



Software Engineering Institute

Measurement and Analysis Infrastructure Diagnostic (MAID) Evaluation Criteria, Version 1.0

Software Engineering Measurement and Analysis (SEMA) Group

December 2009
(Revised February 2010)

TECHNICAL REPORT
CMU/SEI-2009-TR-022
ESC-TR-2009-022

Software Engineering Measurement and Analysis
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This work is sponsored by the U.S. Department of Defense. The Software Engineering Institute is a federally funded research and development center sponsored by the U.S. Department of Defense.

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Acknowledgments

Mark Kasunic authored this document with the help and support of others. David Zubrow, the manager of the Software Engineering Measurement and Analysis (SEMA) group, developed the idea for MAID and has made significant contributions to the direction and development of this document. Robert Ferguson, James McCurley, Robert Stoddard, and David Zubrow provided feedback on early draft sections of this document. The full manuscript was reviewed by Wolf Goethert, Watts Humphrey, and David Zubrow of the SEI; Jose Arturo Mora Soto of the Software Engineering Lab of Universidad Carlos III de Madrid; and James Zitek and Erik Dorsett of Jeppesen. Erin Harper was the technical editor of this document.

Abstract

The Software Engineering Institute (SEI) is developing the Measurement and Analysis Infrastructure Diagnostic (MAID) method. MAID is a criterion-based evaluation method that facilitates the examination and evaluation of data quality issues linked to how the organization implements measurement and analysis practices.

This document presents the set of criteria used during a MAID evaluation. The criteria serve as a checklist for an evaluator to use to rate the quality of an organization's measurement and analysis practices and the quality of the measurement information that results from the implementation of those practices.

The evaluation itself is carried out by a team following the MAID method. The MAID method is described briefly in this document. A full description of the method will be published in a separate document in 2010.

Introduction

Background

Ensuring measurement and analysis (M & A) information quality is a challenge for most organizations. When organizations are not aware of their data quality levels, they cannot know the full business impact of poor or unknown data quality or how to address it.

The Software Engineering Institute (SEI) is developing the Measurement and Analysis Infrastructure Diagnostic (MAID) method. MAID is a criterion-based evaluation method that allows organizations to evaluate key characteristics of their measurement programs. *Can You Trust Your Data? Establishing the Need for a Measurement and Analysis Infrastructure Diagnostic* describes the concept, rationale, and objectives of MAID [Kasunic 2008a].

In this document, we present a set of criteria that can be used to evaluate (1) the four stages of the M & A process:

- M & A Planning
- Data Collection and Storage
- Data Analysis
- M & A Reporting

(2) data and information quality issues, and (3) M & A impact.

The MAID criteria have been organized into five sections as shown in Table 1.

Table 1 Major topics covered by criteria in each section of this document

Section	Major Topics
M & A Planning	• Identifying M & A resource needs and skill training • Identifying M & A information needs • Identifying and defining measures and measurement indicators that address needs • Planning and scheduling M & A activities • Developing M & A processes and procedures to perform M & A activities
Data Collection and Storage	• Collecting M & A data that address information needs • Ensuring completeness and accuracy of the recorded data • Ensuring that data are stored securely
Data Analysis	• Preparing the data for analysis • Transforming the data into tables and graphs that can be analyzed • Selecting the appropriate statistical analysis approach to analyze the data • Conducting statistical analyses of the data

Table continues on next page

Section	Major Activities
M & A Reporting	- Understanding the M & A expertise level of the stakeholders who will use the M & A information to support decision making - Transforming the data analysis results into M & A information that best facilitates comprehension by the stakeholders who will use the information to support decision making
Criteria for All M & A Process or Procedure Documentation	Writing effective M & A documentation

The criteria vary in terms of the impact they might have if met (or not met). A companion document that further details the MAID method will be published in 2010. The Method document will provide guidance on the weighting of criteria.

To develop the criteria, the SEI has drawn upon, synthesized, and organized well-established best practice guidance that is already embodied in existing models, standards, methods, and applicable best practices (see Figure 1).

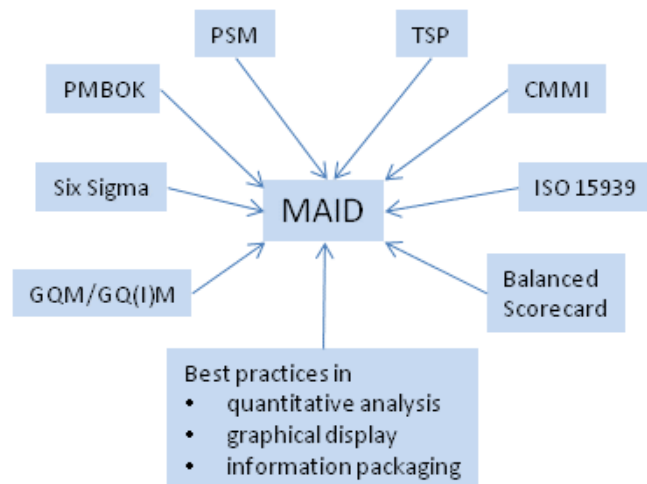


Figure 1: Inputs Considered for Development of MAID¹

The MAID criteria were developed for use by a team during a MAID evaluation. This team can be composed of (a) individuals from within an organization if such expertise exists; (b) external M & A experts who are contracted by the organization to perform the MAID evaluation, or (c) a combination of a and b.

MAID criteria are used as part of the MAID method, summarized in Table 2. MAID criteria are used by the MAID evaluation team during Phase 2, Document Evaluation, and Phase 3, On-Site Evaluation.

¹ Acronyms used in the graphic are defined as follows: Goal-Question-Metric (GQM), Goal-Question-Indicator-Metric (GQ(I)M), Project Management Book of Knowledge (PMBOK), Practical Software and System Measurement (PSM), Team Software Process (TSP), Capability Maturity Model Integration (CMMI), and International Organization for Standards (ISO).

Table 2 Summary of the MAID method

MAID Phase	Description
Collaborative Planning	• Establish roles and expectations. • Determine MAID scope. • Identify client organization's data producers, measurement analysts, and M & A consumers based on scope. • Inventory M & A documents to be reviewed. • Determine schedule.
Document Evaluation	• Review M & A documents and data files (MAID team). • Conduct question and answer sessions by phone and email (MAID team and client). • Provide additional documents upon request (client). • Conduct detailed collaborative planning for site visit. • Finalize detailed daily schedule for site visit. • Send emails to all client interviewees explaining what to expect. • Perform readiness review.
On-Site Evaluation	• Conduct kick-off briefing. • For each focus area defined within the scope conduct the following interviews and examinations: – interview – data consumers – interview – data producers – interview – data manager – examination – data storage mechanism – examination – database contents (if not reviewed during phase 2) – interview – measurement analysts – interview – M & A information designers and presenters
Report Results	• Analyze MAID results. • Prepare briefing. • Deliver briefing. • Conduct lessons learned.

Sections 1 through 5 of this document present the current set of MAID evaluation criteria. Readers are encouraged to provide their own suggestions for and feedback about the criteria. In the future, we plan to review the feedback and publish a revised set of criteria.

Conventions Used in This Document

Beginning with Section 1, terms that appear in italics are defined in the glossary. Further occurrences of the term are not italicized. Paragraphs that appear in unshaded boxes describe the intention of the set of criteria that appear underneath it. Examples and explanations appear in shaded boxes.

1 Measurement and Analysis (M & A) Planning

Organization Level

- 1.1 Organizational policies exist that mandate the establishment of an organization-wide measurement program.
 - 1.2 Organizational business goals are defined and documented.
 - 1.3 Stakeholders of the business goals are explicitly defined.
 - 1.4 Organizational business goals are expressed in measurable terms so progress toward achieving a goal can be assessed.
 - 1.5 Organizational business goals are kept current. That is, they are reviewed on a periodic basis (at least annually) to ensure that they reflect the current viewpoint of management.
 - 1.6 A measurement plan² is documented.³
-

The organization provides adequate infrastructure to implement an organization-wide measurement program.

- 1.7 An educational effort is planned to communicate or emphasize the goals and priorities of the measurement program to obtain support and buy-in from affected individuals.
- 1.8 The plan specifies the resources that are to be allocated for
 - 1.8.1 staffing M & A personnel⁴
 - 1.8.2 software tools
 - 1.8.3 data storage
 - 1.8.4 reporting
 - 1.8.5 M & A training
 - 1.8.5.1 M & A awareness training for all staff
 - 1.8.5.2 M & A skill training and guidance on measurement concepts, data collection, analysis, interpretation, info packaging, and reporting, based on need

² “Plan” does not necessarily imply a single plan. The “plan” might take form as a hierarchy of plans—for example, a management plan may authorize and provide guidelines to planning groups that then develop more detailed, operational plans and procedures for the organization’s measurement program.

³ An M & A plan need not be a separate document. It may be part of an integrated organization process/measurement plan.

⁴ M & A personnel are individuals who are assigned to M & A tasks such as data collection, data graphing, quantitative analysis, and so forth.

The plan specifies that “organization” information needs are to be addressed.

- 1.9 Measurable business goals are documented in the plan.⁵
- 1.10 A structured approach is followed to develop performance measures and measurement *indicators*⁶ [Park 1996; Basili 1994; McGarry 2001; Kaplan 1992; Florac 1999, p. 26].

The documented approach

- 1.10.1 leads to a prioritized list of information needs associated with each business goal of the organization⁷ and the relevant goals of a parent organization or other important stakeholders
- 1.10.2 identifies the data sources that provide measurement information that address the information needs
- 1.10.3 defines measurement indicators that address information needs
- 1.10.4 defines *base measures* and *derived measures* that contribute to development of each measurement indicator
- 1.10.5 identifies the data sources of base measures

The plan is well-organized, technically correct, and understandable by the intended audience.

- 1.11 The plan is structured well and reader-friendly.
- 1.12 The relationship of the plan to other relevant documents is explained (e.g., its relationship to enterprise process/measurement plan, *project* level measurement plans, and improvement initiative plans).
- 1.13 Source locations of reference documents specified in plan documents are provided and readily accessible.
- 1.14 Explanations of measurement concepts within planning documents are correct.
- 1.15 Terms that may not be understood by readers of the plan are defined.
- 1.16 Acronyms used in the plan documents are defined.

⁵ Goals are listed in the measurement plan so it is clear they are the basis for deriving information needs and measurement indicators that address the information needs. In some cases, the goals of an organization result from the need to support the goals of a parent organization to which it is subordinate.

⁶ The objective of the structured approach is to ensure that performance measures and indicators provide the information needed to assess how well the organization is performing against the business goals over time. The citations represent examples of documented structured approaches, but there are others and an organization may have developed their own documented approach for selecting appropriate measures and indicators.

⁷ The prioritized information needs may also include the information needs inherited from a parent organization.

Effective project management principles are followed to plan the development of measurement program products (e.g., M & A procedures, data-collection mechanisms, and storage mechanisms).

- 1.17 Responsibility for developing and maintaining the M & A plan is specified.
- 1.18 Authority for the plan is specified (i.e., the approval requirements).
- 1.19 For all planned M & A activities, the plan provides the following:
 - 1.19.1 activity description
 - 1.19.2 description of work products produced
 - 1.19.3 activity start and stop date
 - 1.19.4 estimated effort
 - 1.19.5 completion criteria⁸
 - 1.19.6 responsible individuals
- 1.20 The plan documents are baselined and then kept under configuration control.
- 1.21 The plan describes the triggers that will lead to replanning and changes to the plan.
- 1.22 The plan is updated as the measurement process is changed.
- 1.23 The plan specifies an activity that results in a description that illustrates the source, destination, and transformation of measurement information throughout the organization.

M & A terminology is defined to align with standards.

- 1.24 M & A terminology is defined.
- 1.25 Common M & A standards and terminology are used within the organization.
- 1.26 The organization adopts M & A terminology and methods defined by standards organizations such as the International Organization for Standardization (ISO).

⁸ Completion criteria are sometimes referred to as exit criteria or success criteria.

The plan specifies guidelines for the structure, content, format, and accessibility of M & A processes and procedures.

1.27 The plan mandates that

- 1.27.1 structure, content (e.g., who, what, when, where, why, and how), and format of *measurement procedure* documents are defined
- 1.27.2 location of and access mechanism for M & A process/procedure documentation is communicated to all affected personnel

Detailed M & A plans specify the content that must be included in M & A procedures.

1.28 Data collection and storage procedures are documented that describe how each base measure is defined, collected, and stored. A **data collection and storage procedure** includes the following:

- 1.28.1 role responsible for maintaining the procedure description
- 1.28.2 role responsible for the data-collection activity
- 1.28.3 list of stakeholders who own the information need
- 1.28.4 entity (e.g., specific process or product) that is being measured
- 1.28.5 attributes of the entity that are to be measured
- 1.28.6 base measure name
- 1.28.7 definition of the base measure as specified by the following characteristics:
 - 1.28.7.1 *measurement method*
 - 1.28.7.2 type of method (*subjective* or *objective*)
 - 1.28.7.3 *scale* to be used
 - 1.28.7.4 *type of scale*
 - 1.28.7.5 *unit of measurement*
- 1.28.8 format of recorded data
- 1.28.9 time and frequency of data collection
- 1.28.10 software application used to record data (e.g., spreadsheet, database, or text document)
- 1.28.11 error-checking sub-procedure
- 1.28.12 identification of the repository for collected data
- 1.28.13 data security requirements
- 1.28.14 data access privileges

- 1.29 A procedure is documented that describes the **analysis approach** (i.e., the who, what, how, and when) for each derived measure and measurement indicator. An analysis procedure specifies the following:
 - 1.29.1 stakeholder or stakeholders who own the information need (by organization and role)
 - 1.29.2 analyst (role description)
 - 1.29.3 entity (e.g., specific process or product) that was measured
 - 1.29.4 attributes of the entity that were measured
 - 1.29.5 pointer to the data collection and storage procedure
 - 1.29.6 frequency of analysis
 - 1.29.7 base measures and definitions or pointer to base measure characterizations
 - 1.29.8 derived measure as characterized by
 - 1.29.8.1 *measurement function*
 - 1.29.8.2 indicator
 - 1.29.8.3 *analysis model*
 - 1.29.8.4 *decision criteria*
 - 1.29.9 repository location for analyzed M & A results
 - 1.29.10 security requirements for stored M & A results
 - 1.29.11 access privileges for stored M & A results
 - 1.29.12 software tools used to process and analyze the data, including the version number of applications
 - 1.29.13 file-naming conventions
 - 1.29.14 version control requirements
 - 1.29.15 storage location of measurement information (e.g., base, derived, and analysis results)
 - 1.29.16 storage guidelines
- 1.30 A procedure is documented that describes the **reporting requirements** for M & A information. An M & A reporting procedure specifies the following:
 - 1.30.1 information need addressed by the measurement indicators
 - 1.30.2 audience (stakeholders)
 - 1.30.3 measurement indicators to be reported
 - 1.30.4 role responsible for reporting the M & A information
 - 1.30.5 frequency of reporting

- 1.30.6 mechanism (e.g., presentation, web access, dashboard, or report)
- 1.30.7 report content (e.g., background, explanation, current status, what has changed, interpretive guidance, recommendations, other insights, and validation check to ensure that information need is met)
- 1.30.8 repository location for M & A reports
- 1.30.9 security requirements for M & A reports
- 1.30.10 access privileges for stored M & A reports

The M & A plan specifies that procedures be developed that enable stable implementation of M & A over time.

- 1.31 A validation mechanism is defined to ensure that each measure or measurement indicator satisfies the information need it is intended to address.
- 1.32 An independent quality assurance function responsible for auditing the execution of the measurement plan is defined.
- 1.33 Tailoring guidelines are documented that describe what, when, and how M & A processes/procedures are tailored.
- 1.34 A procedure is documented that describes how a waiver for confidentiality and disclosure requirements (for M & A information) can be obtained.
- 1.35 A procedure is documented that describes how version and configuration control of M & A artifacts is maintained.

Specific for projects⁹

- 1.36 A project estimation process¹⁰ is developed for estimating
 - 1.36.1 size
 - 1.36.2 effort
 - 1.36.3 staffing
 - 1.36.4 quality
 - 1.36.5 schedule
 - 1.36.6 cost

⁹ Mature organizations will mandate that projects implement this in a common way to support valid comparison among projects and support benchmarking.

¹⁰ The quality of the estimation process will depend on the maturity of the organization/project. Also, one important consideration in the use of a particular estimation technique is that different techniques will apply in different circumstances [McConnell 2006, p. 77].

1.37 The plan specifies that projects collect data that assesses project life-cycle performance including the following:

- 1.37.1 effort
- 1.37.2 cost
- 1.37.3 productivity
- 1.37.4 schedule predictability
- 1.37.5 requirements completion ratio (i.e., functionality delivered)
- 1.37.6 defect density by phase
- 1.37.7 post-release defect density

[Kasunic 2008b]

1.38 The plan specifies that project characterization data (e.g., influence factors found in the SEI report *A Data Specification for Software Project Performance Measures: Results of a Collaboration on Performance Measurement* [Kasunic 2008b] and adjustment factors in COCOMO II) is to be identified and collected by projects to support benchmarking and continuous improvement of project estimation processes including:

- 1.38.1 artifact reuse
- 1.38.2 project type
- 1.38.3 application domain
- 1.38.4 average team size (tracked throughout the project life cycle)
- 1.38.5 maximum team size
- 1.38.6 team expertise
- 1.38.7 process maturity

1.39 The plan specifies that if and when a commercial software estimation tool or some other parametric model (such as COCOMO II) is used, it is calibrated with one of the following approaches [McConnell 2006]:

- using historical data generated by previous and similar projects within the organization
- using industry-based data appropriately, if historical data are unavailable
- using a group of experts employing a structured approach (e.g., wide-band Delphi), if data are not available
- using individual expert judgment, if neither data nor a group of experts is available.

1.40 The plan specifies that actuals (i.e., effort, cost, schedule, and quality) be compared with estimates and the outcomes documented.

- 1.41 The plan specifies that the following are recorded:
 - 1.41.1 number of software requirements changes per time unit and/or per life cycle phase
 - 1.41.2 rationale for a requirements change¹¹
- 1.42 The plan specifies that peer review activities are conducted to identify, characterize, and record defects throughout the project life cycle.¹²
- 1.43 The plan specifies that individuals who contribute to product development collect data to characterize their personal performance [Humphrey 1999].
- 1.44 The plan specifies that personal performance data are combined to characterize team performance [Humphrey 1999].

¹¹ Doing so supports cause and effect analysis.

¹² This refers to any software product artifact including requirements, design, code, and documentation.

2 Data Collection and Storage Criteria

For Data That is Collected¹³

- 2.1 For each measure that is collected, a data-collection process/procedure includes the following information:
 - 2.1.1 role responsible for maintaining the procedure description¹⁴
 - 2.1.2 role responsible for the data-collection activity
 - 2.1.3 a list of stakeholders who own the information need
 - 2.1.4 entity (e.g., specific process or specific product) that is being measured
 - 2.1.5 attributes of the entity that are to be measured
 - 2.1.6 base measure name
 - 2.1.7 definition of the base measure as specified by the following characteristics:
 - 2.1.7.1 measurement method
 - 2.1.7.2 type of method (subjective or objective)
 - 2.1.7.3 scale to be used
 - 2.1.7.4 type of scale
 - 2.1.7.5 unit of measurement
 - 2.1.8 format of recorded data
 - 2.1.9 time and frequency of data collection
 - 2.1.10 software application used to record data (e.g., spreadsheet, database, or text document)
 - 2.1.11 error-checking sub-procedure¹⁵
 - 2.1.12 repository for collected data
 - 2.1.13 data security requirements
 - 2.1.14 data access privileges
 - 2.1.15 special instructions (e.g., mandatory vs. optional recording of information)

¹³ These criteria do not address data collection for special cases such as inferential statistical studies which would imply the need for random sampling plans.

¹⁴ The author of the procedure is identified in the M & A plan. In some cases the author and maintainer of the procedure are the same.

¹⁵ This ensures all data fields were recorded or transcribed correctly.

- 2.1.16 requirement that missing data designated as mandatory to collect be accompanied by the reason information was not recorded
- 2.1.17 file-naming conventions
- 2.1.18 computer system where recorded data resides and path name where data are stored
- 2.1.19 data-collection form to be used, with a copy provided in process/procedure document and pointers to on-line version
- 2.1.20 instructions for completing the form
- 2.1.21 definitions for the data fields located on the form, when needed
- 2.1.22 instructions for submitting the completed data-collection form
- 2.2 A data-collection form/template accompanied by clear instructions is used to collect the measurement data. The form contains the following fields:
 - 2.2.1 a reference to the data-collection procedure
 - 2.2.2 physical location where data are collected, if applicable
 - 2.2.3 identity of specific individual who collects data, with contact information
 - 2.2.4 date and time stamp
 - 2.2.5 information identifying the organization and project
 - 2.2.6 entity name
 - 2.2.7 attribute name
 - 2.2.8 location or source of the measures
 - 2.2.9 confidentiality level of collected data
- 2.3 The data form is consistent with the associated data-collection procedure.
- 2.4 When data are shared among databases, the metadata that characterizes the source of the data are available. For example,
 - 2.4.1 organizational entity (enterprise, organization name, or project name)
 - 2.4.2 entity
 - 2.4.3 attribute
 - 2.4.4 time data was collected
 - 2.4.5 identity of the data collector¹⁶

¹⁶ One of the basic principles of quality is accountability by persons performing the data collection or reporting work. Even automated integrity rules that might be implemented cannot be effective without accountability [English 2004].

- 2.5 An audit of data-collection practices is periodically conducted to ensure that measurement and analysis procedures are being adhered to.
- 2.6 A data quality audit is regularly performed to quantify and correct data recording errors or data entry errors.
- 2.7 A checklist or similar mechanism exists to monitor compliance to the data-collection requirements.

The checklist includes the following:

- 2.7.1 organization entity name
 - 2.7.2 contact information for individual responsible for collecting the information (if data are being collected) or reporting the measurement information (if data are being reported)
 - 2.7.3 measures reported
 - 2.7.4 due date (for reported data)
 - 2.7.5 actual date (for reported data)
 - 2.7.6 number of data-collection errors by severity
 - 2.7.7 percentage of mandatory fields completed with valid data¹⁷
- 2.8 The number of data-collection errors is monitored over time.
 - 2.9 Security mechanisms exist to ensure that stored data cannot be altered by unauthorized individuals.

¹⁷ In this context, "valid data" is used to mean data that is free of transcription errors.

3 Data Analysis Criteria

- 3.1 Data analysis process or procedure specifies the following for each information need:
 - 3.1.1 stakeholders who own the information need (by organization and role)
 - 3.1.2 analyst (role description)
 - 3.1.3 entity (e.g., specific process or product) that was measured
 - 3.1.4 attributes of the entity that were measured
 - 3.1.5 pointer to the data-collection and storage procedure
 - 3.1.6 frequency of analysis
 - 3.1.7 base measures and definitions or pointer to base measure characterizations
 - 3.1.8 derived measure as characterized by
 - 3.1.8.1 measurement function
 - 3.1.8.2 indicator
 - 3.1.8.3 analysis model
 - 3.1.8.4 decision criteria
 - 3.1.9 repository location for analyzed M & A results
 - 3.1.10 security requirements for stored M & A results
 - 3.1.11 access privileges for stored M & A results
 - 3.1.12 software tools used to process and analyze the data, with version number
 - 3.1.13 file-naming conventions
 - 3.1.14 version control requirements
 - 3.1.15 storage location of measurement information (e.g., base, derived, or analysis results)
 - 3.1.16 storage guidelines

- 3.2 When a dataset is examined
 - 3.2.1 a data value is not missing from a data cell unless entry has been specified as optional
 - 3.2.2 data format of each data cell has been correctly set or applied, if applicable
 - 3.2.3 data values are within the permissible range of values for the data cell, if applicable
 - 3.2.4 formula computations with a data cell have been correctly set up, if applicable
- 3.3 Before using a statistical method, the dataset distribution is examined to expose data outliers (if they exist) and to ensure that departures from underlying assumptions associated with the method are understood and documented¹⁸ [NIST 2009a, NIST 2009b].
- 3.4 When quantitative descriptive statistics are used, the measure of central tendency is accompanied by a measure of variability.
- 3.5 In cases where a special study¹⁹ is undertaken, a research plan is developed that describes the following:
 - 3.5.1 problem statement
 - 3.5.2 method or approach to solving the problem
 - 3.5.3 analysis method
 - 3.5.4 reporting method
- 3.6 Model adequacy is checked using residual analysis before assuming that the results of ANOVA analysis are valid.

¹⁸ Techniques for testing the departure from assumptions are available [NIST 2009b].

¹⁹ Special studies are those that are considered sporadic analysis studies conducted to address specific problems or issues. Special studies include those that are carried out to produce quantitative projections of key project attributes and evaluate the accuracy and realism of project plans. Also special studies include those activities that are chartered as a consequence of a corrective action (resulting from routine data analysis) to fix a problem or to explore an improvement opportunity.

- 3.7 When developing measurement instruments (e.g., questionnaires for surveys or test forms) the analyst assesses the reliability of the measures and indicators.

Explanation

There are four general classes of reliability estimates, each of which estimates reliability in a different way.

Inter-rater or inter-observer reliability is used to assess the degree to which different raters or observers give consistent estimates of the same phenomenon.

Test-retest reliability is used to assess the consistency of a measure from one time to another.

Parallel-forms reliability is used to assess the consistency of the results of two tests constructed in the same way from the same content domain.

Internal consistency reliability is used to assess the consistency of results across items within a test.

- 3.8 When using statistical modeling methods, adherence to the following underlying assumptions required for validity of the results are tested:
- 3.8.1 independence
 - 3.8.2 normality
 - 3.8.3 constant variability of the error terms
- 3.9 When a statistical model is developed (e.g., linear regression), confidence intervals are calculated and displayed to illustrate the uncertainty associated with the fitted regression line (the average dependent variable values).
- 3.10 When a statistical model is used (e.g., linear regression) for prediction, a prediction interval is calculated and displayed to illustrate the uncertainty associated with the prediction of new dependent variable values.

4 Measurement and Analysis Reporting Criteria

- 4.1 An audience analysis is conducted to ensure that M & A information is designed for the needs, interests, and backgrounds of the individuals for whom it is intended [Rossi 2001].

Explanation: Each M & A stakeholder is characterized according to audience type so M & A information is packaged in a way that takes into account the expertise level of the audience.²⁰ An audience analysis answers the questions listed below.

- What is your audience's experience with the topic?
- What terms and concepts will they probably not understand?
- What do you need to tell them so that they understand your meaning?
- What misconceptions might they have?

[Perelman 2009]

- 4.2 For each information need identified, a reporting process/procedure defines the following:
- 4.2.1 role responsible for reporting the M & A information
 - 4.2.2 identification of each stakeholder to whom the information is reported (i.e., the owners of the information need)
 - 4.2.3 the measures and/or indicators that will be reported for each stakeholder
 - 4.2.4 frequency that M & A information is to be reported, determined by the timeliness necessary to meet decision-making objectives, and the allowable duration between data collection and reporting
 - 4.2.5 format for reporting measurement information to each stakeholder
 - 4.2.6 mechanism for reporting measurement information to stakeholder (e.g., stand-alone report, dashboard, or presentation)
 - 4.2.7 security, confidentiality level, or access rights of reported M & A information
- 4.3 A validation procedure (i.e., feedback mechanism) is defined to ensure that information needs are satisfied by the suite of M & A indicators.
- 4.4 M & A information that is communicated to support decision making are accompanied by explanations that clarify the message.²¹

²⁰ See Appendix A for an example framework for characterizing audience types.

²¹ Whenever a table or graph does not speak clearly enough on its own, its design should be improved or explanatory text should be added [Few 2004, p. 126].

- 4.5 M & A information that is communicated to support decision making is accompanied by recommendations for what could or should be done based on that information²² [Few 2004, p. 127].
- 4.6 When a measurement indicator value exceeds the acceptability threshold, corrective action is taken.
- 4.7 The communicator of M & A information recognizes and reports opportunities for further exploration, further speculation, and valuable questions that decision-makers ought to be considering [Few 2004, p. 127].
- 4.8 The M & A report includes
 - 4.8.1 author of the report on each page of the report²³ [Few 2004, pp. 128-129]
 - 4.8.2 page number on each page of report [Few 2004, pp. 128-129]
 - 4.8.3 type of quantitative and categorical information that the report represents on every page [Few 2004, pp. 128-129]
 - 4.8.4 date or period when the data was collected [ISO 2007; Few 2004, p. 129]
 - 4.8.5 limitations of the results and any other qualifications (e.g., limitations to the validity of the conclusions drawn) [ISO 2007]
 - 4.8.6 names and versions of software tools used for performing statistical analysis [ISO 2007]
 - 4.8.7 number of observations from which conclusions are drawn [ISO 2007]
 - 4.8.8 sampling procedures that are used [ISO 2007]
 - 4.8.9 assumptions underlying the analysis techniques that are used and the results of any sensitivity analysis performed to check for robustness to violation of assumptions [ISO 2007]
 - 4.8.10 precisely how aggregates are performed (e.g., average or weighted average) [ISO 2007]
 - 4.8.11 unit of observation about which conclusions are drawn (e.g., inspection package or configuration item) [ISO 2007]
 - 4.8.12 how missing data and anomalies were dealt with, where applicable [ISO 2007]
 - 4.8.13 how outliers were dealt with during data analysis, where applicable [ISO 2007]
 - 4.8.14 how combining data across different datasets was performed, where applicable [ISO 2007]
 - 4.8.15 for any statistical tests, whether they are one- or two-sided [ISO 2007]

²² In some cultures, recommendations may not be welcome from the presenter of data. Such a consideration must be factored in within the context of the situation.

²³ Some information should be included on every page of a report because excerpts from multi-page reports are often copied and distributed. If the information that identifies the report's contents only appears at the beginning, readers will have no way of knowing what they are seeing when they have only a portion of the report [Few 2004, p. 128].

- 4.8.16 for any statistical tests, the alpha levels used (i.e., the amount of acceptable error) [ISO 2007]
 - 4.8.17 for any statistical tests, how p values are calculated (i.e., the probability of getting the observed result or a more extreme one by chance) [ISO 2007]
 - 4.8.18 how confidence intervals are calculated, where applicable [ISO 2007]
 - 4.8.19 how prediction intervals are calculated, where applicable
 - 4.9 Text answering the following questions should be included on every page of an M & A report:²⁴
 - 4.9.1 What? (Description of the type of quantitative and categorical information that the report represents.)
 - 4.9.2 When? (A listing of the range of dates the information represents; the point in time when the information was collected.)
 - 4.9.3 Who? (A person to contact if readers have questions.)
 - 4.9.4 Where? (A page number. Within the report the best format is page # of ##.)
- [Few 2004, p. 128]

Explanation: M & A information is reported in one of the three ways (a) in a sentence, (b) in a table, (c) in a graph. The remaining criteria are organized into the following categories:

- tables
- graphs
- tables and graphs

Tables

- 4.10 Tables are used to present quantitative information when
 - the table is used to look up individual values
 - the table is used to compare individual values
 - precise values are required
 - quantitative information to be communicated involves more than one unit of measure[Few 2004, p. 46, Robbins 2005, p. 344]
- 4.11 Table titles, column headings, and footnotes precisely define what each data point in the table means [Klass 2002].
- 4.12 When rates or ratios are reported, both the numerator and denominator are clearly defined [Klass 2002].

²⁴ Excerpts from multi-page reports are often copied and distributed. If the information that identifies the report's contents only appears at the beginning, readers will not have a way of knowing what they're seeing when they have only a portion of the report [Few 2004, p. 128].

4.13 To delineate columns and rows in a table,

- 4.13.1 white space alone is used whenever space allows
- 4.13.2 only enough vertical white space between groups to make breaks noticeable is used
- 4.13.3 subtle fill colors are used when white space cannot be used
- 4.13.4 subtle rules are used when fill colors cannot be used
- 4.13.5 grids are avoided altogether

[Few 2004, pp. 135-136, 139-158; Klass 2002; Ford 2007]

4.14 Arranging data in a table

4.14.1 Columns and rows

- 4.14.1.1 sets of categorical subdivisions are arranged across separate columns if they are few in number and the maximum number of characters in those subdivisions is not too large [Few 2004, pp. 141-142]
- 4.14.1.2 time-series subdivisions are arranged horizontally across separate columns [Few 2004, pp. 142-143]
- 4.14.1.3 ranked subdivisions are arranged vertically down rows [Few 2004, pp. 142-143]

4.14.2 Groups and breaks

- 4.14.2.1 column headers are repeated at beginning of each new group [Few 2004, pp. 143-144]
- 4.14.2.2 each group starts on a new page when groups should be examined independently [Few 2004, pp. 142-143]

4.14.3 Column sequence

- 4.14.3.1 sets of categorical subdivisions arranged down the rows of a single column are placed to the left of quantitative values associated with them [Few 2004, p. 144]
- 4.14.3.2 sets of categorical subdivisions that have a hierarchical relationship (e.g., between product families and products) are placed from left to right to reflect that hierarchy [Few 2004, pp. 144-145]
- 4.14.3.3 quantitative values calculated from another set of quantitative values are placed just to the right of the column from which they were derived [Few 2004, p. 144]
- 4.14.3.4 columns containing data that should be compared are placed close to each other [Few 2004, p. 145; Ford 2007].

4.14.4 Value sequence

- 4.14.4.1 When categorical subdivisions have a meaningful order, they are sorted in that order [Few 2004, p. 146; Klass 2002]

4.15 Formatting text in a table

4.15.1 Orientation

- 4.15.1.1 Text orientation other than horizontal (left to right) is avoided [Few 2004, p. 146]

4.15.2 Alignment

- 4.15.2.1 numbers are aligned to the right, keeping decimal points aligned as well [Few 2004, p. 147]
- 4.15.2.2 calendar dates are aligned to the left using a format that maintains a constant width [Few 2004, p. 148]
- 4.15.2.3 text is aligned to the left [Few 2004, p. 148]
- 4.15.2.4 non-numeric data are centered if they all have the same number of characters and the number of characters in the header is significantly greater [Few 2004, p. 148]

4.15.3 Number formatting

- 4.15.3.1 comma is placed to the left of every three whole number digits²⁵ [Few 2004, p. 149]
- 4.15.3.2 whole numbers are truncated by sets of three digits to the nearest thousand, million, billion, and so forth whenever numeric precision can be reduced without the loss of meaningful information, and this is declared so in the title or header (e.g., U.S. dollars in thousands) [Few 2004, p. 149]
- 4.15.3.3 negative sign or parentheses is used to display negative numbers (e.g., - 8,395.37 or (8,395.37)), but if parentheses are used, the numbers that are enclosed are right aligned with the positive numbers [Few 2004, p. 149]
- 4.15.3.4 percentage sign is placed immediately to the right of every percentage value [Few 2004, p. 149]

²⁵ Note that in some languages this is not the convention. Instead, a period might be used. There may be other differences depending on the culture or language.

- 4.15.4 Date formatting
 - 4.15.4.1 months are expressed either as a two-digit number or a three-digit character word [Few 2004, p. 150]
 - 4.15.4.2 days are expressed as two digits [Few 2004, p. 150]
- 4.15.5 Number and date precision
 - 4.15.5.1 precision of numbers or dates does not exceed the level needed to serve the communication objectives and the needs of the readers²⁶ [Few 2004, p. 151; Klass 2002, Wainer 1997]
- 4.15.6 Font
 - 4.15.6.1 legible font is selected²⁷ [Few 2004 p. 152; Klass 2002]
 - 4.15.6.2 same font is used throughout the table [Few 2004 p. 152]
- 4.15.7 Emphasis and color
 - 4.15.7.1 boldface, italics, or change in color of fonts is used to group or highlight data [Few 2004, p. 153; Klass 2002]
- 4.16 Summarizing values in a table
 - 4.16.1 columns containing group summaries are made visually distinct from detail columns [Few 2004, p. 153]
 - 4.16.2 summaries are placed in the group header if its rows extend down multiple pages [Few 2004, p. 154]
- 4.17 Providing page information in a table
 - 4.17.1 column headers are repeated at the top of each page [Few 2004, p. 156]
 - 4.17.2 current row headers are repeated at the top of each page [Few 2004, pp. 156-157]

Graphs

- 4.18 Graphs are used to present quantitative information when
 - the message is derived from the shape of the values
 - the graph is used to reveal relationships among multiple values
- [Few 2004, p. 46]

²⁶ There are no precise guidelines regarding this since it is based on communication objectives which would need to be learned through interviews.

²⁷ Examples of fonts that have good legibility are Serif: Times New Roman, Palatino, and Courier; Sans-Serif: Arial, Verdana, and Tahoma. Examples of fonts that have poor legibility are Serif: Script, Broadway, Old English; Sans-Serif: Gill Sans Ultra, Papyrus, Tempus Sans ITC [Few 2004, p. 153].

- 4.19 The quantitative scale on a graph starts at zero unless there is a need to show small differences between large values. In the latter case, the reader is alerted that the graph does not provide a contextually accurate visual representation of the values so that readers can adjust their interpretations [Few 2004, p. 169].
- 4.20 Three-dimensional graphics are not used to display quantitative information²⁸ [Coles 1997; Few 2004, p. 170; Robbins 2005, pp. 19-27; Rossi 2001].
- 4.21 The number of categorical subdivisions in a graph is limited to between five and eight [Few 2004, p. 207].
- 4.22 When other text is used in a graph (e.g., titles or notes) the text appears as close to the information that it complements as possible without interfering with that information [Few 2004, p. 206].
- 4.23 Graphical captions are comprehensive and informative. A framework for a caption that can contribute to such a clear explanation is as follows:
- describe everything that is graphed
 - draw attention to important features of the data
 - describe the conclusions that are drawn from the data on the graph
- [Cleveland 1994, p 55]

Explanation: Graphs vary primarily in terms of the types of relationships they are used to communicate. Essentially, there are seven types of relationships that graphs are typically used to display. These types are described in the table below [Few, pp. 65-66].

This graph type ...	Expresses ...
Nominal comparison	the comparative sizes of multiple related but discrete values in no particular order
Time series	the rise and fall of values through time
Part-to-whole	the portion of each part relative to the whole
Deviation	how and the degree to which one or more things differ from another
Distribution	a range of values as well as the shape of the distribution across a range
Correlation	how two paired sets of values vary in relation to one another

- 4.24 For **nominal comparisons**, bar graphs or data points are used [Few 1994, p. 70].

²⁸ This refers to business graphics such as bar, column, line, and pie charts. However, in some cases, three-dimensional graphs are appropriate, such as graphs generated as a result of response surface methodology.

4.25 For **time series designs**

- 4.25.1 lines or points and lines are used to emphasize overall patterns
- 4.25.2 vertical bars are used to emphasize and compare the values associated with an individual point in time rather than with the overall pattern of values as they change through time
- 4.25.3 points connected by lines are used to slightly emphasize individual values while still highlighting the overall pattern
- 4.25.4 time is always placed on the horizontal axis

[Few 1994, pp.70-72]

4.26 For **ranking designs**, bars (either horizontal or vertical) are only used [Few 1994, pp.72-76].

4.27 For **part-to-whole designs**

- 4.27.1 bars (either horizontal or vertical) are used
- 4.27.2 pie charts are not used to impart quantitative information.

[Cleveland 1994, pp. 262-263; Few 2004, p. 60; Few 2006, pp. 134-135; Tufte 2001 p. 178; Becker 1996; Robbins 2005, pp. 3-7; ProcessTrends 2008; Bertin 1983]

- 4.27.3 stacked bar charts are not used to impart quantitative information unless there is a need to display multiple instances of a whole and its parts, with emphasis primarily on the whole [Cleveland 1994, pp. 265-267; Robbins 2005, pp. 29-33; Few 2004, p. 74; Few 2006, pp. 135-137].

4.28 For **deviation designs**

- 4.28.1 lines are used to emphasize the overall pattern only when displaying deviation and time series relationships together
- 4.28.2 points connected by lines are used to slightly emphasize individual data points while also highlighting the overall pattern when displaying deviation and time-series relationships together
- 4.28.3 bars are used to emphasize individual values, but are limited to vertical bars when a time series relationship is included
- 4.28.4 a reference line is always included to compare the measures of deviation against

[Few 1994, pp.76-77]

4.29 For **distribution designs: single distributions**

- 4.29.1 vertical bars are used to emphasize individual values
- 4.29.2 lines are used to emphasize the overall shape

[Few 1994, pp.78-80]

4.30 For **distribution designs: multiple distributions**

4.30.1 vertical or horizontal bars are used (i.e., range bars or boxes) to encode the full range from the low value to the high value, or some meaningful portion of the range (e.g., 90% of the values)²⁹

4.30.2 points or lines are used together to encode measures of the center (e.g., the median)

[Few 1994, pp.80-82]

4.31 For **correlation designs**, points and a trend line are used in the form of a scatter plot [Few 1994, pp.83-84].

4.32 Important quantitative information is highlighted in graphs using one of the techniques presented in the table below [Few 2004, p. 120].

Attribute	Values Useful for Emphasis
Line width	Thicker lines (including words and numbers that are boldfaced) stand out more than thinner lines.
Orientation	Slanted words and numbers (i.e., italics) stand out more than those that are oriented normally (i.e., not slanted), assuming that vertically oriented type is the norm.
Size	Bigger objects, words, and numbers stand out more than smaller objects.
Enclosure	Objects, words, and numbers that are enclosed by lines or background fill color stand out more than those that are not enclosed.
Hue	Objects, words, and numbers that have any hue that are different from the norm stand out.
Color intensity	Objects, words, and numbers that are bright stand out more than those that are light or pale.

4.33 When the orientations of line segments on a graph are judged to decode information about rate of change, the line segments are banked to 45 degrees [Cleveland 1994, p. 70].

4.34 Error bars on graphs are clearly explained³⁰ [Cleveland 1994, p 59].

4.35 A logarithmic scale is used when it is important to understand percent change or multiplicative factors [Cleveland 1994 pp. 95-104; Frees 1997; Frees 1996, Ch. 6; Few 2004, pp. 197-202].

²⁹ An example is the box and whisker plot (i.e., box plot, boxplot, and box and whisker diagram) [Tukey 1977, p. 139].

³⁰ Error bars can convey one of several possibilities: (1) The *sample standard deviation* of the data; (2) An *estimate of the standard deviation* (also called the *standard error*) of a statistical quantity; (3) A *confidence interval* for a statistical quantity [Cleveland 1994, p 59].

Tables and Graphs

- 4.36 Whenever quantitative information is presented in tables or graphs, the data itself stands out clearly, without distraction. This involves eliminating anything that doesn't represent the data, except for visual devices that support the data in a necessary way. In that case, they should be displayed in muted fashion so as to not distract from the data itself [Tufte 2001, Few 2004, pp. 117-120, Cleveland 1994, pp. 25-54].
- 4.37 When descriptive statistics are reported, a measure of variation accompanies the measure of central tendency [Few 2004, p. 25].
- 4.38 The reported M & A information emphasizes how the attributes of interest have changed since the previous reporting events³¹ [Tufte 1997, p. 30; Tufte 2001, pp. 74-75].

³¹ Preferably, the measurement information will illustrate the trend of the data since the last reporting event, showing what has changed over the last several reporting periods (i.e., it will show trends).

5 Criteria for All M & A Process or Procedure Documentation

- 5.1 Individuals who are responsible for writing M & A process and procedures have received training in developing technical documentation.
- 5.2 M & A process and procedure descriptions are appropriate to users' needs. As evidence, one or more of following activities is conducted as part of the process or procedure development process:
- audience and task analysis
 - technical reviews
 - user questionnaires
 - observation
 - usability testing³²
- [Techscribe 2006, Perelman 2009, Horn 1982]
- 5.3 M & A process/procedure descriptions contain easily accessible information [Horn 1982, Techscribe 2006].
- 5.4 M & A process/procedure information is chunked into small manageable units³³ [Horn 1982].
- 5.5 M & A process/procedure information is clearly labeled for quick retrieval [Horn 1982].
- 5.6 Cross-referencing to other sections³⁴ is avoided in process/procedure documentation³⁵ [Horn 1982].
- 5.7 Glossaries, style guides, templates, and controlled language are used to make M & A process and procedure descriptions linguistically accurate and stylistically consistent [Techscribe 2006].

³² This is sometimes referred to as pilot testing.

³³ A manageable unit of information is one consisting of no more than nine pieces of information. Research suggests that people can best process and remember no more than seven plus or minus two (7 ± 2) pieces, or units, of information at one time.

³⁴ That is, the reader should not be forced to reference other sections of the document or scroll to a different part of the document. However, cross-referencing to information via hyperlinks is fine.

³⁵ Forcing readers to other parts of the same document and other documents to perform the task that is the purpose of the provided information should be avoided [Horn 1984].

Request for Feedback

The SEI is interested in feedback from and collaboration with organizations that would like to pilot the MAID method. If you would like to provide suggestions, feedback, or discuss collaboration, please contact SEI info@sei.cmu.edu.

Appendix A: Example of Audience Type Classification

Audience Type	Description
Experts	People who understand M & A theory and practice. Often, they have advanced degrees or training in measurement and analysis.
Specialists	People who possess limited training on how to maintain and interpret a specified number of M & A indicators.
Non-specialists	People who have the least technical knowledge. Their interests are entirely practical and they want to understand M & A theory only enough to use it to support decision making.

Glossary

Analysis model	An algorithm or calculation involving two or more based or derived measures with associated decision criteria. Analysis models produce estimates or evaluations relevant to defined information needs [McGarry 2001, p. 23].
Base measure	A measure defined in terms of an attribute and the method for quantifying it. A base measure is functionally independent of other measures [ISO 2007].
Decision criteria	Thresholds, targets, or patterns used to determine the need for action or further investigation or to describe the level of confidence in a given result [ISO 2007].
Derived measure	A measure defined as a function of two or more base measures [ISO 2007].
Indicator	A measure that provides an estimate or evaluation of specified attributes derived from a model with respect to defined information needs [ISO 2007].
Measurement function	An algorithm or calculation performed to combine two or more base measures [ISO 2007].
Measurement method	A logical sequence of operations, described generically, used in quantifying an attribute with respect to a specified scale. The type of measurement method depends on the nature of the operations used to quantify an attribute. Two types may be distinguished: (a) subjective: a quantification involving human judgment, and (b) objective: a quantification based on numerical rules [ISO 2007].
Measurement procedure	A set of operations, described specifically, used in the performance of a particular measurement according to a given method [ISO 2007].
Objective (measurement method)	A quantification based on numerical rules such as counting. These rules may be implemented by human or automated means. For example, lines of code may be quantified by counting semi-colons [McGarry 2001, p. 21].
Organization	An administrative structure in which people collectively manage one or more projects as a whole, and whose projects share a senior manager and operate under the same policies [CMMI 2006].

Project	A managed set of interrelated resources that delivers one or more products to a customer or end user [CMMI 2006]. A temporary endeavor undertaken to create a unique product, service, or result [PMI 2008].
Scale	An ordered set of values, continuous or discrete, or a set of categories to which an attribute is mapped. The type of scale depends on the nature of the relationship between values on the scale. Four types of scales are commonly defined: (a) nominal – the measurement values are categorical; (b) ordinal – the measurement values are rankings; (c) interval – the measurement values have equal distances corresponding to equal quantities of the attribute; (d) ratio – the measurement values have equal distances corresponding to equal quantities of the attribute where the value of zero corresponds to none of the attribute [ISO 2007].
Subjective (measurement method)	A quantification involving human judgment or rating. For example, relying on an expert to rate the complexity of functions as high, medium or low is a subjective method of measurement [McGarry 2001, p. 21].
Type of scale	Four types of scales are commonly defined: (a) ratio, (b) interval, (c) ordinal, (d) nominal [ISO 2007; Roberts 1979].
Unit of measurement	A particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitude relative to that quantity [ISO 2007].

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REPORT DOCUMENTATION PAGE			<i>Form Approved</i> <i>OMB No. 0704-0188</i>	
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1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE December 2009 (Revised February 2010)		3. REPORT TYPE AND DATES COVERED Final
4. TITLE AND SUBTITLE Measurement and Analysis Infrastructure Diagnostic (MAID) Evaluation Criteria, Version 1.0			5. FUNDING NUMBERS FA8721-05-C-0003	
6. AUTHOR(S) Software Engineering Measurement and Analysis Group (SEMA)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Software Engineering Institute Carnegie Mellon University Pittsburgh, PA 15213			8. PERFORMING ORGANIZATION REPORT NUMBER CMU/SEI-2009-TR-022	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) HQ ESC/XPK 5 Eglin Street Hanscom AFB, MA 01731-2116			10. SPONSORING/MONITORING AGENCY REPORT NUMBER ESC-TR-2009-022	
11. SUPPLEMENTARY NOTES				
12A DISTRIBUTION/AVAILABILITY STATEMENT Unclassified/Unlimited, DTIC, NTIS			12B DISTRIBUTION CODE	
13. ABSTRACT (MAXIMUM 200 WORDS) The Software Engineering Institute (SEI) is developing the Measurement and Analysis Infra-structure Diagnostic (MAID) method. MAID is a criterion-based evaluation method that facilitates the examination and evaluation of data quality issues linked to how the organization implements measurement and analysis practices. This document presents the set of criteria used during a MAID evaluation. The criteria serve as a checklist for an evaluator to use to rate the quality of an organization's measurement and analysis practices and the quality of the measurement information that results from the implementation of those practices. The evaluation itself is carried out by a team following the MAID method. The MAID method is described briefly in this document. A full description of the method will be published in a separate document in 2010.				
14. SUBJECT TERMS measurement and analysis, process, data quality, data integrity, maid			15. NUMBER OF PAGES 51	
16. PRICE CODE				
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	