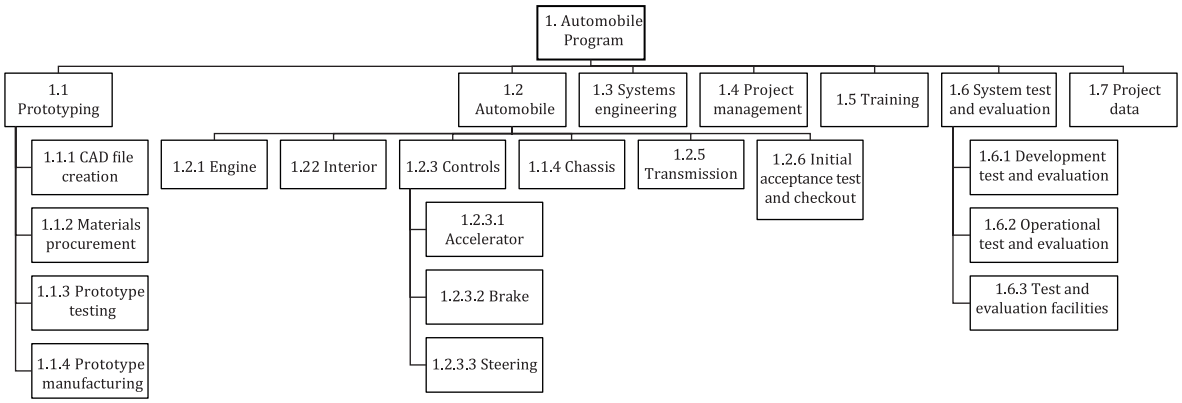


Figure A.1 — Example of a hierarchical work breakdown structure for automobile program

A.3 Step 2: Assign responsibility for project work

Once the work breakdown structure is defined, responsibilities for each of the elements can be assigned and documented in a responsibility assignment matrix. The responsibility assignment matrix is an informed chart describing the participation by roles in completing activities or deliverables (see Clause 5).

Defining the interfaces between the organisational structure and the work breakdown structure allows functional managers within the organization or organizations to determine the level of expertise needed to perform the work within the control accounts and assign control account managers (see Clause 5).

NOTE The responsibility assignment matrix can be shown in a variety of graphic forms containing the information stated in 5.3. In Figure A.2 the responsibility assignment matrix is presented in a monetary format, where the budgets for each control account are shown.

		Control account managers					
WBS code	Control account	Development manager	Systems engineering manager	Project manager	Training lead	Test manager	
1.1	Prototyping	$ 900 000					
1.2	Automobile	$ 42 500 000					
1.3	System engineering		$ 12 000 000				
1.4	Project management			$ 14 000 000			
1.5	Training				$ 4 000 000		
1.6	System test and evaluation					$ 7 500 000	
1.7	Project data			$ 2 500 000			
Total allocated budget							$ 83 400 000

Figure A.2 — Example of a monetary responsibility assignment matrix for new automobile project

A.4 Step 3: Schedule the work

Once responsibility has been assigned for the work, the control account managers should break the scope of each control account down into sequenced, resource-loaded work packages and the tasks in those work packages. Those work packages should be sequenced in the order needed to produce the outcomes that increase the maturity of the deliverables.

The schedule should show the order in which the work packages should be performed to enable the accomplishment of criteria within the project or programme plan and is a breakdown into specific accomplishments. Each specific accomplishment should be decomposed into specific criteria, in other words, defined measures of performance, the key performance parameters and the technical performance measures. The project or programme plan should be used to develop a time-based schedule that shows a networked, contractual, multi-layered schedule showing the detailed activities needed to accomplish the work effort (see Figure A.3).

The schedule should show:

a) what finished looks like for each work package supported by objective evidence of completion;

b) order of the work needed to reach finished for each work package and groupings of work packages up control accounts and the overall project or programme;

c) resources needed to reach finished for each work package up to control accounts and the overall project or programme;

d) identified risks to achieving “finished” with their associated treatment strategies;

e) measured physical progress toward “finished” in units meaningful to the decision-makers.

Automobile program schedule

Task Name	Duration	Start	Finish
Project: Automobile Program	185d	Mon 3 Jan	Fri 16 Sep
1.1 Prototyping	100d	Mon 31 Jan	Fri 17 Jun
1.1.1 CAD file creation	20d	Mon 31 Jan	Fri 25 Feb
1.1.2 Prototype materials procurement	30d	Fri 25 Feb	Fri 8 Apr
1.1.3 Prototype testing	35d	Mon 2 May	Fri 17 Jun
1.1.4 Prototype manufacture	45d	Mon 14 Mar	Fri 13 May
1.2 Automobile	60d	Mon 16 May	Fri 5 Aug
1.2.1 Engine	10d	Mon 16 May	Fri 27 May
1.2.2 Interior	10d	Mon 30 May	Fri 10 Jun
1.2.3 Controls	10d	Mon 13 Jun	Fri 24 Jun
1.2.4 Chassis	10d	Mon 27 Jun	Fri 8 Jul
1.2.5 Transmission	10d	Mon 11 Jul	Fri 22 Jul
1.2.6 Initial acceptance test and checkout	10d	Mon 25 Jul	Fri 5 Aug
1.3 Systems engineering	185d	Mon 3 Jan	Fri 16 Sep
1.4 Project management	185d	Mon 3 Jan	Fri 16 Sep
1.5 Training	55d	Mon 4 Jul	Fri 16 Sep
1.6 Systemtest and evaluation	15d	Mon 8 Aug	Fri 26 Aug
1.6.1 Development test and evaluation	10d	Mon 8 Aug	Fri 19 Aug
1.6.2 Operational test and evaluation	5d	Mon 22 Aug	Fri 26 Aug
1.6.3 Test and evaluation facilities	15d	Mon 8 Aug	Fri 26 Aug
1.7 Project data	185d	Mon 3 Jan	Fri 16 Sep

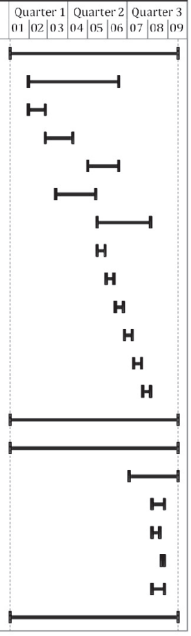


Figure A.3 — Schedule showing project periods, main milestones, processes and procedures using disciplines and parallel tasks

Figure A.4 shows the schedule for the automobile program aligned to level 3 of work breakdown structure shown in Figure A.1.

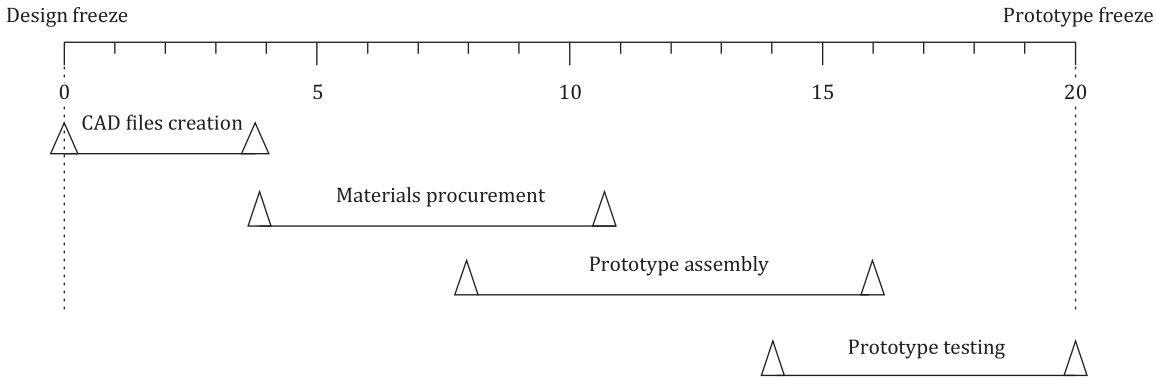


Figure A.4 — Schedule showing prototyping elements of the new automobile project schedule

Figure A.4 shows the prototyping control account derived from the automobile program schedule shown in Figure A.3. This information will be used to demonstrate and explain the remaining earned value process steps in this worked example.

A.5 Step 4: Develop time-phased budget

A.5.1 Resources needed to complete work should now be assigned to the control accounts in the schedule. The resource needs and targets for each activity should be loaded or each work package assigned burdened labour cost for the hours assigned to the staff developing the deliverables, outcomes or outputs. The material, facilities or any other cost for the time-phased work to produce the deliverables should be assigned to the work activities.

A.5.2 The steps for developing the time-phased budget should be:

a) using the schedule activities – assign labour, materials and facilities reflecting the effort necessary to accomplish the deliverables in the work breakdown structure;

b) estimating the labour hours for the planned work and cost of the resources for activities to accumulate the total costs to complete the project or programme;

c) cross-checking the project or programme budget and contractual cost constraints to confirm that there are sufficient resources to complete the project or programme as planned;

d) developing a cost and schedule baseline for the project or programme that includes the risk treatment actions needed to achieve the residual risk position.

A.5.3 The outputs from developing the time-phased budget should be:

a) cost performance baseline that should produce a formal time-phased budget for estimating, tracking, and controlling the overall cost performance of the project or programme;

b) funding requirements of the project or programme that should identify the requirements for the total project or programme funds, including the cost baseline and management reserve;

c) updated documents of the project or programme, including the schedule, risk register and cost estimates (see 5.7).

Figure A.5 shows the outcome of the budgeting process for the prototyping control account of the automobile project. The prototype control account effort has been broken down further to illustrate the devolution of budget to the work package level.

The work breakdown structure elements include the work scope for computer-aided design file creation, materials procurement, prototype testing and within prototype manufacture, a further breakdown of chassis/bodywork, engine and transmission, controls and interior work packages. These work packages sit within the prototyping control account.

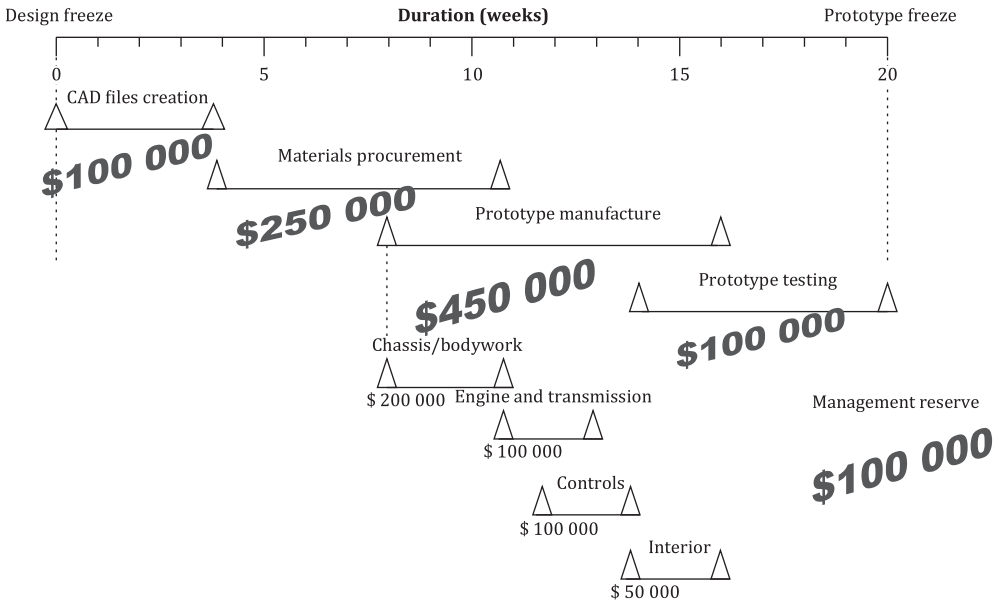


Figure A.5 — Assignment of budget to the prototyping work breakdown structure elements of the new automobile project

NOTE Figure A.5 shows the prototyping control account derived from the automobile program schedule shown in Figure A.4. This schedule is used to demonstrate and explain the remaining earned value process steps in this worked example.

A.6 Step 5: Assign objective measures of performance

A.6.1 General

Work packages should be assigned the objective measure of performance, or earned value techniques, that best suit the work package. These are used to measure the degree of completion of work packages and generate the earned value data. The most common earned value techniques are discussed in the context of the new automobile prototyping control account (see 5.6).

A.6.2 Milestones complete

In Figure A.6, the activities "steel on site" and "steel body panels formed" within the new automobile project are expected to occur within the October reporting period, so the milestone earned value technique is appropriate. "Steel on site" is an event, while "Steel body panels formed" is an activity. In both instances, the budget for resources applied to each of these events is assigned to the completion of the task.

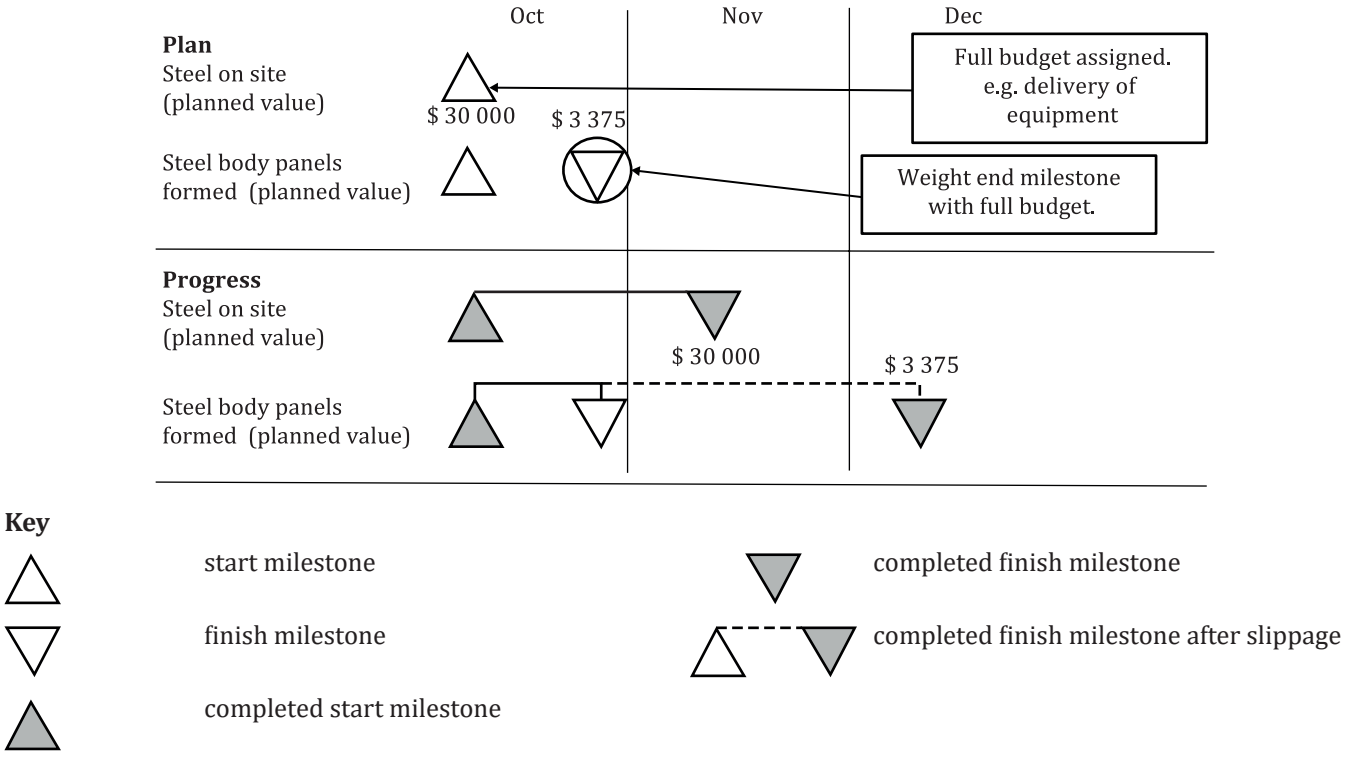


Figure A.6 — Milestones complete earned value technique example

Figure A.6 shows that while the planned value for steel on site was $ 30 000 in October, earned value cannot be claimed until November, when it actually arrived. For steel body panels formed, despite progress towards completion in November, it was not completed until December, so its planned value of $ 3 375 cannot be claimed until that time.

A.6.3 Estimate or percentage complete

On the new automobile project this earned value technique can be applied to systems engineering, prototype assembly or system test and evaluation work (see Figure A.7). Some organisations can have policies in place restricting the maximum claimable percentage complete prior to the work package being completed, for example, 80 %.

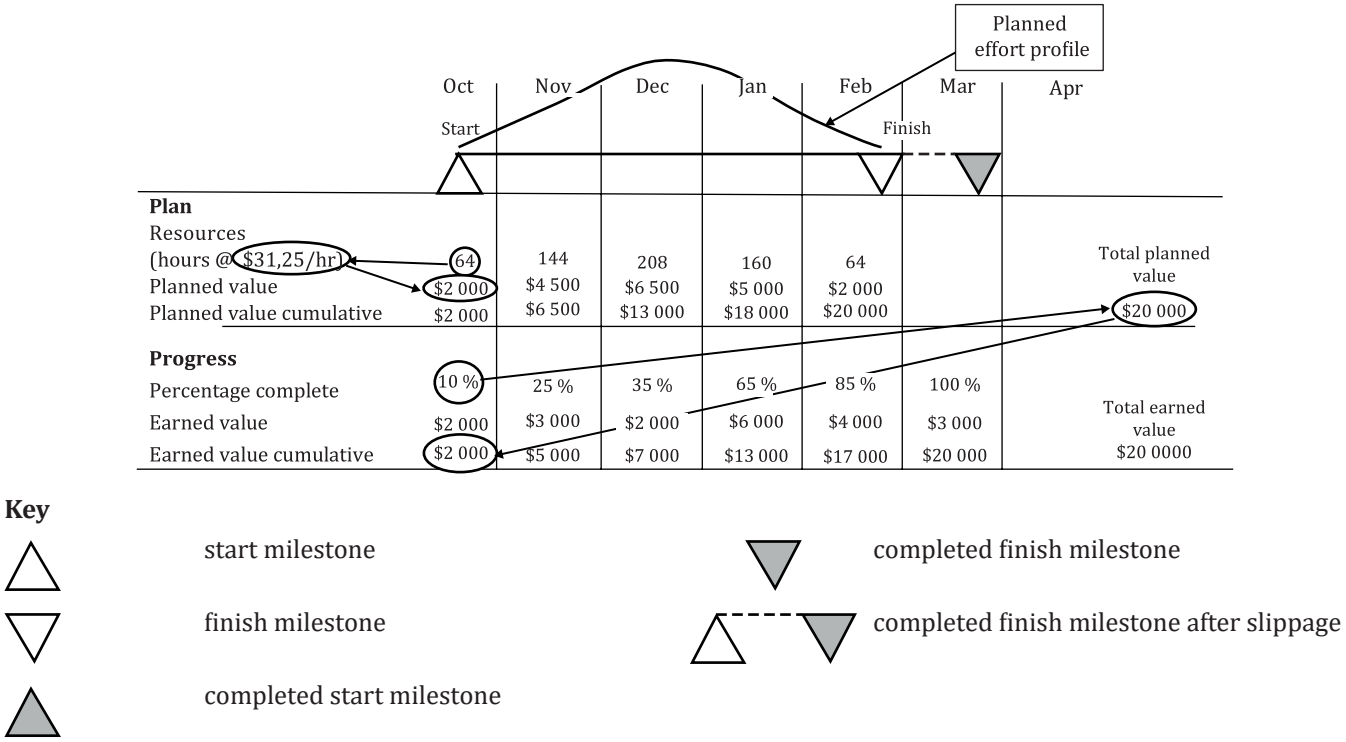


Figure A.7 — Percent complete earned value technique example

For the systems engineering work package in Figure A.7, the resource profile results in a total planned value of $ 20 000. As the work progresses, the control account manager determines how much of the $ 20 000 work scope has been accomplished each month. Less work is earned value than the planned value in November and December, resulting in a negative schedule variance. Although more work is performed than planned in January and February, it is not enough to avoid the work package completion slipping into March.

A.6.4 Units complete or equivalent units

Figure A.8 provides an example of units complete being used to measure the fitting of sets of four tyres during the full rate production phase of the new automobile project. This example also demonstrates the use of hours rather than dollars as a unit of measurement.

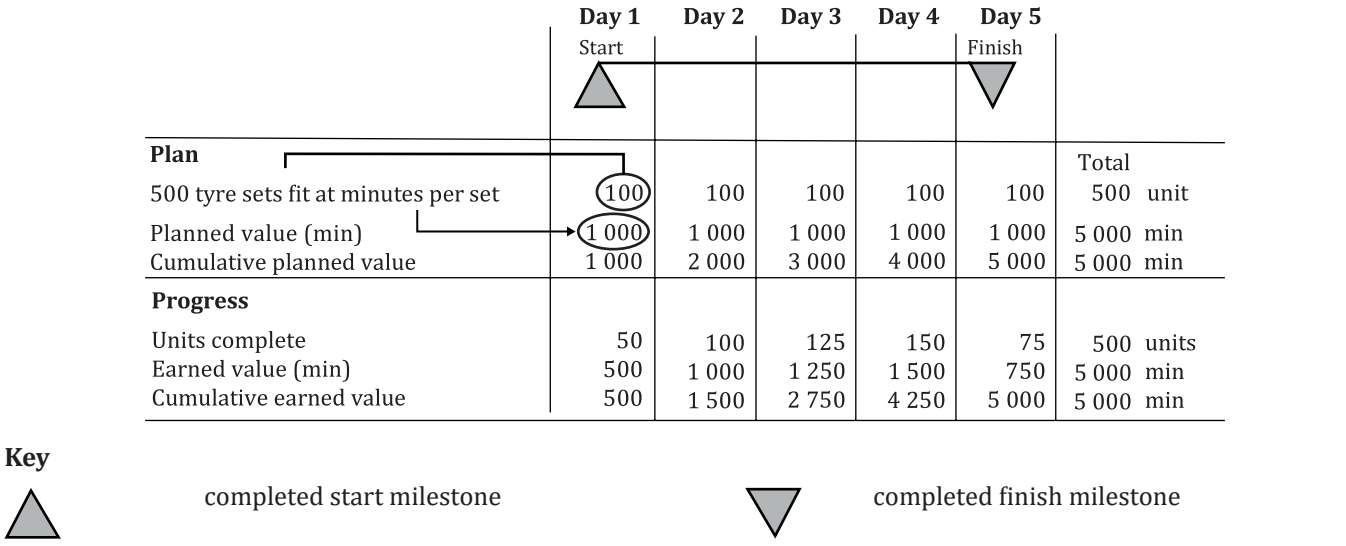
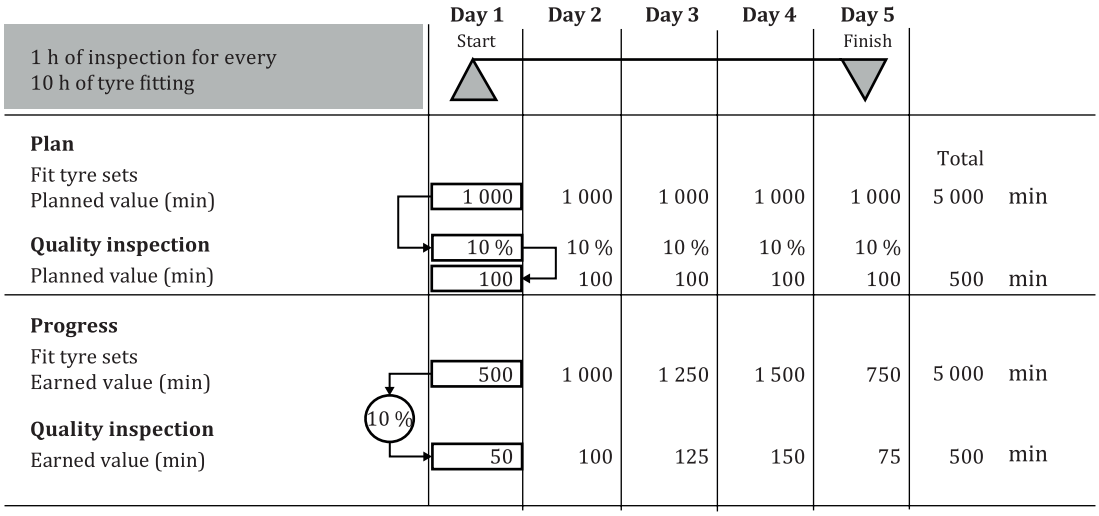


Figure A.8 — Example of units complete or equivalent units earned value technique

A.6.5 Apportioned effort

On the new automobile project, this earned value technique can be used for inspection/quality assurance activities, where the inspection time is directly dependent on the number of items that are produced. Figure A.9 illustrates the inspection of tyre sets described in Figure A.8.



Key

completed start milestone

completed finish milestone

Figure A.9 — Example of an apportioned effort earned value technique

In this example, the inspection work package is directly related to the fit tyre sets work package. The equivalent of 10 % of the time set aside for fitting the tyre sets is devoted to inspecting that work.

In the example in Figure A.9, the planned value for inspection is 10 % of the planned value for tyre fitting; therefore, 100 min. However, as only 50 tyre sets were fitted on day 1, only 500 min in earned value can be claimed for tyre fitting, so only 50 min can be claimed for the inspection of those fitted tyres.

A.6.6 Level of effort

In project management work packages on the new automobile project, planned value is assigned to each level of effort activity, then the planned value is automatically credited as the earned value at the end of each reporting period. For this reason, the project management work packages on the new automobile never exhibit schedule variances.

A.7 Step 6: Set the performance measurement baseline

Establishing the performance measurement baseline should be a process of integrating scope, schedule and cost baselines into a single baseline used to manage and control the performance of the project or programme.

Figure A.10 illustrates this process for the prototyping elements of the new automobile project.

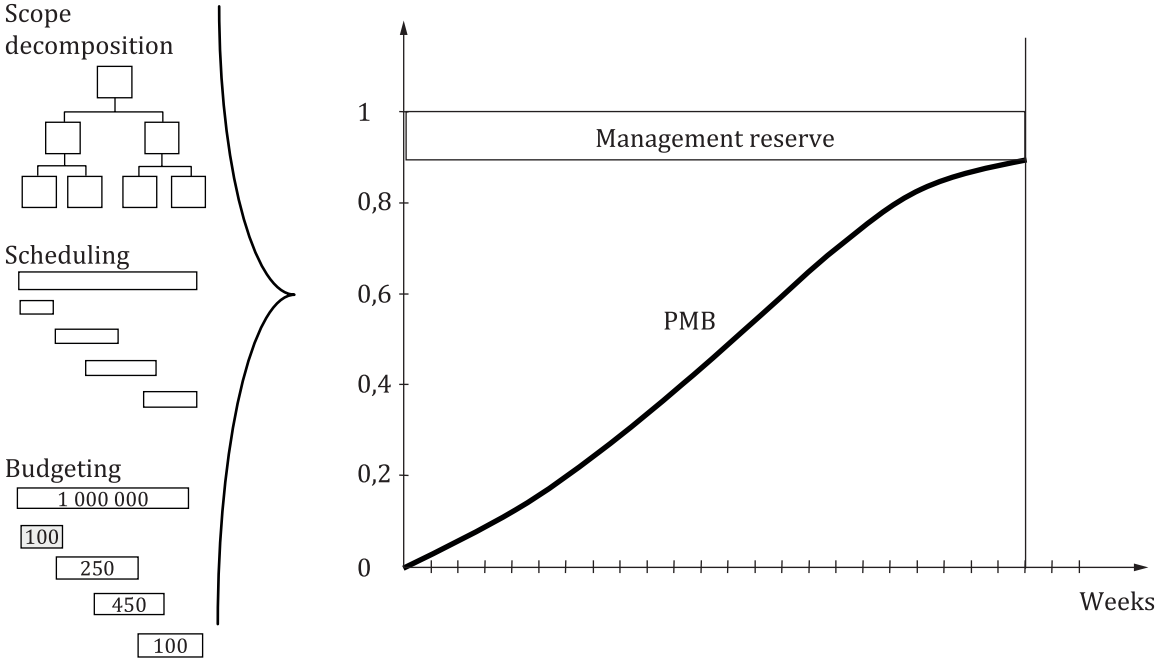


Figure A.10 — Summary of performance measurement baseline development

NOTE The performance measurement baseline can also include an amount of schedule reserve to allow for the occurrence of schedule risk. This can be included at the end of the project or as schedule buffers against milestones within the project schedule (see 9.1.4.4).

The performance measurement baseline should include the undistributed budget, summary level planning package budgets and control account budgets but not the management reserve as illustrated in Figure A.11.

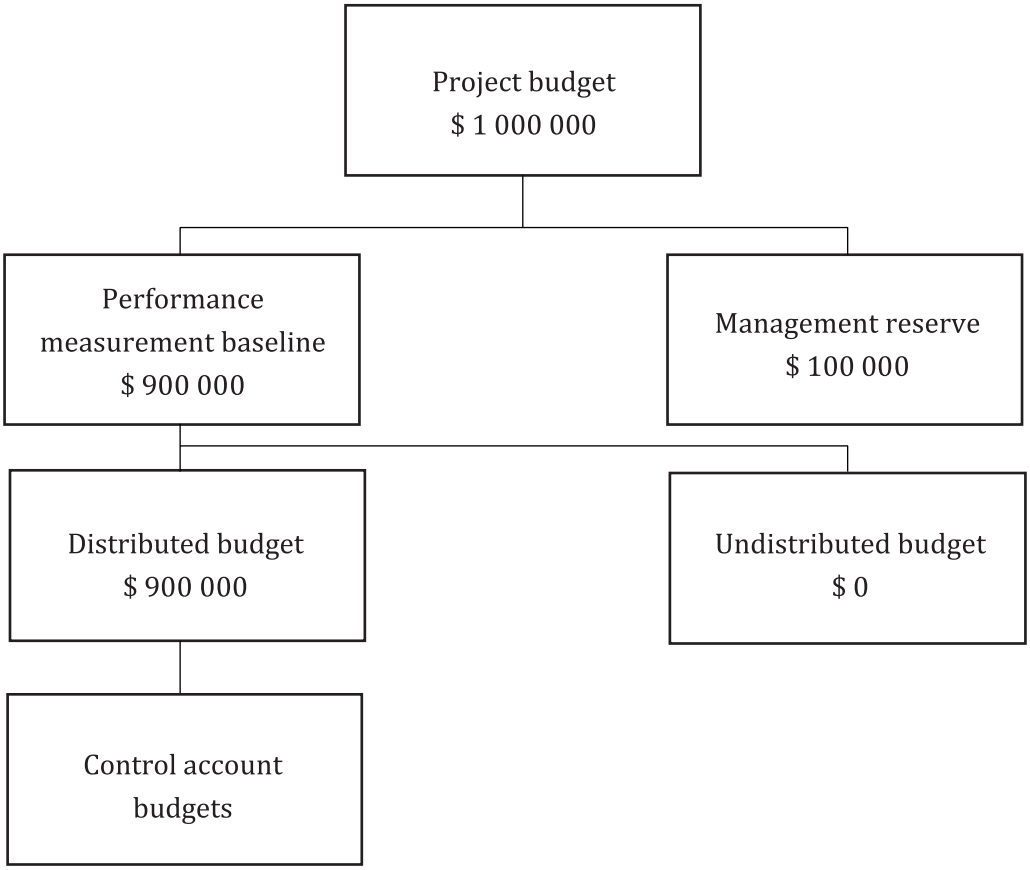


Figure A.11 — Budget breakdown for the prototyping component of the new automobile project

A.8 Step 7: Authorise and perform the work

A.8.1 The work authorisation should be a formal document to provide the project and programme manager the authorisation to begin work, follow the plan or change the plan. Work authorisation should start with the work authorisation document. This document should describe the planned work and provide written permission and direction to begin work on a specific set of schedule activities, work packages or control accounts to enable work to be done by the identified organisation, at the planned time, and in the proper sequence (see Figure A.12).

A.8.2 The work authorisation document should contain:

a) period of performance of the work;

b) schedule of the work performance;

c) budget for each element of work in the schedule.

A.8.3 The work authorisation document should identify:

a) previous budget values;

b) change budget values;

c) current budget value (see 5.8).

Control account plan work authorisation

Project title: New Automobile Project Summary project ID: MF01

Control account title: Prototyping Control account project ID: ME111

WBS element: 1.1 Prototyping

Project director: J.R. Smith

Control account manager: Ozzie Newsome

Control account description: Provide detailed specifications, procurement, assembly and testing of the prototype as identified in the work packages below.

Work packages:
- 1.1.1 CAD file creation
- 1.1.2 Materials procurement
- 1.1.3 Prototype testing
- 1.1.4.1 Chassis and bodywork
- 1.1.4.2 Engine and transmission
- 1.1.4.3 Controls
- 1.1.4.4 Interior

Control account scope: Start date: 31 January Completion date: 17 June

Planned value: See attached

Control account budget: $ 100 000

Milestone/deliverables: See attached transition to operations schedule

Control account authorisation

Earned value method: Percent complete

Approved by:

Project director: J.R. Smith Date: 5 January

Control account manager: Ozzie Newsome Date: 5 January

Reviewed by: _____ Date: _____

Project controls manager: _____ Date: _____

Figure A.12 — Example of a work authorisation document

A.9 Step 8: Accumulate and report performance indices

Once work commences against the performance measurement baseline, performance data should be accumulated and reported against each control account. The three types of data for reporting performance should be:

a) cost data,

b) schedule data, and

c) technical performance data.

Each data type should be used to calculate variances used to inform earned value management progress to plan (see 7.2).

Figure A.13 illustrates the progress of the new automobile prototyping as of week 12 and the relevant earned value performance data. Delays in completing the chassis have impacted on the commencement of engine, transmission and controls installation work. This delay is reflected in earned value figures lagging behind the planned value. The data also shows some cost savings were realized in the earlier computer-aided design and procurement effort.

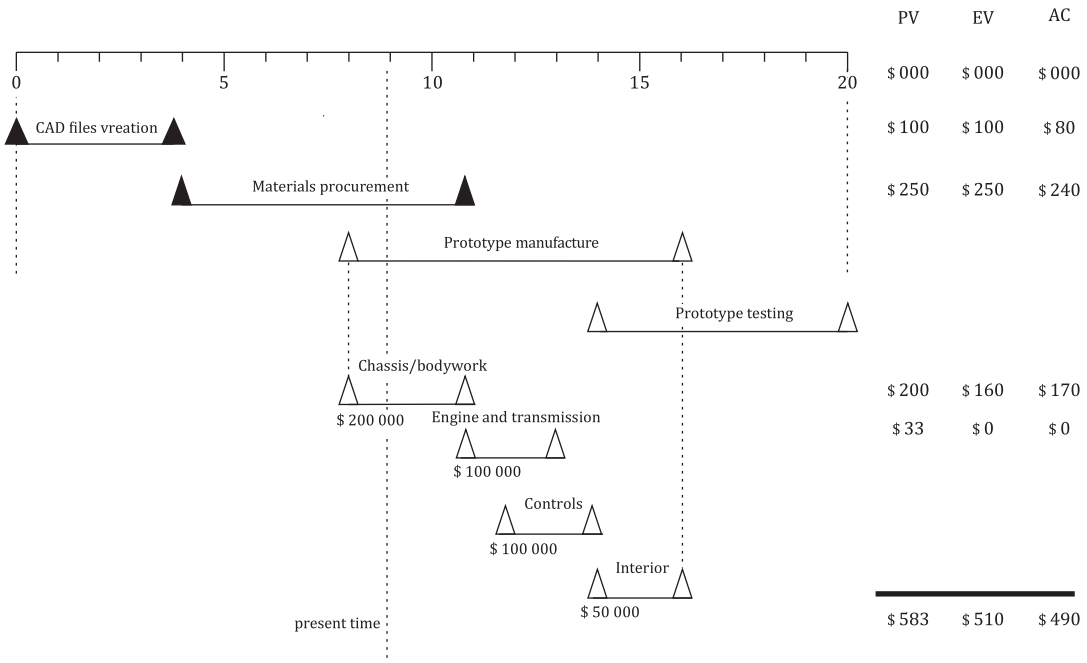


Figure A.13 — Status of new automobile project at week 12

A.10 Step 9: Analyse project performance

A.10.1 The cost and schedule variances highlighted in Figure A.13 can now be analysed in order to inform any corrective actions. Activities for analysing project performance should be:

a) review internal performance reports to quantify the variances and to isolate them by work package;

b) review the work packages driving the variances by element of cost;

c) review the labour charging report;

d) identify the root causes for the variances;

e) quantify the reasons for each identified cause;

f) discuss the impact these variances can have on the project or programme;

g) discuss the rationale to support a new estimate at completion and estimated completion date, as applicable;

h) formulate a plan for corrective action that should include who, what, where, when and how;

i) write the variance analysis report;

j) communicate the report and preventive or corrective actions to be taken with appropriate stakeholders (see 5.10).

A.10.2 The estimate to completion and the estimate at completion should be the foundations for reporting performance using earned value management and are the basis for taking corrective and preventive actions.

The development of the estimate to completion should have the following steps:

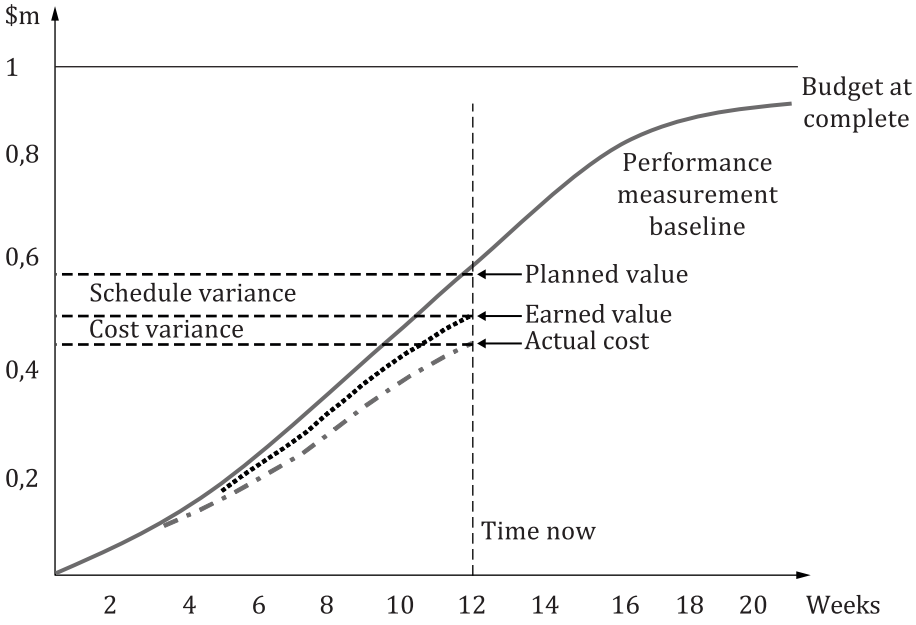
a) perform the schedule risk analysis;

b) perform the cost risk analysis;

c) perform the technical risk analysis;

d) anticipate downstream risks.

Figure A.14 depicts the earned value status of the new automobile prototyping based on the planned value, earned value and actual cost figures recorded in Figure A.13.



The schedule variance is equal to − $ 73 000.

The cost variance is equal to $ 20 000.

Figure A.14 — Earned value status as of week 12

ISO 21508:2018, Annex A defines and describes the earned value management measures and metrics that can be used to assess project or programme performance. The assessment can occur either at the present time or preferably plotted to provide performance trends over time (see Clause 7).

Table A.1 is the performance data for the new automobile prototyping control account at week 12 followed by the earned value calculated metrics.

Table A.1 — Example of an earned value status dashboard (,000) as at week 12

	Measures		Metrics							Future efficiency		Completion		Future predictions			
	PV	EV	AC	CV	SV	CV %	SV %	CPI	SPI	TCPI BAC	TCPI EAC	BAC	EAC	IEAC CPI	IEAC SPI	IEAC 80/20	IEAC CPI × SPI
1.1 Prototyping status update — Week 12	583,3	510,0	490,0	20,0	−73,3	3,9	−12,6	1,04	0,87	0,95	1,00	900,0	880,0	864,7	1 029,4	893,3	989,0
1.1.1 CAD file creation	100,0	100,0	80,0	20,0		20,0		1,25	1,00	—	—	100,0	80,0	—	—	—	—
1.1.2 Materials procurement	250,0	250,0	240,0	10,0		4,0		1,04	1,00	—	—	250,0	240,0	—	—	—	—
1.1.3 Prototype testing										—	—	100,0	100,0				
1.1.4 Prototype manufacture	233,3	160,0	170,0	−10,0	−73,3	−6,3	−31,4	0,94	0,69	1,04	1,00	450,0	460,0	478,1	656,2	505,6	697,3
1.1.4.1 Chassis and bodywork	200,0	160,0	170,0	−10,0	−40,0	−6,3	−20,0	0,94	0,80	1,33	1,00	200,0	210,0	212,5	250,0	219,1	265,6
1.1.4.2 Engine and transmission	33,3				−33,3		−100,0			—	—	100,0	100,0				
1.1.4.3 Controls										—	—	100,0	100,0				
1.3.4.4 Interior										—	—	50,0	50,0				

The overall earned value performance data indicates the prototyping control account is underspent as indicated with a cumulative cost performance index of 1,04 and positive cost variance of $ 20 000. The size of the cost saving relative to the budget for the work performed to date is shown by the cost variance of 3,9 %.

A.10.3 Detailed analysis shows that the current positive cost variance is due to:

a) $ 20 000 underspend to complete 1.1.1 CAD file creation and $ 10 000 underspend to complete 1.1.2 materials procurement;

b) $ 30 000 total savings on completing these two work packages has been offset by a $ 10 000 negative cumulative cost variance in 1.1.4 prototype manufacture;

c) shown by a negative cost variance of 10 000 and unfavourable cost performance index of 0,94;

d) drill down within 1.1.4 prototype manufacture shows the specific cause of this negative cost variance is the overspend on 1.1.4.1 chassis and bodywork.

Overall analysis shows that the prototyping control account is behind schedule, as indicated by a negative cumulative schedule variance of − $ 73 300 and schedule performance index of 0,87. The schedule performance index indicates a schedule efficiency of 87 % compared to plan. The size of the schedule variance, relative to the amount of work planned to be completed at week 12, is shown by the schedule variance percentage of −12,6 %.

The 1.1.4.2 engine and transmission work package has a planned value of $ 33 300. There is no corresponding earned value or actual costs that suggest that the start of this work package has been delayed. This situation also contributes to the overall negative schedule variance for 1.1.4 prototype manufacture.

A.10.4 The work packages should be investigated to determine:

a) specific causes of the delays causing the negative schedule variances;

b) corrective actions that should be implemented to contain further schedule slippage and allow potential recovery from the delays that have already occurred.

Schedule slippage indicated by earned value metrics should be verified by analysis of the project schedule itself.

A.10.5 The control account manager's reported estimate at completion of $ 880 000 is less than the budget at completion of $ 900 000. The projected underspend in the estimate at completion is made from:

a) cost savings to date of $ 30 000 from computer-aided design file creation of $ 20 000 and materials procurement $ 10 000 work packages;

b) offset by a projected cost overrun of $ 10 000 in the delayed chassis and bodywork work package.

A.10.6 Comparison of the control account manager's $ 880 000 estimate at completion to the most common independent formulae used to predict completion costs shows that the estimate at completion is:

a) greater than the independent estimate at completion using cost performance index as the performance factor is $ 864 700; this view is generally regarded as the best-case prediction of completion costs;

b) less than the independent estimates at completion that include schedule performance index as part of the performance factor with a range from $ 893 300 to $ 1 029 400.

A.10.7 While the predicted completion costs assume that performance will remain the same from week 12 until completion, this analysis can provide early warning indicators. The indicators show that the schedule delays in the chassis and bodywork and engine and transmission work packages can, unless effective

corrective actions are promptly undertaken, be placing achievement of control account manager's estimate at completion and budget at completion at risk.

However, comparing:

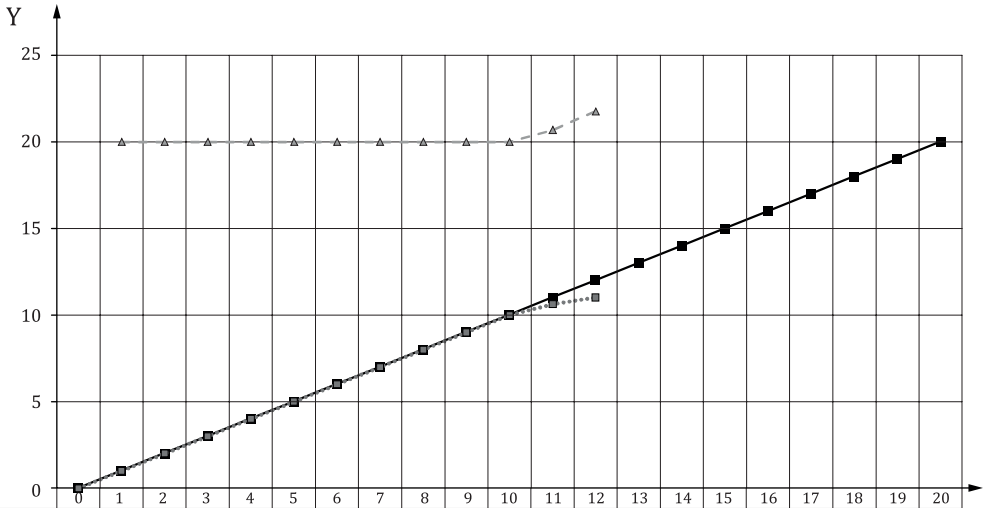
a) the to complete performance index for the budget at completion to the cumulative cost performance index of 1,04 indicates that a future cost efficiency of 0,95 or 95 %, which is less than the cost efficiency achieved to date of 104 %, is needed to complete the remaining work to achieve the budget at completion of $ 900 000;

b) the to complete performance index for the estimate at completion indicates that a future cost efficiency of 1,00 or 100 % is needed to complete the remaining work to achieve the manager's estimate at completion. This projection is slightly less than the cost efficiency to date of 104 %.

ISO 21508:2018, Annex B defines and describes the earned schedule measures and metrics that can be used to assess project schedule performance using time-based metrics derived from earned value data at either time now or, preferably, plotted to provide performance trends over time (see also Clause 8).

Figure A.16 shows the earned schedule performance of the 1,1 prototype control account over time. The chart shows that the control account was proceeding as planned until the delays experienced in 1.1.4 prototype manufacture referred to in A.10.3.

The independent estimate at completion (time), which is scaled by the schedule efficiency calculated by the schedule performance index (time) is currently projecting a two-week delay to project completion. The earned schedule time-based metrics can be directly compared to the project schedule as part of assessing the overall status of the project.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Planned schedule	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Earned schedule cumulative	0	1	2	3	4	5	6	7	8	9	10	10,63	11,02								
Independent estimate at completion (time)		20	20	20	20	20	20	20	20	20	10	20,7	21,8								
Schedule variance (time) cumulative		0	0	0	0	0	0	0	0	0	0	(0,37)	(0,98)								
Schedule performance index (time) cumulative		1	1	1	1	1	1	1	1	1	1	0,97	0,92								

Key

Y duration (weeks)

Figure A.15 — Earned schedule chart showing planned schedule, earned schedule and independent estimate at completion

The efficiency metrics of cost performance index and schedule performance index (time) can be used as inputs for the forecasting of future performance (see Clause 8).

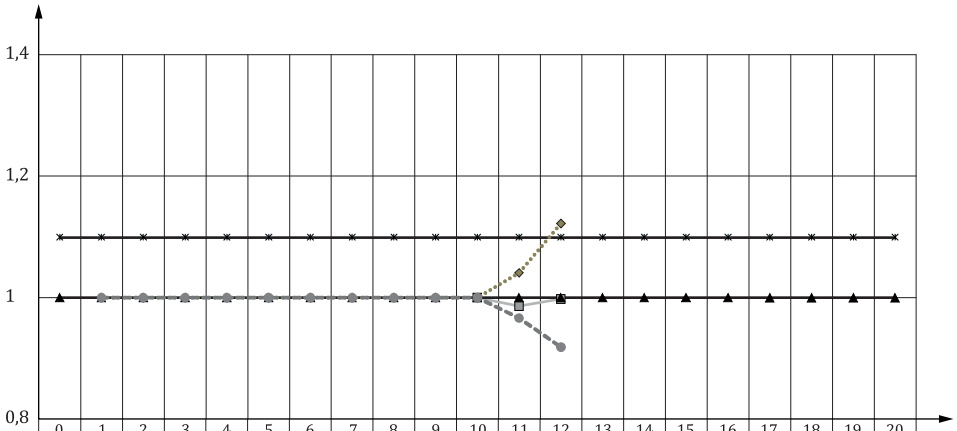
Figure A.15 illustrates the forecasting of future performance based on performance to date using the earned schedule, schedule performance index and to complete schedule performance index for planned duration and estimated duration of the prototyping control account (see Clause 8).

At week 12, the future schedule efficiency needed to achieve the planned duration is 1,12 as compared to the cumulative time-based schedule efficiency achieved to date of 0,92. The to complete schedule performance index of 1,1 for planned duration is on what can be considered the threshold of schedule recovery for being able to achieve the planned duration.

This projection is a further indicator of the importance of management action to stabilise and recover the adverse schedule variances within the prototyping control account.

Achieving the manager's estimated duration of 21 weeks necessitates a future time-based schedule efficiency of 1,0. The implication of the to complete schedule performance index for estimated duration being greater than schedule performance index is that an improvement in the future schedule efficiency will be required to achieve this target.

Input of a range of estimated durations as part of the analysis of actions that can be undertaken to improve future schedule efficiency is one example of "what-if" analysis that can be done using earned value data.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Planned duration	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
TSPI planned duration		1	1	1	1	1	1	1	1	1	1	1.04	1,12								
Estimated duration											20	20,5	21								
TSPI estimated duration											1	0,99	1								
Target SPI (time)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SPI(t) cumulative		1	1	1	1	1	1	1	1	1	1	0,97	0,92								
TSPI recovery threshold	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1

Figure A.16 — Example of a schedule performance index (time), to complete schedule performance index chart at week 12

A.11 Step 10: Take management action

A.11.1 Inputs to take corrective action to manage the project

Using the data from the analysis, significant differences among planned and actual cost, schedule, and performance should be the basis of further analysis to enable significant schedule and cost variances to be analysed, at a level of detail necessary to manage the effort. This action should enable management decision-making and preventive or corrective action (see 5.11 and 9.1.4.11).

A.11.2 Activities in taking corrective actions to manage the project

Using the analysis performed in Step 9, a corrective action plan should be developed to recover the cost, schedule and technical performance variances. These corrective actions should be identified at the appropriate level, then tracked to resolution or closure.

In the worked example, the new automobile prototyping control account is significantly behind schedule and under budget as of week 12. While forecasting an underspend at completion, the detailed analysis also indicates that this outcome is possibly at risk, if schedule recovery does not occur. Given this data, management action can include an assessment of whether the application of more resources to the

prototyping control account, perhaps from a reallocation of resources within the project, can stabilise and recover the schedule variance.

Control account managers can be obligated to provide a variance analysis report where variances breach an agreed cost or schedule threshold. The variance analysis report should detail the cause and impact of the variance, as well as details of a corrective action plan.

Table A.2 is an example of a variance analysis report for cost and schedule variances within 1.1.4.3 controls.

Table A.2 — Example of a variance analysis report

Variance analysis report							
Project	New Automobile			**Report period**		April 2022	
CAM	Ozzie Newsome			**WBS element**		1.1.4.3 Controls	
	PV	**EV**	**AC**	**CV**		**SV**	
Current period	$ 30 920	$ 11 176	$ 25 000	(13 824)	−124 %	($ 19 744)	−64 %
Cumulative	$ 30 920	$ 11 176	$ 25 000	(13 824)	−124 %	($ 19 744)	−64 %
At completion	**BAC**	**EAC**	**VAC**				
	$ 100 000	$ 104 653	($ 4 653)				
	Schedule variance			**Cost variance**			
Problem analysis	Components from one vendor have failed receipt inspection, resulting in approximately $ 3 000 of parts associated with the accelerator system that were returned to the vendor for modifications. These parts were planned to be delivered by 30 April; however, they are anticipated to be returned on 21 May. It is anticipated that the schedule variance will reduce to zero at that time.			$ 2 650 of the cost variance is due to a higher than anticipated cost associated with the brake callipers and pads. The remaining $ 1 767 is labour associated with managing early receipt of wiring components.			
Program or task impact	The braking system is on the critical path of the program. Delays in these deliveries can impact all downstream activity including the integration, assembly and test. The anticipated impact to the braking system is a 3-week delay in completion.			The 2 650 $ pad and calliper have no corrective action and is included in the braking system EAC. No impact projected for the labour variance.			
Corrective action plan (including expected recovery date)	The braking system team is working with the project manager and other component teams on a corrective action plan to recover some of the 3-week delay. Specifically, some component tests and product tests may begin without the braking system. In addition, we are working with the shifting system team to assess if activities can be performed simultaneously rather than serially as planned. Anticipate completion of the braking system by 25 May, and program impact is still being managed and assessed.			The $ 1 767 of labour variance is the level of effort activity performed earlier than anticipated. Since the associated wiring components have arrived early, these LOE activities will not have to be performed when anticipated in late February and the $ 1 767 variance will go to zero at that time.			
Impact to EAC	—			Purchase orders released to vendors for braking system parts, primarily the pads and callipers, were negotiated $ 1 767 higher than budgeted. Cost impacts associated with part inspection failures are still being evaluated, but a potential $ 1 000 to $ 1 500 EAC impact is possible.			

A.11.3 Outputs from take corrective action to manage the project

The outputs from the preventive or corrective action plans for further action should be:

a) verified through follow-up of the implementation of the plans;

b) assessed for reasonableness of the corrective or preventive actions for effectiveness and performance;

c) updated with the to complete performance index.

A.12 Step 11: Maintain the baseline and management reserve

A.12.1 General

The performance measurement baseline and management reserve should be maintained to reflect changes to the scope and to maintain the integrity of the performance measurement baseline. Since changes are inevitable, project or programme management should expect that capabilities, technical needs and the performance measurement baseline can evolve.

Maintaining the performance measurement baseline reserve should be a critical success factor of the project and programme management processes. With the three elements of the performance measurement baseline – planned value, earned value and actual cost – the management team can track actual performance against planned performance to alert management to any potential problems and to take preventive or corrective actions to keep the project or programme within the objectives (see 5.12).

A.12.2 Original baseline plan left out some work elements

The first action should be to establish a time when new work elements can be added. This time can be an open timeframe, on the rolling wave boundaries, through a formal process of change management. The time established should be something that is predictable.

These changes should be connected to the current scope. The changes to be initiated should have an agreed upon reason for the change. The approaches can be to connect the change to the business case or similar documentation, governance documentation and the mission statement or other similar document. But if the changes expand the scope of the project or programme, there should be another process. The process should be established to avoid the scope growing without bounds, which means the value of earned value becomes meaningless.

A.12.3 Realized risks or identified risks which will not occur

Risks that are realized or that are no longer are considered a risk can need treatment actions added to or removed from the baseline (see 9.1).

A.12.4 Original estimates for the budget and duration require updates

Learning should occur as the project or programme progresses. Using this knowledge to improve the cost, schedule and technical baseline should take place (see 5.11.4).

A.12.5 Actual changes to the project or programme from the stakeholder

Additional scope, not just improvements in the current scope, should go through a formal change management process. This process should not be an impediment to improving the project or programme. If there are changes in the scope without understanding the impact, the organisational value of those changes and the risk impacts of those changes should be an indication that the project or programme manager is not in management control (see 5.12).

A.12.6 Work late and costing more

Work schedules taking longer and cost overruns are not valid reasons to change the baseline. If the work is late, it is late. If the work is over budget, it is over budget. Progress against the performance measurement baseline should show the reality. Redefining the baseline in these instances can reduce the effectiveness of using earned value.

For earned value to produce value for the project or programme, baseline integrity should be maintained. Manipulating the baseline can negate the beneficial outcomes of earned value (see 5.12).

A.12.7 Inputs to maintaining the performance measurement baseline

The planning documentation should define the processes used to implement, control and close the project or programme. Two important elements of the planning documentation are the performance measurement baseline and the integrated change control process (see 5.12).

A.12.8 Activities for maintaining the performance measurement baseline

Starting with a change control board or other similar process group or individual, the impact of the change request to cost, schedule, and technical performance should be analysed. The performance measurement baseline maintenance process should account for the analysis of any changes on the probability of success of the project or programme.

Each cost, schedule or scope change should be analysed, and the impact assessed. When new scope is added the project or programme performance measurement baseline should be updated starting at the work breakdown structure level where the scope change occurs.

If new scope is added to one or more work breakdown structure elements, the assigned budgets should be closed out with the actual cost, earned value at the time of the change, and a new budget assigned to the new work breakdown structure scope element. This approach should maintain the historical cost and schedule variance as a contributor to the overall cost and schedule variance of the project or programme (see 5.12).

A.12.9 Outputs from maintaining the performance measurement baseline

The outputs from maintaining the performance measurement baseline should be:

a) updates to the performance measurement baseline and management reserve;

b) updates to the planning documentation;

c) status updates from the change control process.

In the new automobile project, a risk within the prototype testing is identified during week 12. Consequently, a risk treatment activity, commencing in week 15, is approved and added to the schedule at a cost of $ 50 000. Figure A.17 illustrates the drawing down of $ 50 000 from management reserve into the performance measurement baseline.

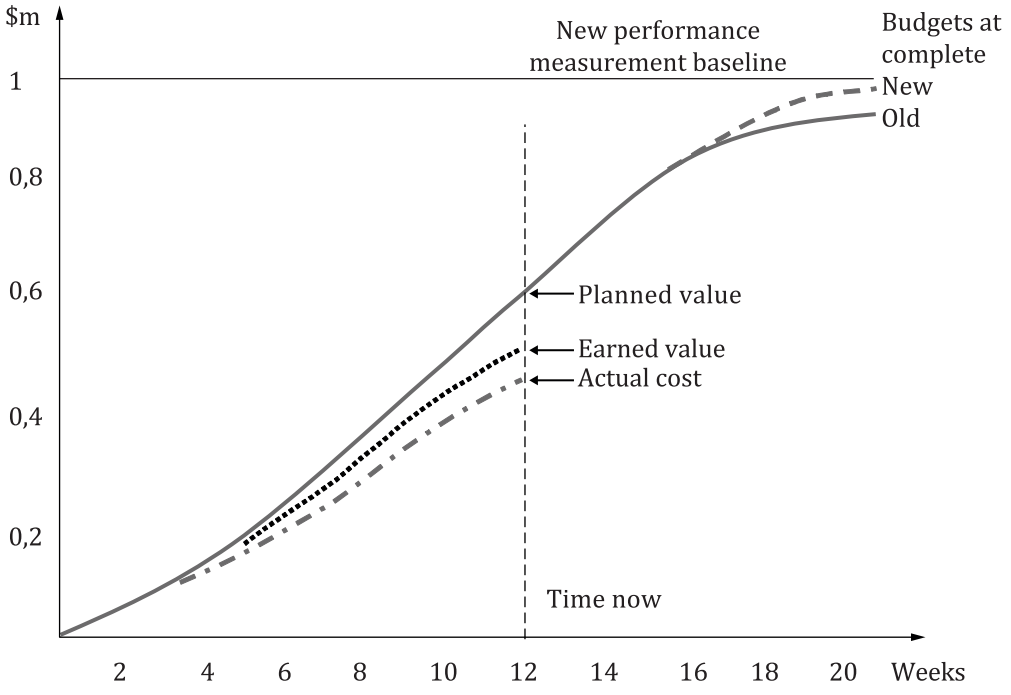


Figure A.17 — Introduction of risk treatment activity into the baseline in week 15

Figure A.18 illustrates the changes to the management reserve, performance measurement baseline and distributed budget values resulting from approval of the $ 50 000 risk treatment activity.

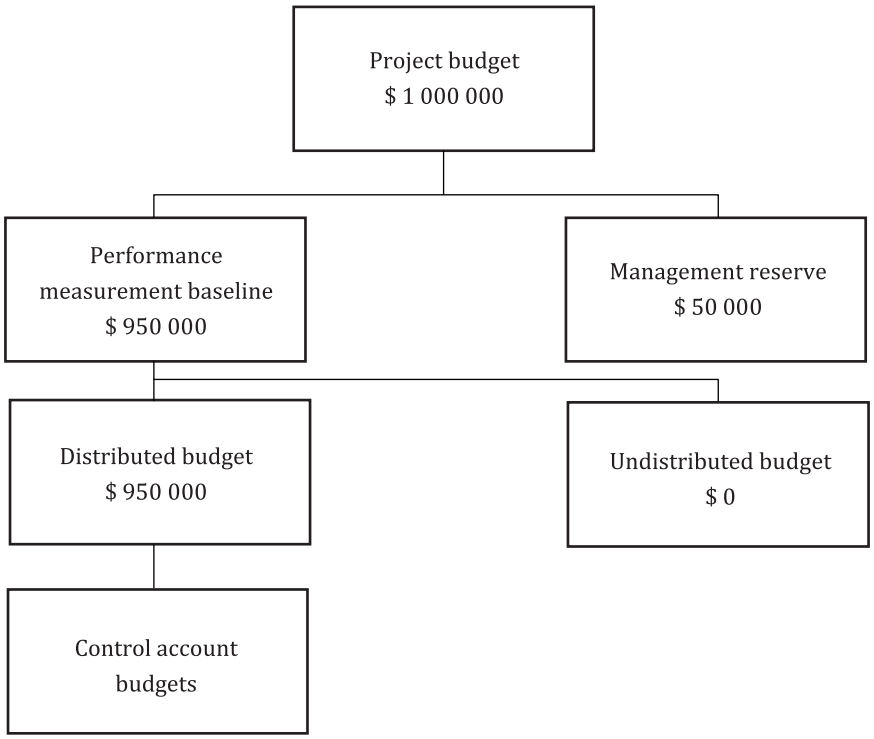


Figure A.18 — Revised management reserve, performance measurement baseline and distributed budgets

Annex B

(informative)

Integrated baseline review

B.1 Overview

The purpose of an integrated baseline review should be to achieve and maintain a project or programme management and customer understanding of the content and the risks inherent in the performance measurement baseline, as well as the management control processes that can operate during implementation.

The integrated baseline review should confirm that:

a) performance measurement baseline incorporates the entire scope;

b) work is scheduled to meet the project or programme objectives;

c) risks are identified and are being managed;

d) amount and mix of resources have been appropriately assigned to accomplish and deliver against requirements;

e) management control processes are being implemented.

This review should provide both the project or programme management team and its customers the affirmation that valid and timely performance indices are being provided throughout the implementation. The output of the integrated baseline review should be reported using an organization's existing organizational, project or programme governance, or governance based upon the terms and conditions of the contract.

Any documented preventive or corrective actions arising from the integrated baseline review should be analysed prior to implementing to understand, whether the cause is systemic or systematic. This analysis can indicate additional reviews are necessary to gather data for implementation of preventive or corrective actions or modifications to the earned value management system.

B.2 Review timing

The project or programme management team should determine that the baseline is as complete as possible before holding an integrated baseline review per the governance regarding performance measurement baselines and earned value management systems.

The initial review should seek to achieve an understanding and agreement that the project or programme is appropriately planned and ready for implementation of the baseline from which performance indices will be generated. The initial review should be as close to the start of the project or programme as possible. This timing of the review can help affirm thorough planning has been undertaken early in the lifecycle, as well as help reduce the cost of any correction activities.

Subsequent reviews should be planned and conducted whenever the project or programme management team and the customer agree that conducting a review would be beneficial. These reviews can be established on a periodic basis, aligned with project planning phases, or with pre-planned management reviews, such as gateway reviews or similar decision points.

The timing of subsequent reviews can be dependent upon a number of factors including:

a) duration;

b) risk;

c) organizational policy or contract terms and conditions;

d) complexity;

e) performance;

f) amount and type of change;

g) customer needs and specifications.

The duration of an integrated baseline review should depend upon the terms of reference for the review or governance. The duration can range from a few days to a few weeks.

B.3 Integrated baseline review process summary

B.3.1 General

The integrated baseline review should be comprised of four main stages:

a) pre-integrated baseline review;

b) preparation;

c) implementation;

d) post review.

B.3.2 Pre-integrated baseline review

Table B.1 shows details of pre-integrated baseline review stage of the integrated baseline review process.

Table B.1 — Pre-integrated baseline review

Serial no.	Input	Process	Output	Responsibility
1.1	New contract/ contract change/ company policy/ significant project change	Decision to hold an IBR	Documented decision – contract, project plan etc.	Contractual or joint or internal
1.2	IBR guideline Contract	Agree objectives and acceptance criteria	Notification of IBR and timing. Plan, including objectives, acceptance criteria and expectations for the IBR.	Customer lead + project or programme

B.3.3 Preparation

Table B.2 shows details of the preparation stage of the integrated baseline review process.

Table B.2 — IBR preparation

Serial no.	Input	Process	Output	Responsibility
2.1	Skills + competencies IBR plan Available resources	Identify teams	Contact list, roles and responsibilities agreed.	Customer lead + project or programme
2.2	This handbook IBR plan, project control system description	Produce draft IBR briefing pack/handbook	Draft IBR briefing pack/handbook	Customer lead + project or programme
2.3	Team knowledge, skills + abilities Training resources	Educate teams (reviewers and project team)	Competent team members	Customer lead + project or programme
2.4	Project and risk data	Mock/practice IBR	Issues for resolution prior to the IBR	Project or programme
2.5	Availability, resources, locations	Define and agree visit schedule	Timetable	Customer lead + project or programme
2.6	Review team requirements	Administration + domestics		Project or programme
2.7		Produce final IBR handbook	Final IBR handbook	Customer lead + project or programme
2.8	Baseline data and documentation IBR handbook	Collate and deliver IBR deliverables	Documentation issued to review team	Project or programme
2.9	Documentation with review team	Review and familiarise with deliverables	Review team ready	Review team

B.3.4 Implementation

Table B.3 shows details of the implementation stage of the integrated baseline review process.

Table B.3 — IBR implementation

Serial no.	Input	Process	Output	Responsibility
3.1	Agenda	In-brief & Launch	Fully briefed team	Joint
3.2	IBR documentation Data requests Storyboard	Data traces, assessment of EVMS or PCSD, such as against criteria in ISO 21508	Write-ups	Review team
3.3	CAM specific data	CAM/manager discussions	Write-ups	Review team
3.4	Write-ups	Collate write-ups to be progressed throughout implementation	Topic write-ups	Review team
3.5	Write-ups	Feedback sessions / issues board	Daily issues raised with project	Review team
3.6	Issues and write-ups	Review closure	Outbrief presentation material	Joint

B.3.5 Post review

Table B.4 shows details of post review stage of the IBR process.

Table B.4 — Post IBR review

Serial no.	Input	Process	Output	Responsibility
4.1	IBR report	Prepare and agree actions for closure of corrective actions	Corrective action closure plan	Project or programme + review team
4.2	Feedback form	Post review feedback	Completed feedback form, lessons learnt documentation	Project or programme + review team
4.3	Corrective action closure plan	Joint surveillance	Agreed schedule of future reviews	Review sponsor + project or programme

B.4 Pre-integrated baseline review

B.4.1 Decision to hold an integrated baseline review

The schedule of reviews should be planned and agreed in advance; however, events that affect the project or programme can also trigger a review, including:

a) new contract;

b) contract change;

c) company policy;

d) significant project change, such as:

   1) process;

   2) organization;

   3) work content;

   4) time-phasing;

   5) emergent risk;

   6) funding, both annual and total.

B.4.2 Agreed objectives and acceptance criteria

B.4.2.1 As soon as the decision to conduct an integrated baseline review has been taken, the project manager and, if part of a programme, the programme manager within the performing organization and the customer should agree and define the specific objectives and acceptance criteria for the review. This agreement should be documented in an initial draft of the project integrated baseline review handbook. The integrated baseline review objectives to assess the performance measurement baseline should be established and achieved using the following items:

a) assumptions underlying the plan are reasonable and documented;

b) specifications have been translated into appropriate breakdown structures and authorised through documents, such as work breakdown structure and statement of work;

c) schedule milestones are identified and reflect a logical flow to accomplish the work scope;

d) project or programme organization is identified and a clear responsibility linkage to the work breakdown structure is shown, such as a responsibility assignment matrix;

e) planned use of resources, such as budgets, facilities, personnel, skills and other resources, reflect availability and is sufficient to accomplish the work scope within schedule constraints over the entire performance period;

f) sub-contract effort and performance reporting is integrated to the level that is necessary for project or programme control;

g) earned value measurement techniques are applicable to the work scope being undertaken in order that performance indices will reflect achievement during the entire performance period.

B.4.2.2 The following risk areas should be assessed:

a) technical risk;

b) schedule risk;

c) management control processes;

d) cost risk;

e) supplier management.

Having taken project or programme specifics into account and agreed to the integrated baseline objectives, care should be exercised to enable the parties involved to be aware of the approach to be taken in conducting the review.

In order to formalise the review, the customer should prepare an integrated baseline review notification letter that includes review dates, team members, review conduct, documentation needed for the review and any other pertinent information. This letter should be sent to team members and the contractor.

B.5 Preparation

B.5.1 Identify teams

Reviews should be led by the customer, an organization subcontracted by the customer or by the organization's lead reviewer, who should provide a suitably qualified representative to enable a comprehensive evaluation of the performance measurement baseline is performed and that control aspects have been addressed and documented.

Team members for the review should comprise a mixture of the project or programme technical expertise and technical staff with support from the control specialists. Project or programme staff should be knowledgeable on the subject matter being examined. Team members should be allocated specific work breakdown structure areas of responsibility associated with their field of expertise and management responsibility. A multifunctional integrated baseline review team's results should enable the transfer of project or programme knowledge among the participants.

B.5.2 Responsibilities

Table B.5 outlines the responsibilities, which should be assigned to the various stakeholders involved in the integrated baseline review.

Table B.5 — Assignments for the integrated baseline review

Stakeholder	Responsibilities of the integrated baseline review
Project or programme manager/customer Jointly responsible for integrated baseline review process	— agree the objectives and schedule for the integrated baseline review process and supporting reviews; — enable an adequate number of suitably qualified and experienced personnel are available to support the integrated baseline review process; and — enable issues resulting from reviews are resolved in a timely manner.
Team leaders Can be project or programme managers	— provide technical direction and leadership; — assign responsibilities to review team members; — provide team members are adequately trained and prepared for reviews; and — management of the day-to-day activities of the integrated baseline review process and reviews.
Team members	— be prepared for the review and attend integrated baseline review training workshops; — become familiar with the statement of work or statement of requirements and objectives prior to the review; — review the project planning documentation and undertake data traces; — conduct discussions; and — provide write-up assessments and contribute to the final review report.
Project	— provide the appropriate planning documentation to the team for review prior to the start of the integrated baseline review; — provide working space and support for the integrated baseline review team; and — arrange schedules for discussions with relevant project or programme personnel.

Review teams can allocate responsibilities to team leads by process elements for documenting of the final report, which should be organized by those process elements. The team lead should cause collation of the relevant elements of the control account managers' discussions, data traces and other necessary items for synthesis into the report.

B.5.3 Team composition

The project and programme manager or team with the customer should identify the team leaders and members. Persons selected for the integrated baseline review team should be experienced in project or programme management or the technical disciplines under review.

For the integrated baseline review, the team should include personnel independent of the project and programme with relevant experience.

The areas of discipline that should be involved are:

a) project or programme management;

b) project or programme control;

c) business management;

d) subcontract management;

e) technical management from the primary technical areas of the scope;

f) contract management.

The size of team and duration of the review should be commensurate with the project or programme size and complexity.

B.5.4 Produce a draft integrated baseline review handbook

A briefing handbook or packet covering the aspects that are applicable to the review in question should be produced. This handbook production should enable everyone involved in the review to have a clear understanding of the expectations, conduct and timing of the review.

B.5.5 Train teams

B.5.5.1 General

Joint training sessions should be held wherever practicable for the personnel involved in the review, either as reviewers or members of the project or programme team subject to review. The intent of the training is to provide sufficient information, so the teams can mutually understand the cost, schedule, technical and management processes used on the project or programme. When necessary, it can be appropriate to bring in external personnel for training and facilitation.

B.5.5.2 Review team training

The following trainings should be conducted for the review team:

a) project or programme control training – basics of control and the analysis of data;

b) review methodology training – discussion techniques, data tracing process, and document techniques for findings and issues;

c) project familiarisation – general items and specifics and dynamics:

   1) review handbook;

   2) review leader's expectations;

   3) project organization;

   4) budget baseline;

   5) schedule baseline;

   6) funding issues regarding sources, constraints and timing;

   7) scope of work or statement of requirements and objectives;

   8) identified risks and risk documentation;

   9) subcontractors' management;

   10) procurement;

   11) change management;

   12) reporting.

B.5.5.3 Joint project and review team training

Projects, programme and project or programme management office personnel during normal operations can conduct training sessions. Where training is conducted, the review team can seek to participate in these training opportunities.

B.5.5.4 Project or programme team training

The project or programme team should prepare for the review by training the necessary personnel in the process and conduct of a review.

A series of communication briefings can be conducted to enable the personnel involved in the review are aware of the overall review objectives, processes, timing and any activities needed to complete in readiness for the review. The review team should be provided the necessary priority by the participating stakeholders, particularly control account managers and the project or programme management team and sponsor.

B.5.6 Practice of the integrated baseline review

To assist in the preparation of a review, a practice or mock review can be held. This practice review can completely replicate the entire scope of the integrated baseline review, or it can be focused on preparing the integrated baseline review team with particular attention toward the control account managers.

In order to prepare the control account managers and enable them to be capable during the integrated baseline review discussion, the project or programme management office, designated trainer, or an organization offering such training can provide integrated baseline review coaching. Following the agreed format for the review, the coaching can take the form of mock discussions conducted by independent personnel. Feedback should be provided to the control account manager as to the performance and areas for improvement. The mock discussion can also identify areas in the control account manager's data that need to be developed further prior to the review.

The project or programme management team should undertake data tracing, as part of a mock review to identify any potential problem areas that subsequently can be briefed to the review team.

B.5.7 Define and agree to a schedule

B.5.7.1 The major activities of the integrated baseline review should include the following items:

a) in-brief for the review team explaining the purpose of the review and providing the opportunity for the introduction of team members;

b) overview by the project or programme management team familiarising the team with the characteristics of the earned value management system;

c) review of planning data, including system data traces and review of the control system description or equivalent, and any associated directives or instructions supporting the control system description;

d) discussions with control account managers identifying the basis on which the plan was established, providing those resources have been allocated and that relevant performance measurement techniques have been identified;

e) exception report addressing the review team's concerns and findings, including concerns, which should be identified, needing resolution and, if not already resolved prior to completion of the integrated baseline review, the estimated dates for resolution should be agreed;

f) joint exit briefing by the review team addressing the team's review findings.

B.5.7.2 Each day should commence with a team meeting held in the office designated for the integrated review and should conclude at the completion of the following activities:

a) completion of activities scheduled for the day;

b) write-up reports of discussions conducted;

c) project or programme office daily debriefs.

A generic agenda is shown in Table B.6.

Table B.6 — Example of an agenda

	In-briefing	
Repeat as many days as necessary	**Control account review** — CAM discussions — document review — risk review	**Project or programme wide review** — data traces — budget — schedule — authorisation — project or programme management — document review — document review — risk review
	Daily out-briefing	
	Final out-briefing	

B.5.8 Administration

The integrated baseline review should have an administration in order to enable the conduct of the review for the benefit of the stakeholders.

The project or programme management should arrange the following:

a) enable the review team and other necessary visitors are cleared for security requirements and arrangements are in place for them to be on site;

b) provide working space and support for the integrated baseline review team, including a working area and administrative support, as needed;

c) arrange schedules for discussions with control account managers and other project or programme management staff and enable availability of personnel; and control account manager discussions are available.

B.5.9 Production of final integrated baseline review handbook

The draft integrated baseline review handbook should be finalised and issued to the stakeholders to enable an understanding of the intent, objectives, process and timetable for the review.

B.5.10 Collation and delivery of integrated baseline review deliverables

The following documentation should be provided to the review team prior to the review and sufficiently in advance for the team to become familiar with the content:

a) statement of work;

b) planning documents for project and programme management;

c) work breakdown structure and work breakdown structure dictionary;

d) organizational breakdown structure;

e) responsibility assignment matrix;

f) work authorisation documents;

g) schedules, including any contract master schedule and detail schedules that support control accounts;

h) schedule risk analysis;

i) risk and issue registers;

j) control account plans or equivalent;

k) records documenting contractual changes and internal actions;

l) current earned value performance report, if available at the time of the first review;

m) control management system;

n) list of subcontractors and vendors, including description of product, applicable work breakdown structure elements, value of subcontracts and purchase orders, period of performance, and responsible control account manager;

o) basic contract, task orders and modifications.

In order to reduce the paperwork, it can be possible to transfer this material over a shared data environment. Alternative electronic formats for deliverables can be used, if deemed appropriate.

B.6 Implementation

B.6.1 General

When reviewing the performance measurement baseline and associated system documentation, a distinction should be made between the acceptability of the intended approach, as defined in any governance documentation, and the extent to which the approach is being used.

The final report should be made up of a number of practice related sections, such as organization, scheduling, budgeting and others, as needed. Documented preventive and corrective action reports should be included in the final report. Responsibility for compiling these sections should be allocated to the appropriate team members, which should assist in a timely report preparation.

B.6.2 Brief and launch

The brief should be used as an opportunity for the review team to gain an understanding of the project or programme being reviewed. This brief can include:

a) group introductions;

b) communication session for familiarisation;

c) site tour, if pertinent to review;

d) overview of the project or programme; and

e) review team being made aware of known control system deficiencies and current corrective actions.

B.6.3 Data traces

Data tracing is a methodology for identifying and tracking a source data element through the earned value management system and to provide an understanding of how the total system operates. When conducting traces, evidence should be documented. In some cases, the team leader can request that examples of the trace be obtained.

The following data traces should be considered during the review:

a) control system description comparison to the relevant project control guidance document;

b) organization and authorisation;

c) schedule, including subcontractors;

d) budget;

e) labour;

f) material;

g) status, including progress and performance;

h) risk and issue; and change management controls.

One of the objectives of the review should be to enable traceability throughout the system. If any inconsistencies or anomalies are identified, they should be addressed on the control account and cost account management evaluation sheets.

B.6.4 Control account, project and programme manager discussions

B.6.4.1 General

B.6.4.1.1 A key feature of the integrated baseline review should be the conduct of discussions by the review team with a sample group of the control account managers and functional managers, such as finance, human resources, commercial, senior management and other stakeholders.

Depending on the organizational structure of the contractor or organization, value can be attained by conducting interviews with other personnel in the contractors or performing organization's office, such as control personnel, functional or programme manager, team leaders and the project manager. The functional manager and team leader interviews should focus on their role with respect to the control account managers and project or programme manager, regarding assistance with schedule, resourcing, review of risks and progress.

The manager interview should focus on risks, risk treatment strategies, management reserve, reporting mechanisms within the contractor's office, as well as the manager's confidence in the performance measurement baseline and the earned value management system. An interview with the programme manager should also take place regarding these topics, as well as the general governance of the project management functions under the programme. The project or programme manager or appropriate member of the project or programme management team should provide details on the risk management structures and responsibilities, and these details should be verified through interviews with other team managers and members.

An interview with the finance manager should be conducted to verify the manner in which overheads and indirect costs are applied to the project or programme contract, if work is done under a contract.

B.6.4.1.2 The objective of these discussions should be to enable the review team to understand the methods and reasoning for how the performance measurement baseline has been developed and should be maintained. The final objective should be how performance indices are or will be used to manage the project or programme. The discussions regarding risk should consider the following:

a) structure of the particular control system;

b) risks and current issues known to the review team prior to the review;

c) risks and issues identified during the review.

B.6.4.1.3 Prior to each discussion, the review team should familiarise themselves with the following control account manager related information for formulating inquiries:

a) budgetary information from the responsibility assignment matrix;

b) control account definition and authorisation documents;

c) work package definitions and associated budget structures;

d) schedules;

e) performance reports.

B.6.4.1.4 A dedicated portion of the review team can be made available to undertake pre-discussion data scrubs. This pre-discussion should entail an off-line review of the control account manager folder, highlighting any areas of inconsistency or concern. The pre-discussion sessions should be documented and briefed to the review team member, who has responsibility for the interview. A sample data scrub checklist can be found in Reference [4].

To prepare for an integrated baseline review with the control account manager's discussion, it is recommended to:

a) check the schedule for the name of your first control account manager discussion;

b) find their location on the organization chart and responsibility assignment matrix;

c) determine their responsibility area on the work breakdown structure;

d) determine what the scope of work entails;

e) check the work breakdown structure, work breakdown structure dictionary and other documentation;

f) determine if the total work effort is consistent with the statement of work or statement of work contained in the contract;

g) determine how many control accounts exist, what the values are and check the responsibility assignment matrix;

h) find the work authorisation document that authorises the control account manager to do the work, determine if it shows the work they are authorised to do, a schedule to do the work, a control account or work package number to charge the work, and a budget for performing the work;

i) review the control account manager's authorising documentation, including the work, schedule, control account number and budget, which should be consistent with authorised on the work authorisation document;

j) review the allocated control account budgets, in terms of work content, total resources and time-phasing;

k) review the transition from the control account plan to an internal computer data system to determine if it correlates to the control account manager's plan;

l) review the methods the control account manager is using to take earned value that can be shown on the control account plan or similar documentation for the earned value-being reported to the authority on the contract performance report that should be consistent and reconcilable to the internal earned value;

m) trace the control account schedule to the next higher-level schedule and check that the dates and milestones agree;

n) check to determine if the control account manager made any changes to their control account plan and the authorisation for the change.

The number of control account manager discussions to be conducted and the choice of control account managers and other levels or types of managers should be based on achieving an acceptable level of confidence that the sample is indicative of the overall performance. Particular attention should be given to any areas of the performance measurement baseline or functional departments that the review team has determined pose the greatest risk to the successful achievement of the project's or programme's objectives.

Discussions should be conducted in a non-adversarial manner and be treated as a joint exercise for the benefit of both parties.

The discussion team should consist of no more than two representatives from the review team, one leading and asking the questions and the other taking notes and documenting that the identified areas have been covered and noting particular items from the responses. A representative from the project or programme, who has comprehensive knowledge of the earned value management system, should be present as an observer to document and raise any generic system issues. Where either the review team, project or programme manager wish to add further observers, care should be taken not to detract from the objectives of the discussion or put either party in a position of unease. There can be occasions where the reviewers need to include a technical peer to the control account manager in the interview to test the basis of estimate, scheduling, budget and risk.

B.6.4.2 Discussion guidance

Where possible the review should be done in the control account manager work area. This work location review meeting should enable a comfortable environment for the control account manager and provide the opportunity for evidence not immediately accessible to be quickly located by the control account manager. The questions should be phrased, so they can be easily understood and are not closed questions that can be answered by “yes” or “no”. The interviewer should use the technique of asking for information to be shown.

The discussion should be structured to allow the interviewee time to discuss how the process is followed. The control account manager should use documents when answering questions. If the control account manager struggles to understand a question, one should rephrase the question avoiding technical jargon. Remember that some control account managers can be in training; however, being in training should not necessarily mean that they do not understand the technical scope and plan for their work.

If needed, one should ask for relevant documents that are referenced to document the review and provide adequate evidence of conclusions. This information is used to substantiate the control account manager’s responses. If documentation is requested, but cannot be made available until after the discussion, one should get a documented commitment as to when the data should be received. This information is also used to substantiate the control account manager’s responses.

The control account manager should be treated respectfully throughout the review process.

Immediately following the discussion, the interview notes should be compiled into observations and documented in the control account or control account manager evaluation sheets. Reviewers should maintain their own discussion files to keep notes for subsequent write-ups. The reviewer can refer to them along with other data compiled to complete the final write-up for the assigned cost work breakdown structure area. One should follow-up on data requests, if they are slow in being completed per agreed upon date.

The team leaders should review the corrective action reports, and if considered necessary, present them to the performing organization to be resolved. It should be the responsibility of the various review team members to prepare clear and well-documented corrective action reports.

B.6.4.3 Collate write-up

Results of the control account manager discussions should be documented on the evaluation sheets. An agreement should be attained at the outset of the integrated baseline review whether or not these reports will be part of the final review.

B.6.5 Feedback sessions or issue board

During the review of and to give feedback on the main findings on a daily basis, an issues board, known also as the review issues log, and documentation should be maintained to document outstanding items. This documentation should be done at the end of each day. This approach should provide the review team members with an overview of how the review is progressing and enable the project or programme management team to address or begin to address any findings before the end of the review.

B.6.6 Review closure

After completion of a review, a closure meeting should be held with the relevant stakeholders in order to agree on relevant key findings and actions. The project or programme manager and customer or review requester should agree on a plan of closeout actions, the person responsible for the action and completion date. These actions should be documented in writing, considered as project or programme risks or issues, and treated accordingly.

Reporting the results of the review can be done through a formal or informal letter or memo for record depending upon the governance of the organization, project or programme, or contract. The letter should address any action items that have been agreed upon between the contractor and procuring authority or requester of the review. When applicable, the letter should summarise the findings that need corrective action and assign the surveillance of the corrective action to the project or programme manager.

B.7 Post review

B.7.1 Corrective action plan

At the conclusion of the on-site integrated baseline review activity, the concerns needing resolution should be identified with an estimated date for resolution proposed by the review team.

Depending on the number and severity of the findings, the project or programme management team can identify a date by which a corrective action plan should be provided to address the findings. Where only a few findings exist, the team can be in a position to provide dates against each item prior to the team leaving. The corrective action plan should provide sufficient detail to allow the integrated baseline review team leader to review the adequacy of the proposed solution. These corrective actions should be tracked to closure prior to final approval of the performance measurement baseline.

Additional risks or issues identified during the integrated baseline review should be placed in the internal risk and issues register and managed accordingly. The integrated baseline review team leader should also ascertain that the project or programme team has taken appropriate action to record any risks or issues identified during the integrated baseline review process.

B.7.2 Post review feedback

In order to support the continuous improvement of the integrated baseline review process, post review feedback should be provided. Feedback should be provided to both the review team and the project or programme management team, as to the success of the review process from the participants' point of view. Findings should be passed on to other review teams in order to improve the process, wherever possible.

B.7.3 Joint surveillance

There can be more than one review being conducted besides the integrated baseline review. The need for any other type of review to periodically re-assess the earned value management system can be evaluated by the customer or requester of the review in conjunction with the project and programme manager, if the project is part of a programme. The plan for either demonstration or surveillance activities should be based upon the degree of risk identified during the integrated baseline review and the degree to which the earned value management system satisfies contractual requirements.

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