NISTIR 4738

Models, Managing Models, Quality Models: An Example of Quality Management

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"The concept of quality improvement is directly applicable to small companies as well as large, to service industries as well as manufacturing, and to the public sector as well as private enterprise. In order to be successful, quality improvement programs must be management-led and customer-oriented and this may require fundamental changes in the way companies and agencies do business."

Excerpts from The Findings and Purposes Section of Public Law 100-107 responsible for creation of The Malcolm Baldrige National Quality Award.

Abstract

Quality is an increasingly important element in competitiveness. This paper will focus on strategies used by an international standards committee for improving the development of its complex standard. The paper outlines an approach for use within the standards-making community. Aside from the standards-making community, any organization interested in establishing quality metrics and quality thresholds to assess technical quality should find this paper useful. An overview of a methodology for evaluating the technical quality of information and data models is also included. These models provide the basis for the emerging STEP standard. The types of models denoted in the title include information, activity, data or process models which are represented in some formal modeling language. Quality thresholds to guide information model developers and evaluators are described, along with an overview of the team approach used in applying the methodology. Quality management techniques for models are described along with management's role in ensuring that high quality models are produced. Many basic concepts of the Malcolm Baldrige National Quality Award were used in building the foundation for this new approach to standards development.

Key Words

Malcolm Baldrige National Quality Award; data models; IGES/PDES Organization; information models; IPO; PDES; Product Data Exchange using STEP; quality management architecture; Standard for the Exchange of Product Model Data; STEP

The work described in this document was funded by the Factory Automation Systems Division, National Institute of Standards and Technology, U.S. Department of Commerce, Technology Administration and is not subject to copyright.

1 Purpose

The purpose of this paper is to describe an organizational approach to ensuring the quality of a design specification. The ongoing efforts of a committee developing an international standard are used to illustrate the approach. Methods for ensuring quality must be appropriate to the products they intend to improve. This paper describes fundamental principles of quality assessment, such as continuous improvement, management by fact, and the development and use of metrics, and their application to a product which is a design specification, in this case, an international standard. Ensuring quality demands persistent application of quality techniques at appropriate points in the product development process.

2 Background

The International Organization for Standardization (ISO) is currently developing a standard known as the Standard for the Exchange of Product Model Data (STEP)[1]. STEP is intended to support all aspects of product description from initial conception through product design, manufacture, support and disposal. U.S. proponents of STEP have asserted that the application of product data sharing will revolutionize U.S. manufacturing and enable U.S. industry to build on its traditional strengths to regain its competitive edge for the twenty-first century [1].

U.S. industry supports STEP development through the IGES/PDES[2] Organization (IPO). The primary objective of the PDES/STEP effort is to develop a standardized, neutral, computer-based format for the definition of product data that can be used by different industrial applications [2].

Information modeling technology provides a formal technique for representing the information requirements of the standard. Why is the development of STEP based upon the use of information modeling technology? Figure 1 illustrates the basic elements leading to this decision:

(1) An information model provides a mechanism for describing agreements about a subject and stating the requirements.

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[1] STEP will be adopted as ISO 10303, Industrial Automation Systems and Integration Product Data Representation and Exchange, and is being developed within Subcommittee 4 of International Organization for Standardization Technical Committee 184 (ISO TC184/SC4).

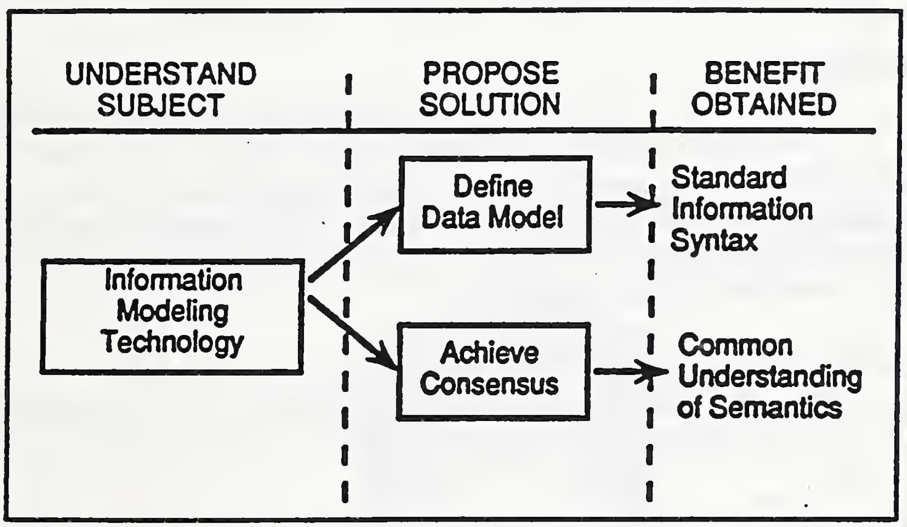
[2] IGES, the Initial Graphics Exchange Specification, defines a neutral data format that allows for the digital exchange of information among computer-aided design (CAD) systems. The PDES (Product Data Exchange using STEP) project within the IPO is the United States development activity in support of the international standard.

(2) Information modeling techniques provide the capability to formulate a computer-based representation of an information model.

(3) An information model facilitates communication by providing a baseline for building consensus.

(4) Information modeling techniques concentrate on the data requirements without prescribing or specifying implementation requirements.

Figure 1. Information Models Form the Basis for the Standard



syn·tax
1: the arrangement of elements to show their relationship to one another

se·man·tic
1: of or relating to meaning in language

Figure 1 places the design aspects of information modeling in a much larger context. The ultimate objective is a common understanding of semantics and a standard syntax for information specification. These features are two of the benefits derived from using this technology to drive the standard. These benefits, coupled with the requirement for achieving consensus, are key reasons for using this technology for STEP.

The standard itself will consist of a set of information models that describe product data to be used by many industries. The STEP models contain general information about product descriptions, business rules, market requirements, design, manufacture, and support. They are either resource models or application models. Resource models describe aspects of product information such as: geometry, tolerance, shape, size, weight. The application models contain information specific to a particular domain such as: manufacturing, electronics, apparel, building and construction, etc.

The resource models are reusable and will remain the cornerstone for future development.

The focus of this paper is on the approach taken by the STEP qualification methods team in developing a system of metrics for ensuring the quality of information models. The quality techniques were developed to be appropriate for the information modeling methods used by STEP. The notion of continuous improvement is advocated. The quality management process developed for STEP includes regular cycles of planning, execution and evaluation. The quality management process begins early in the STEP model development process and feedback is provided to both the qualification methods team and model development team. Investigation of quality methods for other types of models continues in attempts to apply them to the quality management of information models. This approach was influenced by efforts to promote the use of quality management techniques in U.S. built products, which is the subject of the following section.

3 The Baldrige Influence

Many basic concepts of the Malcolm Baldrige National Quality Award[3] were used in building the foundation for this new approach to standards development. The qualification methods team gained useful information and insight through an in-depth examination of the Award Criteria in the 1991 edition of the Application Guidelines [3] for the Malcolm Baldrige National Quality Award.

Several key characteristics directly influenced the development of the model qualification methods. A more detailed description can be found in the 1992 edition of the Award Criteria [4] for the Malcolm Baldrige National Quality Award, excerpted here:

(1) The Award Criteria are directed toward producing results. Assessment of these results is based upon one or more of three factors: (1) improvement trends; (2) current levels; and (3) benchmarks, evaluations, and other comparisons that establish levels and trends relative to the performance of others, especially appropriately selected leaders.

(2) The Award Criteria provide a link between processes and results. Integration in the Criteria is achieved through many direct and indirect relationships and linkages among the requirements. In addition, many parts of the Criteria call for aggregation and assessment of levels of performance, thus encouraging an integrated view of all activities.

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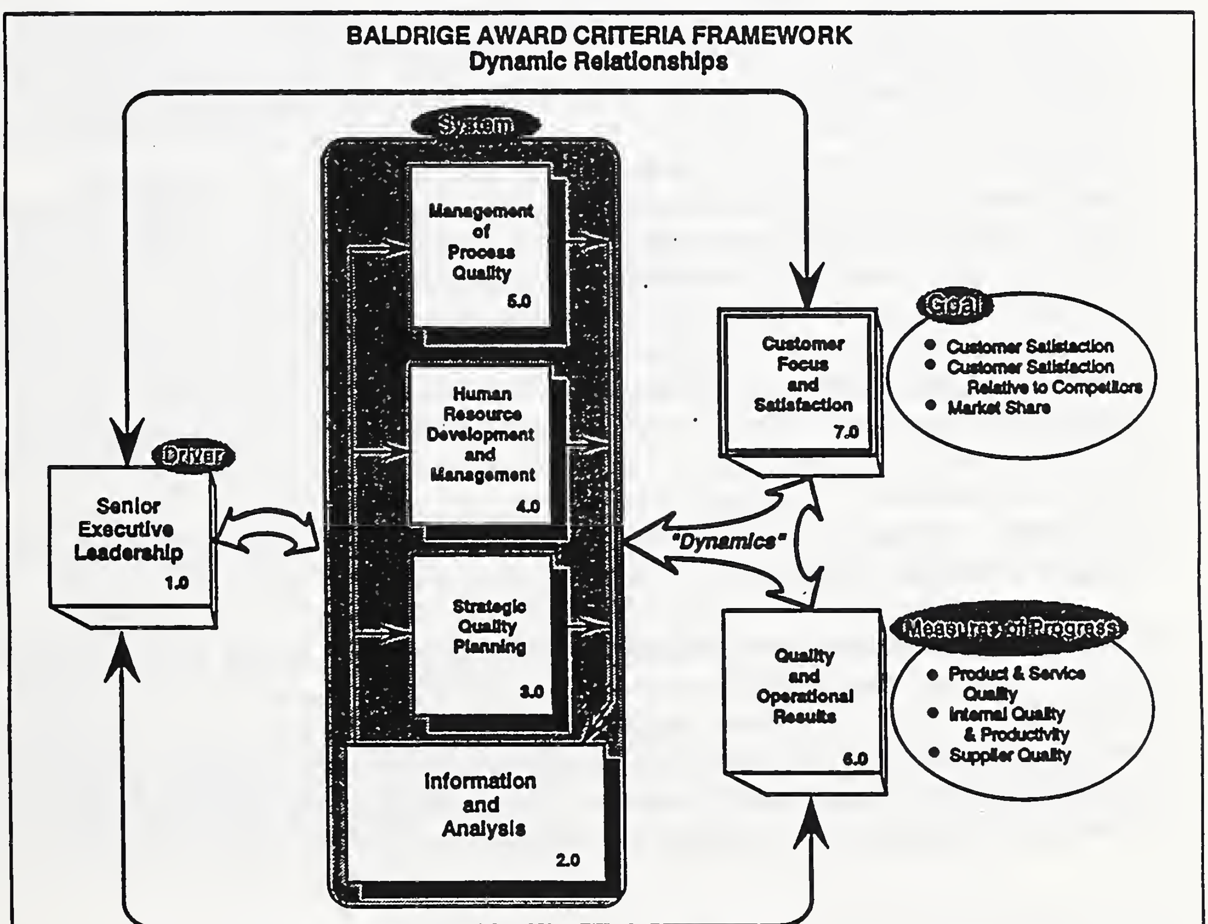
[3] The National Institute of Standards and Technology (NIST), an agency of the Department of Commerce's Technology Administration, was given the responsibility for the creation and management of the Award Program.

(3) The Award Criteria are part of a two-part diagnostic system. The Criteria focus on requirements. The scoring system focuses on the factors that should be used in assessing strengths and areas for improvement. Together the two parts of the diagnostic system direct attention to activities that contribute to reaching the goals of the Criteria.

(4) The Award Criteria include key learning cycles. The arrows in Figure 2 [4] denote linkage and dynamic relationships and feedback among the framework elements. The primary dynamic characteristic of the Criteria is their inclusion of cycles of continuous improvement. These cycles of learning, adaptation, and improvement are explicit and implicit in every part of the Criteria. The cycles have four stages: (a) planning, design of processes, selection of indicators, deployment of requirements; (b) execution of plans; (c) assessment of progress, taking into consideration internal and external indicators; and (d) revision of plans, taking into consideration progress, learning, and new information.

Figure 2. Baldrige Award Criteria Framework



These specific characteristics are cited to give the reader an idea of how these generic criteria can be used to tailor a system for another domain. The Criteria can also aid developers searching for assessment techniques.

These Baldrige concepts played a central role in the development of the metrics to verify the quality of information models supporting the STEP standard. Probably the most important lesson learned is that high quality thresholds are attainable with appropriate strategies and persistent application. A recent General Accounting Office Study [5] revealed that to succeed, Total Quality Management (TQM) systems must be based on a continuous and systemic approach of gathering, evaluating, and acting on facts and data. The model qualification team's development effort to support quality ideals were built around these notions.

4 Need for a Model Quality Strategy

While there are many advantages to using information modeling technology as suggested in Section 2, there are also risks in using it as the underpinning of a standard. An effective quality strategy can be used to manage these risks.

The models in STEP will be ready for standardization when they are coherent, complete and stable. The need for a quality strategy becomes apparent from the fact that in many of the STEP models, the information content was changing and consequently the models seemed to be incomplete. There was no consistent method for applying the information modeling techniques used in STEP. Integrating information from many resources is an important phase in the life cycle of developing STEP. This is a function of the Integration Committee[4]. The groups responsible for the models may have achieved technical consensus, but the models were not usable because they could not be understood outside the group that developed them. As one of the engineers from a well known aircraft company put it: "Without building in quality as the standard emerges, there is a risk that my company will be using a standard based on untried, untested foundations." This is an important concern for companies which build products to the standard or the companies which buy products built to the standard. To mitigate this problem, the quality strategy must include techniques for recognizing stable and reliable models and evaluating the consistency of the model representation.

Because many countries are demanding a workable STEP now, it is important to project an accurate estimate of when the models will be ready for external review. Sometimes, progress on models could not be discerned. There were a number of plausible explanations, such as unavailability of subject matter experts or a decision to modify the extent of the model coverage. Some explanations require no action by management and others provide warning signals that call for immediate action. It is

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[4] The Integration Committee of the IPO is supporting a project within Working Group 4 (WG4) of ISO TC184/SC4.

important that both progress and warning signals are visible to management. Therefore, the quality strategy must include techniques for evaluating and reporting upon progress.

A requirement of STEP is that the models be integrated into a single usable standard. The Integration Committee is responsible for ensuring that models can be used together. Using poorly organized or improperly documented models for the integration is undesirable because it leads to an unacceptable margin for error. A model needs to be of sufficient quality for the integration team to understand the model intent. The quality strategy must include techniques for evaluating the organization and documentation of the models.

A number of things can go wrong during the development of models. A strategy is needed for recognizing concerns and taking corrective action as early in the process as possible. The quality strategy must proactively seek both external and internal users' expectations at the beginning of any quality planning and development process.

5 The Model Qualification Approach

A new approach for ensuring quality and measuring it has been developed for the PDES/STEP effort. The approach focuses on the quality of design specifications, for resource and application models. This quality method can be extended to related technologies with only minor tailoring.

The method developed and used in the STEP community, under the direction of the Qualification Methods project[5], has often been referred to as "Qualification," the process of using the methods developed by the qualification methods team. Qualification takes place before the integration process described in Section 4. The Qualification process imposes a set of criteria on all STEP resource and application models. Model qualification verifies the **technical quality** of models at various levels of completion. As progress on a model is made, the audience which can comprehend the model expands.

The notion of model quality as it pertains to product data has its roots in the PDES Initiation Activities [6]. Much of the early evaluation was done intuitively, but this early thinking fostered many of the ideas in the current document on the qualification process [7]. There is now a more formal method for both measuring and managing model quality.

When the model meets the established metrics, the true functionality of the model itself can be more accurately determined. These measurements can help determine if a model has attained a level of quality sufficient to be promoted in the standards

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[5] Qualification Methods is a project within Working Group 5 of ISO TC184/SC4.

process. The measurements in the approach are quantifiable and can be very useful in making management decisions.

This approach to quality assurance differs from those of other quality assurance systems in two respects. First the methodology provides for ensuring quality in information models. The methodology ensures that the models are understandable, stable, reliable, and maintainable. Second, it provides structured techniques for managing quality. It manages quality in a formal way by organizing the technical knowledge conveyed by a model into manageable groupings, and by providing techniques for tracking and assessing the development for each grouping. Thus for example, "maintainability" is affected by specific measurable indicators.

The model qualification measurement system includes:

- the identification of indicators to be used in quality assessment,
- the definition of a technique for measuring progress, and
- the provision for the management of staff resources.

6 Model Qualification Methodology

This section describes the methodology developed for the review of STEP models. This methodology builds on the model qualification approach discussed in Section 5. In addition, a short example of the application of the methodology is given in Section 6.2.

6.1 Model Quality Levels

Model quality levels represent a generic measure of quality that can be applied to any measurable aspect of quality (i.e., across all categories and indicators). Levels signify an increasingly meaningful and useful condition or state of quality. As the levels of quality of a model increase, the model should become more valuable and be of use to a wider audience.

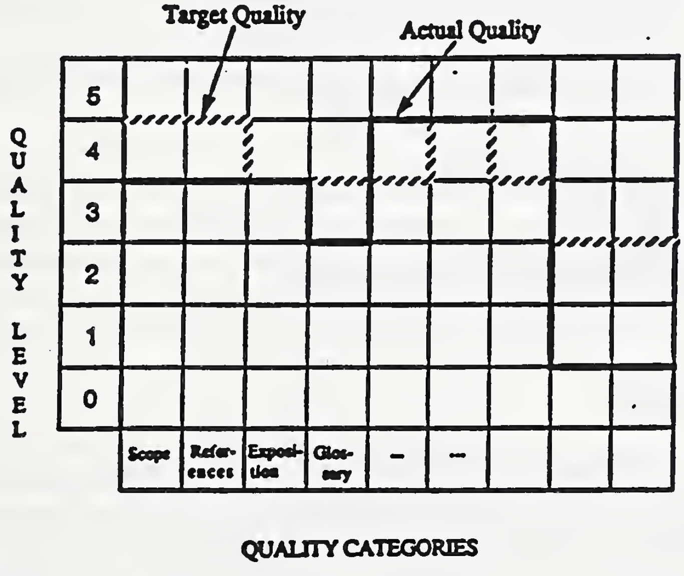
The quality levels are related to the promotion levels in the standardization process, as specified in the procedures for approval of STEP [8]. The definitions for each of the quality levels used in STEP are given in Table 1. For a model to be released to a broad community for review, it should have attained a measure of progress equivalent to Quality Level 3 (i.e., the model can be clearly understood).

Table 1. Quality Levels

Level	Title	Description
Level 0	Baseline Established	The work item has been identified and scope of the activity has been defined. The context of the work item is defined at a level necessary to attain management approval to proceed.
Level 1	Initial Documentation	The work item has been identified and scope of the activity has been defined. The context of the work item is defined at a level necessary to attain management approval to proceed.
Level 2	Basic Comprehension	Anyone with a PDES/STEP background can understand the essential model concepts.
Level 3	Clarity of Understanding	Model is documented sufficiently to support prototype implementation.
Level 4	Precision of Expression	The definition and representation of the model or part enables subject area experts who have not participated in the development to apply its concepts consistently to real-world problems.
Level 5	Industrial Suitability	The model is sufficiently defined for the use and implementation in an industrial application context.

The Measures of Progress Report depicted in Figure 3 shows the level of completion necessary to be a "qualified model", the target quality, and the actual quality level that the model has attained. Across the horizontal axis are categories for the quality of the model component being evaluated, and the vertical axis shows the quality levels (see Table 1) for assessing the semantics for the information modeling technique used.

Figure 3. Measures of Progress Report



The methodology calls for the assignment of **quality levels** based upon an evaluation that uses three technical components. Each of these have specific criteria for measuring progress to determine the extent of improvement required. In this section, the first component, **quality categories**, is explicitly described, while the other two components, **quality indicators** and **quality characteristics** are only briefly introduced. Sections 6.2 and 7 describe how these three components are applied.

6.1.1 Model Quality Categories

The quality categories referenced in Figure 3 are broad classes of subjects which are used to organize the quality measurement. This division for overall quality measurement can be done either by identifying the required components of the completed product or by identifying activities in the development process. Both of these approaches to defining the quality categories have been used in STEP. The categories provide a high-level view of the types of quality assessments performed on a model. However, each quality category is related to the model as a whole and not just to a section of the model. For instance, quality category 1, Scope, is used heavily in evaluating the scope statement that is present in each STEP model, but it is also used to evaluate any issues related to scope across the entire model. Thirteen categories are used in the STEP qualification process, as shown in Table 2.

Table 2. Quality Categories

Quality Category	Title
QC1	Scope
QC2	References
QC3	Expositions for Understandability
QC4	Glossary
QC5	Model Design History Capture
QC6	Configuration Management Conformance
QC7	Information Requirements Compliance
QC8	Syntax Evaluation
QC9	Formal Semantic Representation QC9.1 Model Language Usage QC9.2 Semantics QC9.3 Model Stability
QC10	Integration
QC11	Industrial Assessment
QC12	Industrial Exposure & Recognition
QC13	ISO Directives

6.1.2 Model Quality Indicators

Quality indicators are the concrete, measurable aspects of quality for any given category. The indicator is measured by evaluating one or more facts about a product. Each fact that is to be evaluated is called a quality characteristic. Each time a model is evaluated, the quality indicators are assigned a quality level. The quality level is determined by analyzing the assessment results from the set of constituent quality characteristics.

6.1.3 Quality Characteristics

Quality characteristics are specific measurable aspects of quality. Quality characteristics are like a checklist of information about states, conditions, events and data for a given quality indicator. Each quality characteristic has a measurement technique associated with it. For example, some characteristics, such as a statement of scope in the model document, either exist or are absent (pass or fail).

6.2 Example for STEP Information Models

Due to space limitations, a sample is provided here for only one of the 13 categories listed in Table 2. The following example for the category **Scope** details how the quality categories, indicators and characteristics are used to judge the quality of a model. A model must contain a "scope" statement and the criteria for this aspect are grouped into the category called "scope." Guidance is provided for assigning a quality level to the category "scope." There are five quality indicators for "scope." Each indicator has its own set of descriptive characteristics. The set of quality characteristics for the quality indicator 1.1, "limits of applicability covered," is provided.

Category: Scope (QC1)

Scope is defined to be a complete and unambiguous statement or view of the domain that is being studied. This statement should define the bounds of the information to be covered in the model, and with this in mind, the scope can either be broad or narrow. The statement should define any limits that apply to the subject matter found in the model. For this reason, the scope statement can describe material that should or should not be found in the model.

Quality Levels for the Category "Scope"

During the development of the model, quality progresses through the quality levels defined in Table 1. Once an initial statement has been agreed to by the group developing the model, Level 1 has been attained. The model will evolve with nominal change until the model has achieved a Level 2. However, the scope should crystallize by Level 3, with a complete and precise statement by Level 4. At Level 4, tests which simulate representative uses for the model are defined and the model is examined to ensure that it can support the tests for scope. At Level 5, a more global perspective is pursued by studying the relationship of this model scope to those in other existing models in STEP. The model is examined for any overlap with other models and how the model is logically organized with respect to the rest of STEP. An unambiguous scope definition which is consistent with the remaining STEP specifications is expected by Level 5.

Quality Indicators for the Category "Scope"

QI 1.1 Limits of applicability covered: This indicator is used to evaluate the definition and intent of the model. Any guidance or rules that should be applied to verify that the model achieves this intent are also included.

QI 1.2 **Definition of subjects and aspects covered:** This indicator is used to evaluate the definitions of terms and how the model will be used.

QI 1.3 **Global planning perspective covered:** This indicator is used to evaluate if the model describes how the information represented by a model fits into a larger scale, i.e., "the big picture". A context on a very broad scale is provided, along with a smaller context which represents the actual model under review.

QI 1.4 Subject planning perspective covered: This indicator is used to evaluate if the model provides a high-level overview of the information that is within the scope of the model. All of the significant concepts in the model under review should be represented. They should be consistent with the viewpoint of the scope but the details on concepts are not provided.

QI 1.5 Project planning perspective covered: This indicator is used to evaluate if the model provides for the viewpoint of the project in broad enough terms to include both the subject planning model (i.e., the significant concepts) and the interfaces to any related models. This model acts as an integrator and project management tool since it identifies the information requirements needed by the related models.

Quality Characteristics for "Limits of Applicability Statement (QI 1.1)"

The scope statement should be reviewed for the existence of the following items which indicate increasing levels of quality:

QCh 1.1.1 Scoping definition statement which specifies the position of the model within a larger context;

QCh 1.1.2 Statement that explains the scope early in the text with prominent appearance;

QCh 1.1.3 Preliminary limits of applicability statement;

QCh 1.1.4 Complete and unambiguous statement of scope;

QCh 1.1.5 Statement referencing any other STEP models that are needed to understand or use the model;

QCh 1.1.6 Boundaries, limits, rules or conventions that determine all aspects of scope;

QCh 1.1.7 Criteria for determining if the scope has been achieved, defined precisely enough for subject area experts; criteria demonstrates clarity, is obvious, and is firmly stated; and

QCh 1.1.8 Precision of terms used within the subject domain are evident; and exceptions are identified; terms are concrete, specific, and limited in extent.

7 Model Assessment Process

A Qualification Practices team has been formed to execute reviews of the models in STEP using this methodology and to provide feedback on the quality assessment techniques. The team has developed a script for guiding their activity during the review of the models and for applying the model qualification criteria [7]. The team chooses the necessary quality indicators to apply to each component of the models in STEP. The team consists of individuals who are experts in the domain that the model describes and individuals who are experts in the STEP development methods such as information modeling. The team provides feedback to STEP developers in the form of qualification reports. The team also provides feedback to the Qualification Methods team so that the model qualification methods can be further improved. The team determines strengths of the model, identifies areas for improvement and states the issues with the model.

The Qualification Practices team leader will organize and summarize the information. These reports are principally used by the model development team. The two reports listed below may also be useful to individuals who manage STEP development because they illustrate both the progress and the areas where developer resources need to be added in a particular area. These summary reports could include: (1) Measures of Progress Report (see Figure 3), and (2) Evaluators for Model Qualification Report (see Figure 4).

Figure 4. Evaluators for Model Qualification

Quality Level → ; Quality Characteristic →

Quality Level					
level 5	5.6	5.12	5.13	5.14	5.15
level 4	4.11	4.12	4.13	4.14	4.15
level 3	3.11, 3.16	3.12	3.13	3.14	3.15
level 2	2.11	2.12	2.13	2.14	2.15
level 1	1.11	1.12	1.5, 1.9, 1.10, 1.13	1.6, 1.14	1.7, 1.15
Quality Indicator →	QI 1.1	QI 1.2	QI 1.3	QI 1.4	QI 1.5

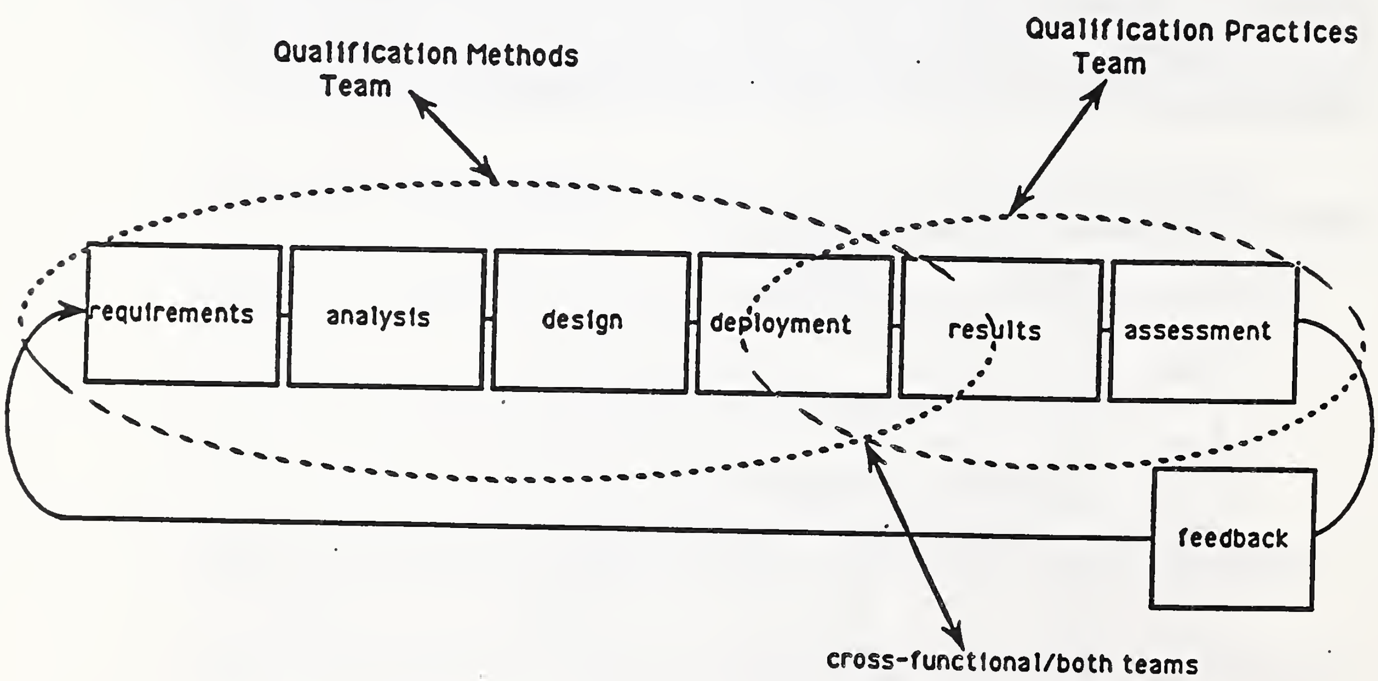
QC 1 Scope

- QI 1.1 Limits of Applicability Statement (Inclusion/Exclusion Criteria)
- QI 1.2 Definition of Subjects and Aspects Covered
- QI 1.3 Global Planning Model
- QI 1.4 Subject Planning Model
- QI 1.5 Project Planning Model

In the Evaluators for Model Qualification Report (see Figure 4), the quality characteristics that are to be reviewed for each quality indicator are identified. Each quality level has one or more characteristics associated with a given indicator. The set of characteristics for a quality level and a given indicator are illustrated in the cells of the matrix. A model is evaluated for the presence of each characteristic. The model is graded by a specific indicator at the highest level for which all of the characteristics are present. The "measures of progress" can be defined as the selected set of quality indicators that are appropriate for a quality assessment problem. The scores for all of the quality indicators are then compared to the target "measure of progress" (see Figure 3) to determine if the model is ready to progress to the next stage in the standardization process.

The Qualification Practices team works closely with the Qualification Methods team to provide the continuous feedback necessary for quality improvement. There have been regular cycles of enhanced model qualification methods from the methods team, followed by trial and feedback from the practices team. These roles are depicted in Figure 5.

Figure 5. Continuous Quality Improvement



8 Management Role

The model qualification process provides a structure for the assessment and collection of technical knowledge about products, and structural components to support managing product development. This structure promotes "management by fact" by providing visibility to the results of quality assessments.

The model qualification process provides a system that manages the model development, model assessment, and model integration for STEP. The process provides techniques for managing the complexity by:

(1) compartmentalizing the model quality indicators, so that persons with modeling skills or subject area knowledge can work on different aspects of a problem; and

(2) breaking a complex problem into recognizable components so that the development of the model can be managed.

One aspect of this management technique is the use of target "measures of progress." The first action required by management[6] is to set the measures of progress for model development. These target measures of progress play three roles in the STEP development process.

(1) The first role is to guide the team by **setting and communicating measurable targets for quality well in advance.** The development team can strive for the target quality and can use the qualification metrics to build quality into the product.

(2) The second role is to establish **the minimum expected quality for each stage in model development** by stating the targets just prior to each measurement of progress on the product.

(3) The third role is to **require a quality level for approval measures** by only allowing a model to move to the next stage of development when the quality level has met or exceeded the target measure of progress.

STEP, as an international standard, demands an appropriate level of quality. A model must achieve the target quality level for the appropriate quality indicators before it is promoted to the next stage in the standards process. It is the responsibility of management to select the overall level of quality required, and to select the appropriate set of quality indicators for each type of model.

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[6] The management function for this ISO effort is under the coordination, planning and direction of the Project Management Advisory Group (PMAG) for STEP.

9 Summary

The goal of the "Model Qualification Process" is to shorten the time from technology innovation to development and then introduction into the market by providing for continuous process and quality improvement. The "Model Qualification Process" has contributed to both the effectiveness and productivity of information modeling within STEP. The Methodology is generic and can be used across industry boundaries for assessing models and establishing quality thresholds. The methodology also contributes to making STEP resource and application models more accessible to industry, and to managing the quality of these models. Other contributions from this effort are:

(1) criteria containing the concrete nature of quality indicators and quality characteristics used to measure design products (the models);

(2) a quality management system structured to facilitate the capture of technical quality knowledge;

(3) a strategy that provides for formal management roles for directing, tracking and assessing quality.

The paper presents a methodology that was tailored for ensuring quality in information models. The quality methods from other domains were transferred to STEP. The principles found in existing quality techniques were not directly transferable to STEP information models. The techniques were modified to be appropriate for the modeling methods used by STEP. The reader should have sufficient information from the example provided by STEP to use the Baldrige Award Criteria in another domain.

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Acknowledgements

The author wishes to thank Mary Mitchell, Alice Settle-Raskin, Susan Katz, Cita Furlani and Robert Chapman for their contributions in producing this document.

NIST-114A
(REV. 3-90)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 4738

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
DECEMBER 1991

4. TITLE AND SUBTITLE

Models, Managing Models, Quality Models: An Example of Quality Management

5. AUTHOR(S)

Joan E. Tyler

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

National Institute of Standards & Technology
Factory Automation Systems Division
Building 220, Room A127
Gaithersburg, MD 20899

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

Quality is an increasingly important element in competitiveness. This paper will focus on strategies underway within a standards-making organization for improving its complex standard. This paper explains the quality approach developed to function within this standards environment. Aside from the standards-making community, any organization interested in establishing quality metrics and quality thresholds to assess technical quality will find this paper useful. Also included is an overview of a methodology developed to verify the technical quality of information and data models. These models provide the basis for the standard. The types of models denoted in the title include information, activity, data or process models which are notated in some formal modeling language. Quality thresholds to guide information model developers and evaluators are described, along with an overview of the team approach used in applying the methodology. A description of quality management for models is included along with the roles of management in assuring that quality models are produced.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

Malcolm Baldridge National Quality Award; data models; IGES/PDES Organization; information models; IPO; PDES; Product Data Exchange using STEP; quality management architecture; Standard for the Exchange of Product Model Data; STEP

13. AVAILABILITY

- [X] UNLIMITED
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- [X] ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
20

15. PRICE
A02

ELECTRONIC FORM