
Data quality —

Part 311:

**Guidance for the application of product
data quality for shape (PDQ-S)**

Qualité des données —

*Partie 311: Directives pour l'application de la qualité des données de
produit pour les formes (PDQ-S)*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative documents:

- an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50% of the members of the parent committee casting a vote;
- an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed every three years with a view to deciding whether it can be transformed into an International Standard.

Attention is drawn to the possibility that some of the elements of this part of ISO 8000 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 8000-311 was prepared by Technical Committee ISO/TC184, *Automation systems and integration*, Subcommittee SC4, *Industrial data*.

ISO 8000 is organized as a series of parts, each published separately. The structure of ISO 8000 is described in ISO/TS 8000-1.

Each part of ISO 8000 is a member of one of the following series: general data quality, master data quality, transactional data quality and product data quality. This part of ISO 8000 is a member of the product data quality series.

A complete list of parts of ISO 8000 is available from the Internet:

<http://www.tc184-sc4.org/titles/DATA_QUALITY_Titles.htm>

Introduction

The ability to create, collect, store, maintain, transfer, process and present data to support business processes in a timely and cost effective manner requires both an understanding of the characteristics of the data that determine its quality, and an ability to measure, manage and report on data quality.

ISO 8000 defines characteristics that can be tested by any organization in the data supply chain to objectively determine conformance of the data to ISO 8000.

ISO 8000 provides a framework for improving data quality that can be used independently or in conjunction with quality management systems.

ISO 8000 covers industrial data quality characteristics throughout the product life cycle from conception to disposal. ISO 8000 addresses specific kinds of data including, but not limited to, master data, transaction data, and product data.

Assets can be grouped into real and intellectual property. Information is intellectual property. Data is a prerequisite to information. Thus, the quality of data is a key determinant of an organization's ability to preserve and transfer intellectual property.

A characteristic of data is its portability from one system to another. Syntax and semantics encoding determine whether data is portable in a reliable way. ISO 8000 specifies requirements for the declaration of syntax and semantic encoding. This allows the user to determine the limitations of data portability. By requesting data that conforms to ISO 8000, the user is able to manage data portability and protect its intellectual property assets.

Data quality is the degree to which data meets user requirements. ISO 8000 contains specifications for the declaration of the conformance to stated data requirements. This allows the user to request data that meets its requirements and to determine if the data received meets its requirements.

This part of ISO 8000 is a member of the product data quality series and aims at facilitating effective use of product data quality for shape (PDQ-S), as described in ISO 10303-59.

Since the publication of ISO 10303-59, the worldwide automotive industry has made use of PDQ-S in ISO/PAS 26183, whilst the joint automotive and aerospace project, ISO 10303-242, will make use of the PDQ modules, which are a modular version of PDQ-S.

NOTE The first edition of ISO 10303-59, published in 2008, provides general specifications for the representation of quality criteria, quality measurement requirements, quality assessment specifications and quality inspection results for product data. These specifications are provided so that PDQ-S can be extended to deal with the quality of non-shape product data in the future. Extensions to externally conditioned data quality and geometric dimensioning and tolerance (GD&T) data quality, which are currently under development in the revision of ISO 10303-59, are examples of such extension. By focusing on three dimensional shape data, PDQ-S also provides detailed specifications for the representation of shape data quality criteria, together with associated measurement requirements, shape data quality assessment specifications and detailed results of shape data quality inspections.

PDQ-S is applicable to any International Standard dealing with product data. In order to further extend its usage, this part of ISO 8000 provides the necessary background knowledge to enable the effective use of PDQ-S in various circumstances.

Clause 4 provides a condensed description of PDQ-S.

Clause 5 facilitates the use of PDQ-S.

Clause 6 focuses on ensuring conformance with PDQ-S.

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Data quality —

Part 311:

Guidance for the application of product data quality for shape (PDQ-S)

1. Scope

This part of ISO 8000 provides guidance for the application of product data quality for shape (PDQ-S), as described in ISO 10303-59.

The following are within the scope of this part of ISO 8000:

- purpose, approach and expected usage scenarios;
- the structure of PDQ-S;
- PDQ-S schema structure;
- target shape model;
- the relationship between ISO 10303-59 and other International Standards dealing with the nominal representation of product data;
- the major characteristics of PDQ-S;
- the relationship between product data quality problems and quality criteria in PDQ-S;
- some examples for selecting appropriate quality criteria;
- ensuring conformance with PDQ-S.

The following is outside the scope of this part of ISO 8000:

- guidance relating to the quality of product data other than shape data.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated reference, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10303-42, *Industrial automation systems and integration — Product data representation and exchange — Part 42: Integrated generic resource: Geometric and topological representation*

ISO 10303-59, *Industrial automation systems and integration — Product data representation and exchange — Part 59: Integrated generic resource: Quality of product shape data*

ISO 8000-2, *Data quality — Part 2: Vocabulary*

3. Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8000-2 and the following apply.

3.1.1

application

group of one or more processes creating or using product data

[ISO 10303-1:1994, definition 3.2.2]

3.1.2

application protocol

AP

part of ISO 10303 that specifies an application interpreted model satisfying the scope and information requirements for a specific application

NOTE Adapted from ISO 10303-1:1994, definition 3.2.7

3.1.3

application reference model

ARM

information model that describes the information requirements and constraints of a specific application context

[ISO 10303-1: 1994, definition 3.2.8]

3.1.4

data exchange

storing, accessing, transferring and archiving of data

[ISO 10303-1:1994, definition 3.2.15]

3.1.5

product

thing or substance produced by a natural or artificial process

[ISO 10303-1:1994, definition 3.2.26]

3.1.6

product data

representation of information about a product in a formal manner suitable for communication, interpretation or processing by human beings or by computers

[ISO 10303-1:1994, definition 3.2.27]

3.1.7

accuracy

specification to control precision of approximate solution

NOTE The intended interpretation of the accuracy is that an approximate solution is acceptable if the difference between that approximate solution and any other approximate solution obtained by calculation with a finer distribution of sampling points is smaller than the given accuracy. There are two types of accuracy:

- general accuracy applied to all the measurement, and
- specific accuracy applied only to specified measurement.

3.1.8

inspection result

result of inspection which indicates whether, or not, the product shape data inspected contains quality defects

NOTE Such results can also include detailed information on what type of quality defects exist, and how serious the defect is, together with the shape element data where the problem is detected.

3.1.9

measurement requirement

textual description of how a criterion is measured, including any necessary additional attributes and rules to control the test and the element or elements to be tested, and which plays the role of an external specification for reliable measurement algorithm

NOTE It is important to take care that the measurement requirement does not provide an algorithm for the measurement process, since it is understood that algorithm development is a competitive arena for engineering system vendors and cannot be standardized by an International Standard.

3.1.10

product data quality

consistency, completeness, and suitability for its purpose of the product data

[ISO 10303-59:2008, definition 3.5.2]

3.1.11

product shape data

data representing product shape with geometric and topological information in accordance with ISO 10303-42

[ISO 10303-59:2008, definition 3.5.4]

3.1.12

quality criterion

criterion for evaluating product data quality

3.1.13**threshold**

allowance used for the assessment of shape data quality by numerical test

NOTE An example of a typical threshold is distance threshold for evaluating the gap between a base surface and bounding curves for trimming the effective portion of the surface. That distance threshold implies that if the maximum distance between the surface and the curves is greater than or equal to the specified minimum value, then the gap is understood as a quality defect.

3.1.14**inspection**

conformity evaluation by observation and judgement accompanied as appropriate by measurement, testing or gauging

[ISO 9000:2005, definition 3.8.2]

3.1.15**quality**

degree to which a set of inherent characteristics fulfils requirements

NOTE 1 The term “quality” can be used with adjectives such as poor, good or excellent.

NOTE 2 “Inherent” as opposed to “assigned” means existing in something, especially as a permanent characteristic.

[ISO 9000:2005, definition 3.1.1]

3.1.16**quality requirement**

need or expectation that is stated, generally implied or obligatory

NOTE Adapted from ISO 9000:2005, definition 3.1.2.

3.2 Abbreviated terms

AP application protocol

ARM application reference model

AM application module

B-rep boundary representation

IR integrated resource (of ISO 10303)

PDQ-S product data quality for shape (as described in ISO 10303-59)

4. Overview of PDQ-S

4.1 Purpose, approach and expected usage scenarios

The purpose of PDQ-S, as described in ISO 10303-59, is to eliminate inadequate quality product data which is a major reason for rework and repair of data by the data receiver. The approach of PDQ-S is to enumerate concrete measures for eliminating inadequate quality product data.

Amongst the expected scenarios for the use of PDQ-S are as follows.

- **Requirement of quality:** The company placing an order requires the company receiving the order to create product data that satisfies prescribed quality requirements. Examples are exclusion of infinitesimal geometry smaller than the given tolerance and exclusion of redundant geometry not contributing to the representation of product shape. Very limited information, namely relevant criteria together with required thresholds from those provided in PDQ-S, is necessary in this scenario. The information is transferred together with the order.
- **Declaration of quality:** The creator of a product data uses quality information for explicitly declaring the quality level satisfied by the product model. Depending on the design method and the CAD system used, the quality of the product data can be unambiguously declared without any inspection. Selective criteria and thresholds for which the model is judged to be free from quality defects are required information in this scenario. The quality information is transferred together with the corresponding product model data.
- **Assurance of quality:** A quality assurance organization uses quality information for representing the results of quality inspection for a particular product model. This scenario will require inspected quality criteria together with thresholds used, measurement requirements deployed and inspection results obtained. The accuracies used can also be included. The information is transferred together with the corresponding product model data.
- **Quality information for use in quality improvement:** If a quality defect is detected by quality inspection, necessary actions for improving critical data will be required. For that purpose, information on the nature and severity of any quality defects is provided. Therefore, this scenario will require a detailed inspection result report at the level of geometric entity instances. The information is transferred together with the corresponding product model data.
- **Long-term archiving of product data:** It is desirable that a detailed record of product model data quality is archived with product data. The data requirement for this purpose is similar to that needed for assurance of quality.

4.2 Structure of ISO 10303-59

Terminology specific to ISO 10303-59:2008 is described in Clause 3. The main body of ISO 10303-59 contains the following schemas:

- Clause 4: Product data quality definition schema;
- Clause 5: Product data quality criteria schema;
- Clause 6: Product data quality inspection result schema;
- Clause 7: Shape data quality criteria schema;
- Clause 8: Shape data quality inspection result schema.

Appendices include EXPRESS-G diagrams, graphical notation of EXPRESS schemas to ease understanding of structure and relationships of entity data types, technical discussion that summarizes

basic understanding of standard developers on key technical issues, expected usage scenarios and some examples in entity instance level.

4.3 PDQ-S schema structure

PDQ-S consists of five mutually related schemas. Each schema is a collection concepts, functions and entities.

Product data quality definition schema defines high-level data elements for managing product data quality information.

Product data quality criteria schema provides general specifications for the representation of quality criteria, quality measurement requirements and quality assessment specifications for product data.

Product data quality inspection result schema provides general specifications for the representation of quality inspection results for a particular product data.

Shape data quality criteria schema provides representations of shape data quality criteria together with corresponding measurement requirements, thresholds for judging the existence or absence of quality defects and assessment specifications for product shape data.

Shape data quality inspection result schema provides representations of quality inspection results for a particular product shape data with regard to specified quality criteria. Detailed information on what type of quality defect is existing, and how serious the defect is, together with the shape element data where the problem is detected can also be represented.

These schemas are related as depicted in Figure 1 where the number in each block indicates the relevant clause number in ISO 10303-59:2008. The product data quality definition schema plays the role of a root node for a set of quality information. The shape data quality criteria schema is a specialization of the product data quality criteria schema to three dimensional shape data. In the same way, the shape data quality inspection result schema is a specialization of the product data quality inspection result schema to three dimensional shape data.

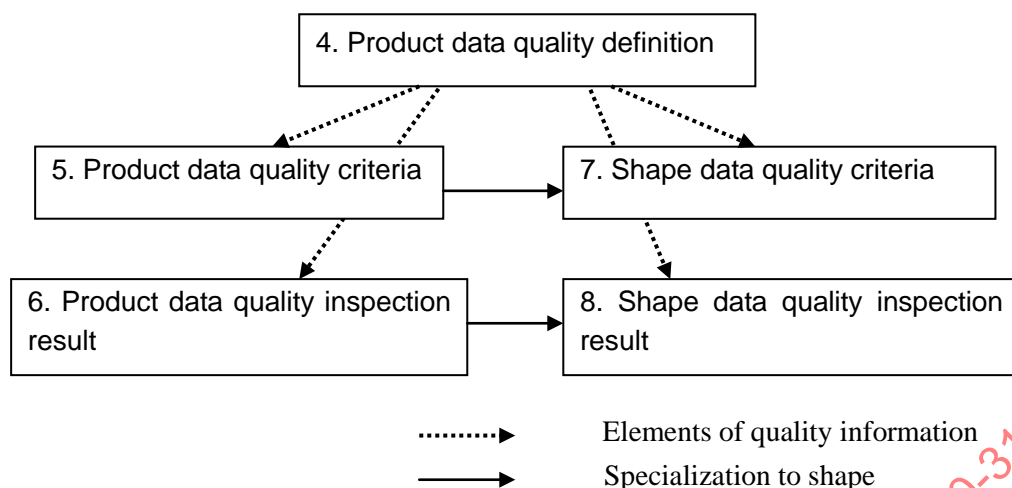


Figure 1 — Structure of PDQ-S schemas

In ISO 10303-59:2008, each schema is structured in the following way, where X is a schema number:

- X.1: Introduction
- X.2: Fundamental concepts and assumptions
- X.3: Type definitions
- X.4: Entity definitions
- X.5: Function definitions

X.2 describes the basic concepts and assumptions of schema-X. X.3 defines schema-X specific data type definitions that are used in the EXPRESS specifications in X.4. X.4 is the main body of schema-X where criteria are described as entity data types. Functions used in the EXPRESS specifications of X.4 are described in X.5.

4.4 Target shape model

The target shape model of PDQ-S is a boundary representation (B-rep) model conformant to the manifold_solid_brep entity definition in ISO 10303-42. Such models are implemented in many of today's commercial CAD system for representing product shape. In APs and modules they typically form part of an advanced_brep_shape_representation.

4.5 Relationship between ISO 10303-59 and other International Standards dealing with nominal representation of product data

The direct relationship between PDQ-S schemas and other resource schemas is depicted in Figure 2. A major difference between PDQ-S and other International Standards dealing with nominal representation of product data is that PDQ-S deals with quality aspect of instanced data. The major reason why data exchange between two IT systems which claim STEP conformance (such as CAD systems), frequently fails due to instanced data quality problems is that the implementation of B-rep model and the guaranteed numerical accuracy guaranteed are IT system dependent. Therefore, STEP conformance is not a sufficient condition for successful data exchange or sharing but it is also necessary that the quality of instanced data should be satisfactory.

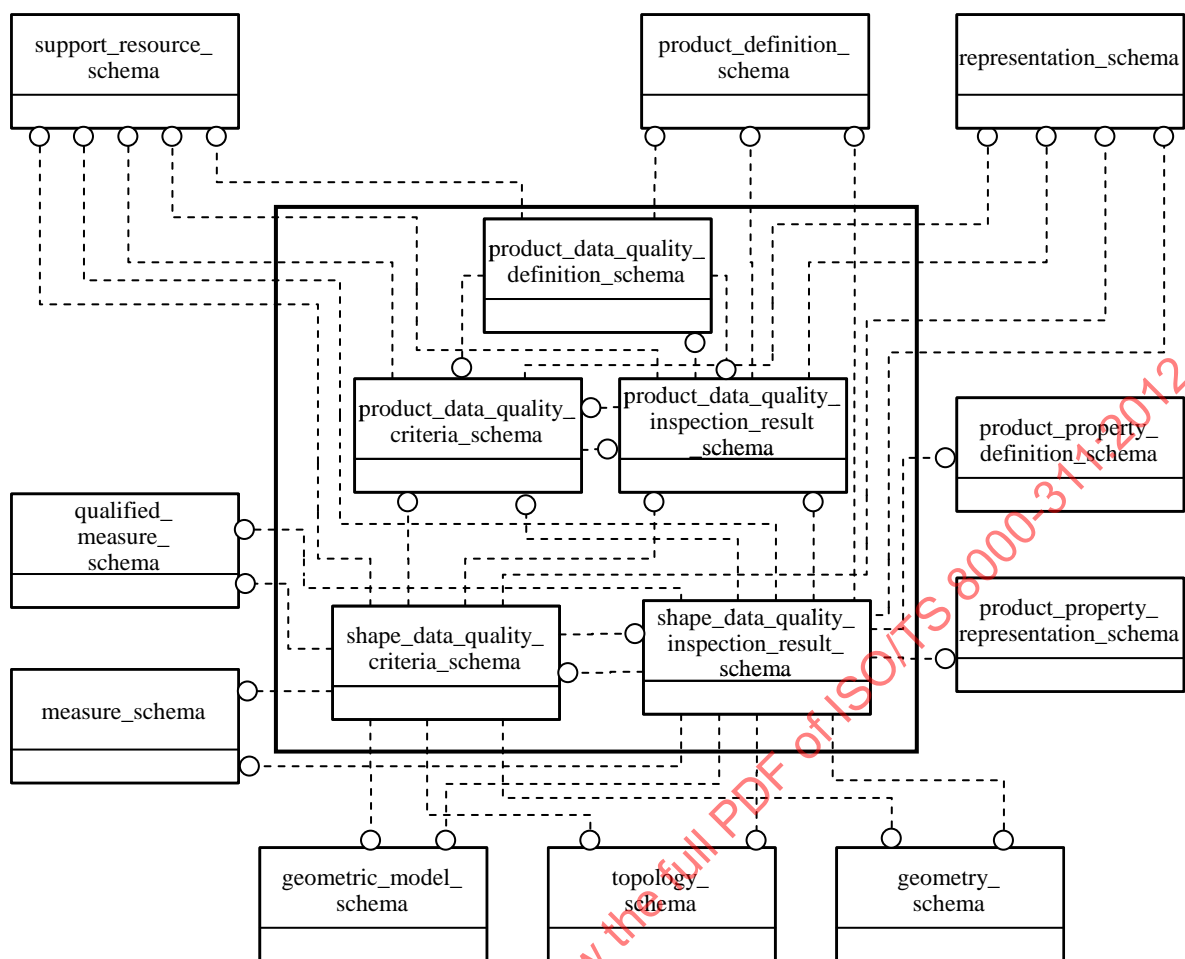


Figure 2 — Schema level diagram of relationships between PDQ-S schemas (inside the box) and other resource schemas

The schemas occurring in Figure 2 are components of ISO 10303 integrated generic resources, and they are specified in the following resource parts:

measure_schema	ISO 10303-41
product_definition_schema	ISO 10303-41
product_property_definition_schema	ISO 10303-41
product_property_representation_schema	ISO 10303-41
support_resource_schema	ISO 10303-41
geometric_model_schema	ISO 10303-42
geometry_schema	ISO 10303-42
topology_schema	ISO 10303-42
representation_schema	ISO 10303-43
qualified_measure_schema	ISO 10303-45

4.6 Major characteristics of PDQ-S

4.6.1 Quality criteria of three dimensional shape data

Quality criteria of three-dimensional shape data fall into the following classes:

- Erroneous data;
- Inapt data;

Each of these classes is further categorized into the following sub-classes:

- Geometry specific issue;
- Topology specific issue;
- Combined geometry and topology issue;
- Geometric model issue.

‘Erroneous data’ implies a mathematically invalid product shape data. Typical examples are erroneous b_spline surface definition, open edge loop and inconsistent face and underlying surface normals. An example of an erroneous instance of a b_spline_surface is one in which there is an inconsistency between the degrees, the number of knots, the knot multiplicities and the number of control points. Such an instance will violate one, or more, of the WHERE rules in the definition of the corresponding b_spline_surface_with_knots entity. The judgement of erroneous data is generally a binary decision as to whether or not rules in the entity definition are broken and does not involve a numerical threshold value.

‘Inapt data’ implies data inappropriate for some applications though it is not necessarily mathematically incorrect. Amongst examples are self-intersecting curve, excessively high curve degree, surface with small radii of curvature and narrow width surface patches. Even when shape data have acceptable quality in the senses described above, there exists a number of cases where engineers in downstream processes have to rework the data so that it can be effectively used.

For example, mould design engineers have to modify a product shape data if an appropriate draft angle is not taken into account in the data. The knowledge as to whether various manufacturing requirements are incorporated into the data or not may save the cost of rework.

4.6.2 Enabler of better association between PDQ checking systems and healing systems

There is basically no association between separate PDQ checking and healing systems. Lack of reliable inspection result representation at the entity instance level is the major reason of this non association. Even when results of a PDQ check by some checking system exist, any separate PDQ healing system tends to check data quality again for obtaining reliable check results before starting the healing process. Inspection result representation at the entity instance level provided by PDQ-S may

be used to resolve this redundant check situation.

The shape data quality inspection result schema provides representation of quality inspection results for specific product shape data with regard to specified quality criteria. The inspection result indicates whether or not the product shape data inspected contains quality defects. It may also include detailed information on what type of quality defect exists, and how serious the defect is, together with the shape element data where the problem is detected. This information is expected to be useful for quality healing processes and to help efficient cooperation between quality checking systems and healing systems for product shape data.

4.6.3 Standardization of the external specifications of quality checking algorithms

Two different PDQ checking systems may produce different check results for inspection of the same product data where the same criteria and the same thresholds are specified for the check, which deteriorates reliability of PDQ checking systems. The reason why this problem occurs is that the quality check algorithm for each quality criterion is left to the PDQ checking system vendor's freedom and there is no guideline for acceptable quality check algorithm.

The solution by PDQ-S to this problem is the introduction of a concept named 'measurement requirement', which is an external specification of an acceptable algorithm. Each shape quality criterion includes a pertaining measurement requirement, which is a textual description of how the criterion is to be measured and may have additional attributes and rules to control the test and the element or elements to be tested. It is expected that the dependence of check results on individual PDQ checking systems be drastically reduced if developers of a PDQ checking system review their system as to whether or not they satisfy the requested measurement requirements and improve the system as necessary.

NOTE Measurement algorithms are outside the scope of PDQ-S since it is understood that algorithm development is a competitive arena for engineering system vendors and cannot be standardized by an international standard.

4.6.4 Optimization of data quality check environment by the user

Data quality requirements, thresholds to be applied for quality test and numerical calculation accuracies to be applied in the quality test algorithm are obviously dependent on the target design/manufacturing object and/or design/manufacturing activity. Therefore, these should be user definable. PDQ-S provides sufficient resources for the users to select the most appropriate quality criteria together with thresholds to be applied for the 3D shape data under development. Assuming that some users may even want to specify the accuracy of numerical calculations, the accuracy to be applied in a quality test by PDQ checking systems is also user definable. This standard provides some examples and suggestions for selecting appropriate criteria in Clause 5.

User definable thresholds from application protocols supporting shape models, such as ISO 10303-203 and ISO 10303-214, play a key role in the assessment of shape data quality by numerical test. An example of a typical threshold is a distance threshold for evaluating a gap between a base surface and bounding curves for trimming the effective portion of the surface. That distance threshold implies that if the maximum distance between the surface and the curves is greater than or equal to the specified

minimum value, then the gap should be understood as a quality defect. Appropriate thresholds depend on many factors such as the size of a product, design requirements and the sensitivity of engineering systems to numerical imprecision, etc. Therefore, the actual threshold value to use needs to be carefully determined in each business situation based on agreement among the business partners.

In most cases, especially when free form geometry is involved, the measurement algorithm calculates an approximate solution not an exact solution. In the above example, surfaces and curves consist of an infinite number of points. Since calculation on an infinite number of points is impossible, any algorithm tries to calculate the solution using a sufficient finite number of points. In order to require the difference of the approximate solution and the exact solution, even when it is unknown, to be smaller than the expected value, an accuracy specification is provided. An approximate solution is acceptable if the difference of the approximate solution and another approximate solution obtained by calculation with another finer set of sampling points is smaller than the specified accuracy. There are two types of accuracy specification, general accuracy applied to all the measurements or specific accuracy applied only to a specified measurement.

Thus, users can optimize the data quality check environment by an appropriate combination of quality criteria, thresholds and accuracy.

NOTE The above focuses on how to optimize data quality testing so that it is appropriate for the target shape data. The underlying assumption is that the shape data are suited for quality testing. The general requirement for this suitability is that precision of the shape data satisfies the requirements of ISO 16792:2006, 6.2.

4.6.5 Extensibility to non-shape product data quality problems

Although the detailed specification of PDQ-S currently focuses on product shape data, it has two general schemas for representing any quality related property of product data. One is **product data quality criteria schema** and the other is **product data quality inspection result schema**.

The **product data quality criteria schema** and **product data quality inspection result schema** may be applied to non-shape data quality issues such as externally conditioned data quality problems and GD&T data quality problems.

5. Considerations for facilitating the use of PDQ-S

5.1 General

This clause discusses the following considerations:

- the relationship between practical data quality problems and PDQ criteria in PDQ-S, from the point of view of standard developers (see 5.2);
- concrete PDQ criteria deployed for three different scenarios (see 5.3);
- the processes by which to promote PDQ activity (see 5.4).

The latter two considerations (see 5.3 and 5.4) are based on actual deployment of PDQ criteria in the Japanese automotive industry.

5.2 Relationship between product data quality problems and quality criteria

5.2.1 Types of product data quality problem

The following three different types of practical data quality problem have corresponding PDQ criteria.

- a) B-rep is not appropriate (see 5.2.2).
- b) Accuracy of B-rep does not satisfy requirements (see 5.2.3).
- c) Shape manipulation process by CAX systems fails (see 5.2.4).

Of the above, item a) is the most basic and critical problem for all type of 3D shape data, while b) and c) are problems for which the severity depends on the use case.

5.2.2 B-rep is not appropriate (**erroneous_data**)

The B-rep of 3D shape data shall conform to ISO 10303-42. All the shape data quality criteria that are subtypes of **erroneous_data** in PDQ-S are those to check for conformance to ISO 10303-42. Quality defects detected by those criteria are regarded as illegal data and are useless in any application. The spread of 3D CAD systems has promoted improvement of these systems. Therefore, it is very rare today that quality defects of this category are detected against data created by modern CAD systems. The check for quality defects of this category is especially meaningful for legacy CAD data or for CAD data obtained by unstable data transformation systems.

5.2.3 Accuracy of B-rep is not satisfactory

The tolerance within which to regard two different points in 3D space as coincident plays a key role in numerical error analysis of a B-rep model. If the distance between two geometric entities, one of which is defined as being on the other (including, point on curve, curve on surface and curve bounded surface), is actually greater than the coincidence tolerance, or if there exists a curve or a surface having an extent that is smaller than the coincidence tolerance, it may cause various unsatisfactory results, including unexpected untrimmed surface, missing entities and erroneous termination of CAD commands.

PDQ-S supports:

- detection of gaps between two geometric entities greater than a threshold using **geometric_gap_in_topology** with six associated concrete criteria;
 - detection of infinitesimal entities, using **nearly_degenerate_geometry** (three associated concrete criteria) and **topology_related_to_nearly_degenerate_geometry** (three associated concrete criteria).
- The following explains how to select the appropriate criterion for detecting serious gaps between two adjacent surfaces from among three related criteria, and how to select the appropriate criterion for detecting serious infinitesimal entities from among two or more related criteria are explained below.

(1) Effective use of criteria for detecting a serious gap between adjacent surfaces

There are three criteria concerning a gap between two adjacent surfaces as follows:

- (a) **gap_between_edge_and_base_surface**;
- (b) **gap_between_faces_related_to_an_edge**;
- (c) **gap_between_pcurves_related_to_an_edge**.

Most commercial CAD systems internally hold curve data similar to the notion 'pcurve' in ISO 10303-42. It is understood that the effective portion of one face is the area bounded by pcurves. (c) above directly evaluates the distance between two pcurves in 3D space. For reducing the amount of data, it is frequently the case that pcurves are not output in a STEP file. In these cases, (b) can be used as an alternative. (a) is a criterion to evaluate the distance between bounding 3D curves and a single reference surface. What is calculated for (a) is essentially different from that for (b) and (c) but there is high similarity between the detected data quality defects. Therefore, (a) may well be used in place of (b) or (c). Only edges referred from faces twice are the target of calculation in (b), all the edges referred from one face are target of calculation in (a). In summary, it is recommended to use (c) when pcurve data exists. Otherwise (b) or (a) may be used.

(2) Effective use of criteria for detecting infinitesimal entity

For detecting infinitesimal faces/surfaces or volumes, two types of criteria exist. One is **entirely_narrow_*** and the other is **small_***. The former type of criteria use width for the calculation and the latter type of criteria use area/volume for the calculation. The threshold for widths can be directly calculated from the basic accuracy of CAD systems which is represented as a distance. As for area/volume, it is difficult to calculate its threshold since area/volume have different units of measure from that of distance. Namely, it is not possible to conclude that an entity having an area/volume smaller than the given threshold causes trouble in various manipulations of the data in a CAD system. Therefore, **entirely_narrow_*** is recommended for detecting a face or a surface smaller than the basic accuracy of a CAD system. The difficulty of the **entirely_narrow_*** criteria is that inspection logic could become complex since the definition of width is more complicated than those of area or volume.

5.2.4 Shape manipulation process by CAX systems fails

In general, input to a commercial CAD system has infinite variation. It is known from experience that CAD functionalities or data exchange can fail even if the PDQ criteria explained so far in 5.2 all pass satisfactorily. The PDQ criteria that are effective for detecting problematic 3D shape according to extensive users experience are collected in PDQ-S. The recommended typical means to select appropriate criteria is to analyse the relationship between low quality data and the PDQ criteria in PDQ-S. The following explains a practical task oriented classification of shape data quality problems and corresponding PDQ criteria will be explained.

(1) Inappropriate shapes

PDQ-S contains various kinds of criteria that can detect inappropriate shapes. Those criteria may be classified into the categories below. In order to observe the relationship between shape data quality problems and PDQ errors, it is required to select appropriate criteria and thresholds.

— Self intersection

self_intersecting_curve, **self_intersecting_surface**, **self_intersecting_loop**, **self_intersecting_shell** and **intersecting_connected_face_sets** are provided for detecting self intersection. These quality defects are very close to **erroneous_data**. All of these are prohibited in ISO 10303-42 by informal propositions.

— Bad condition of normal or curvature

curve_with_small_curvature_radius, **surface_with_small_curvature_radius**, **zero_surface_normal**, **abrupt_change_of_surface_normal**, **steep_angle_between_adjacent_edges** and **steep_angle_between_adjacent_faces** fall into this category.

— Inappropriate polynomial curve or surface

short_length_curve_segment, **small_area_surface_patch**, **narrow_surface_patch**, **indistinct_curve_knots**, **indistinct_surface_knots**, **nearly_degenerate_surface_patch**, **extreme_patch_width_variation** and **nearly_degenerate_surface_boundary** fall into this category.

In order to have an image of criteria of these kinds, it is useful to imagine dragging a self-intersecting string into a line (See Figure 3). Similar discussion also applies to the case of surface.

self_intersecting_curve is the most appropriate criterion for detecting the case (i) of Figure 3. Curves detected by this criterion will cause failures or unsatisfactory results in shape manipulation. An issue in using this criterion is how to distinguish (i) and (ii) of Figure 3. It is especially difficult to distinguish them in a 3D environment. **arc_length_separation_factor** and **interference_tolerance** can be used for this purpose, but determining appropriate values especially for **arc_length_separation_factor** is not straightforward, and needs trial and error in order to achieve successful determination.

Case (ii) can still be problematic in some calculations. In this case, the shape is one the user did not intend to create, but one the CAD system has automatically generated. There are several criteria that can detect this case including **curve_with_small_curvature_radius**. Determining an appropriate threshold for this criterion also needs some experimental investigation. In case of surfaces, **abrupt_change_of_surface_normal** can detect surface shapes of this kind. **steep_angle_between_adjacent_edges** can detect the case where two different edges form the

problematic shape. Although not directly related to shape itself, **short_length_curve_segment** often detects data quality defects for curves with the shape of case (ii). But this criterion sometimes detects data quality defects for curve with the shape of case (iii), which causes no problem in most applications, and the shape could be one that a designer wanted to create. This means that over-detection often happens for this criterion. A merit of this criterion is that detection of quality defect by this criterion is in most cases stable and fast, and that the curve detected by this criterion is too heavy and complex even if it causes no problem.

The criteria mentioned above can be used to detect shapes that designers did not want to create, which can cause various downstream problems. But, as described above, selecting appropriate criteria and threshold values needs experimental investigation based on practical data.

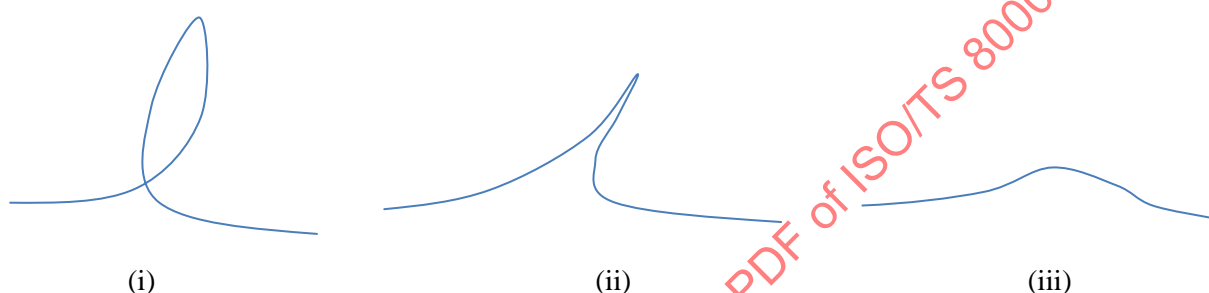


Figure 3 — Dragging a self-intersecting string into a line

In the case of surfaces, critical problems occur CAD systems fail to calculate normal vectors, which often happens. Criteria such as **zero_surface_normal**, **nearly_degenerate_surface_boundary** and **nearly_degenerated_surface_patch** are appropriate to detect this type of surface.

(2) Redundant shape

PDQ-S contains various kinds of criteria that can detect overlapping entities. Overlapping entities can happen for several reasons. Entities whose shapes are completely identical can be generated by erroneous operations or inappropriate data translation. Partly overlapping entities can also be generated by erroneous operations or defects in data translation such as a failure of the surface trimming process. In both cases, these entities are often not intended to be created, make data heavier than necessary, and sometimes causes operational errors. The criteria listed below can be used for detecting overlapping entities.

— All criteria subtyped under **multiply_defined_geometry**, all criteria subtyped under **overlapping_geometry**, all criteria subtyped under **topology_related_to_multiply_defined_geometry**, all criteria subtyped under **topology_related_to_overlapping_geometry**, **multiply_defined_solids** and **partly_overlapping_solids** fall into this category.

There are other categories of criteria that can detect entities that make data unnecessarily heavy. Entities detected by these criteria do not necessarily cause direct failure, but often affect the effectiveness of data usage.

— All criteria subtyped under **overcomplex_topology_and_geometry_relationship**, **excessively_high_degree_curve**, **curve_with_excessive_segments**, **excessively_high_degree_surface** and **surface_with_excessive_patches_in_one_direction** fall into this category.

5.3 Examples of selecting data quality criteria for practical engineering purposes

5.3.1 Overview of the example scenarios

This clause shows practical scenarios of selecting data quality criteria as per current practices in the Japanese automotive industry today. The specific examples are all in actual use by one particular automotive assembly maker. Although the criteria in use are both shape related and non-shape related, the following focuses just shape related criteria.

NOTE ISO TC184/SC4/WG13 intends to show examples for non-shape criteria after the completion of the revision of ISO 10303-59, which will support data quality criteria in the area of non-shape data that reference external documents where acceptance conditions are defined.

The following three scenarios are distinguished for selecting appropriate data quality criteria.

- a scenario of product data exchange during digital assembly;
- a scenario of product data exchange during collaborative product development by an assembly maker and parts suppliers;
- a scenario of product data exchange during production equipment/die development aiming at machining dies.

5.3.2 A scenario of product data exchange during digital assembly

Digital assembly process is a process to perform virtual assembly by using digital data for checking

- there are no functional problems of the component parts;
- there are no unacceptable collisions between the component parts;
- the existence of appropriate gaps between the component parts;
- the feasibility of assembly during mass production;
- the feasibility of inspection.

Digital assembly is performed by collecting the necessary component parts data into one CAD system. Typically, some of these data are developed by departments within the assembly manufacturer and others by parts suppliers. In order to perform efficient digital assembly, all the collected data should be displayed on the screen and should be usable during inspection without requiring any rework or repair activity. In order to confirm whether or not all the collected data satisfy this condition, the PDQ criteria below are used. Criteria for detecting considerable gap between entities and those for detecting too small entity which may cause incomplete display of the target product shape data by missing entities or deformed entities are selected. A criterion for detecting duplicate faces, which may cause user's confusion, is also selected.

short_length_edge
 gap_between_adjacent_edges_in_loop
 gap_between_edge_and_base_surface
 entirely_narrow_face
 multiply_defined_faces
 small_volume_solid

5.3.3 A scenario of product data exchange during collaborative product development by an assembly manufacturer and parts suppliers

In collaborative product development environments, product data are frequently exchanged among participating companies. The received data are expected to be usable in any product development process such as shape modelling. Therefore, the requirements on PDQ for these data are far more severe than the scenario described in 5.3.2. The PDQ criteria used for this scenario are below.

The criteria necessary for guaranteeing complete display of the target product shape data without any missing or deformed entities and a criterion for preventing confusion of the user are similar to those requested in 5.3.2. In this scenario, the additional criteria are those for enabling successful geometry processing by CAD systems and include those such as for detection of discontinuous entities, self-intersecting entities and topologically unexpected entities.

short_length_curve
 self_intersecting_curve
 entirely_narrow_surface
 self_intersecting_surface
 short_length_edge
 self_intersecting_loop
 gap_between_pcurves_related_to_an_edge
 entirely_narrow_face
 multiply_defined_faces
 gap_between_faces_related_to_an_edge
 non_manifold_at_edge

5.3.4 A scenario of product data exchange during production equipment/die development aiming at machining dies

Automotive panels are usually formed by stamping or injection moulding dies. The die shape includes complicated free form surfaces and is developed by sophisticated NC machining. As is well understood by subject matter experts, the die shape is not equal to the received product shape. The die shape allows for manufacturing requirements such as spring back estimation or estimation of the thermal deformation of the physical die. This implies that a very complicated shape deformation process is necessary in this scenario. Therefore, the PDQ requirement for this scenario is even more severe than for the preceding two scenarios. The PDQ criteria employed in this scenario are below and are classified as:

*1: those necessary for complete display of the target shape without any missing or deformed entities and those necessary for enabling successful geometry processing by CAD systems, including criteria for detecting gaps, discontinuities, entities that are too small, self intersecting entities and topologically unexpected entities;

*2: those necessary for successful CAM model creation and NC cutter path calculation, including criteria for detecting gaps, discontinuities, entities that are too small, self intersecting entities,

degenerate entities and topologically unexpected entities;

*3: those necessary for preventing confusion of the user, including criteria for detecting multiply defined entities;

*4: those necessary for guaranteeing manufacturability, including criteria for detecting too small entities, acute entities and internal voids.

g1_discontinuous_curve(*1,*2)
short_length_curve(*1,*2)
short_length_curve_segment(*2)
self_intersecting_curve(*1,*2)
multiply_defined_curves(*3)
curve_with_small_curvature_radius(*2,*4)
g1_discontinuous_surface(*1,*2)
narrow_surface_patch(*2)
nearly_degenerate_surface_boundary(*2)
nearly_degenerate_surface_patch(*2)
zero_surface_normal(*2)
self_intersecting_surface(*1,*2)
multiply_defined_surfaces(*3)
abrupt_change_of_surface_normal(*4)
surface_with_small_curvature_radius(*2,*4)
short_length_edge(*1,*2)
gap_between_adjacent_edges_in_loop(*1)
self_intersecting_loop(*1,*2)
steep_angle_between_adjacent_edges(*4)
gap_between_edge_and_base_surface(*1)
gap_between_vertex_and_base_surface(*1)
entirely_narrow_face(*2,*4)
self_intersecting_loop(*1,*2,*4)
intersecting_loops_in_face(*4)
multiply_defined_faces(*3)
gap_between_faces_related_to_an_edge(*1)
gap_between_pcurves_related_to_an_edge(*1)
g1_discontinuity_between_adjacent_faces(*1,*2)
self_intersecting_shell(*4)
steep_angle_between_adjacent_faces(*4)
over_used_vertex(*1)
small_volume_solid(*4)
intersecting_shells_in_solid(*4)
multiply_defined_solids(*3)
solid_with_excessive_number_of_voids(*4)

5.4 Recommended procedure for promoting PDQ activity

The following discusses the recommended preparation and operations for promoting PDQ activity. The Japanese automotive industry already currently performs such activity.

< Process-1> Capture of the severity of problems caused by unacceptable PDQ

The first step for promoting company-wide PDQ activity is to estimate the losses caused by unacceptable PDQ. This process should consist of identifying financial and lead time implications of rework or repair of data necessitated by unacceptable PDQ, or re-manufacturing of component parts after discovering that existing data do not satisfy PDQ requirements.

There are two main difficulties for conducting this process. One is that it is difficult to judge whether or not erroneous results of CAX (CAD, CAM or CAE) operations are caused by unacceptable PDQ. The other is that designers and engineers very frequently do not recognize PDQ problems since they have accumulated knowhow on how to go forward when they encounter erroneous results. Since the time they have available is limited, they tend to try to go forward without stopping their job when they encounter erroneous results.

With respect to the first difficulty, indispensable mitigation comes from the contribution of PDQ experts who are familiar with the erroneous results caused by inappropriate PDQ, the related CAD operations and applicable company rules. In the case of the second difficulty, PDQ experts are expected not only to listen to designers and engineers but also to identify, by looking at the operations of designers and engineers, those PDQ problems that the designers and engineers fail to recognize.

Even if the identification of the losses caused by inappropriate PDQ are investigated as described above, it is time consuming and difficult to capture the total losses company-wide. To resolve this problem, organizations working together are choosing to adopt a new type of PDQ approach, whereby data quality should be guaranteed by its creator, along the same lines as asking the creator of a physical product to guarantee the quality of that product. This approach could simplify the process because the requirement reduces to the capture of only typical PDQ phenomena rather than capture of comprehensive phenomena.

< Process-2> Identification of PDQ criteria that can detect inappropriate quality data

As reliable commercial PDQ tools are now available, inspection of the quality of CAD data is not difficult. After running the same quality checks on both problematic and non-problematic data, comparison of the two results will highlight which PDQ criteria best detect inappropriate quality data. Another approach is to perform comprehensive quality checks against currently active CAD data by a prescribed set of PDQ criteria together with appropriate thresholds. The prescribed set of PDQ criteria together with appropriate thresholds can be obtained by experiences as written in the JAMA/JAPIA PDQ Guidelines. If quality defects are identified by the comprehensive checking, the standard set of PDQ criteria should be those that detected the quality defects.

< Process-3> Establishment of company rules and creation of an operational environment

After identifying effective PDQ criteria, organizations should establish of company rules to prevent inappropriate quality data and create an operational environment to support the activities of designers and engineers. Establishment of company rules is effective when simple satisfaction of company rules

can prevent occurrence of inappropriate quality data. However, often the occurrence of inappropriate quality shape data is only becomes apparent after actual creation of the data. When to perform quality checks and to modify unacceptable data should be carefully determined by considering design efficiency and the costs of checking and modification. Quality check after each shape manipulation operation will result in minimum incurred modification costs but significantly deteriorate design efficiency. Quality checking by running the PDQ tool (for example, at midnight) and modification the next morning as necessary will result in medium levels of both cost and deterioration in design efficiency. Quality checking after the completion of the component part design will result in lowest deterioration of design efficiency but could incur significant modification costs.

< Process-4> Company training

Company training is necessary to create understanding of the aims of PDQ activity and the associated company rules. In the case of establishing PDQ checking and any necessary modification of data, on-the-job training is most appropriate. This type of training is especially effective in identifying operations that frequently cause inappropriate PDQ.

< Process-5> Start of operation and establishment of stable operation

Following on from Processes 1 to 4 above, actual operations can begin with the aim to achieve acceptable PDQ. It is important to perform monitoring of PDQ so that designers and engineers themselves can judge the quality of the data they are creating. Such responsibility provides motivation to those individuals. Ongoing checking is necessary to assess the validity of the implemented PDQ criteria and associated thresholds, resulting in modification of the criteria selection or thresholds as necessary.

6. Ensuring conformance with PDQ-S

6.1 General

Shape data quality information is used in relation with product shape data. This clause describes how to adapt existing ISO 10303 APs in order to make them PDQ-S conformant. The approach to the relationship between shape data quality information and product data deployed in the development of PDQ-S is described. It is understood that there are two ways to associate PDQ-S and ISO 10303 APs. This clause describes the first method where an existing AP is modified into an AP with shape data quality information. The second method where shape data quality information is associated with an existing AP without any modification to the AP itself may be discussed in the future when the necessary external reference mechanism becomes available.

6.2 Underlying concepts of PDQ-S

6.2.1 Usage scenarios of PDQ-S

Three scenarios for using PDQ-S are described in ISO 10303-59:2008, Annex G, as follows.

a) Requirement and declaration of data quality

The ordering company may require the supplying company to create product model data so that it satisfies prescribed quality requirements. The quality requirements may be transferred together with the ordering sheet. The creator of product data may use quality information for explicitly declaring the quality level satisfied by his/her model. Depending on the design method and the CAD system used, the quality of the product model data may be unambiguously declared without any inspection. The quality information may be transferred together with the corresponding product model data.

b) Assurance of data quality and long-term data archiving

A quality assurance organization may use quality information for representing the results of quality inspection for a particular set of product model data. This scenario will require the inspected quality criteria together with thresholds used, measurement requirements deployed and inspection results obtained. The accuracies used may also be included. The information is transferred together with the corresponding product model data. It is desirable that a detailed record of product model data quality is archived together with the associated product data. The data requirement for this purpose is similar to that needed for assurance of quality.

c) Data quality information for use in quality improvement

If a quality defect is detected by quality inspection, necessary actions for improving critical data will be required. For that purpose, information on the nature and severity of any quality defects should be provided. Therefore, this scenario will require a detailed inspection result report at the geometric entity instance level. This information is transferred together with the corresponding product model data.

6.2.2 Relationship between a product data and its data quality information

PDQ-S was developed with the following assumptions.

a) Product data quality information is independent from product model data.

Product data quality information should be understood as basically independent from product model data and should not be considered as a constituent part. Although product data quality information is related with product model data in most usage scenarios, it may also be used independently.

b) Product data quality information should include specific requirements for data quality and inspection results against those specific requirements as necessary.

In the scenario of requirement and declaration of product data quality against specific requirements, only requirement information for product data quality will be used. On the other hand, inspection result information should be coupled with the corresponding requirement information since the result is meaningful only when the corresponding requirement is known.

c) When product data quality information is used in association with product model data, one way reference from product data quality information to product model data inspected. In the scenario of assurance of product data quality and long-term data archiving, product data quality information requires reference to product model data inspected. In addition, for the scenario of data quality information for use in quality improvement, reference to shape element data that that caused quality defect is also required.

To satisfy these assumptions, product data quality is related with product model data at the four points shown with encircled alphabet characters in Figure 4.

NOTE: Some details of the model which have no relation with this discussion are omitted in this figure.

(A) Product data quality definition and product definition

A relationship entity relates the root entity of product data quality information **product_data_quality_definition** with the **product_definition** defined in ISO 10303-41 that identifies the product model data inspected. This entity establishes the relation between product data quality information and product data in their definition level.

Figure 4 — Relation between product data quality information in PDQ-S and product model data

(B) Inspection result on product shape data quality and product shape

A relationship entity relates the **shape_data_quality_inspection_result_representation** representing the inspection result on product shape data quality and the **shape_representation** defined in ISO 10303-41 representing the shape representation of inspected product data. This **shape_representation** shall be a representation of the shape of **product_definition** identified by (A).

(C) Inspected shape element violating a requirement on shape data quality

An entity in the selection represents an inspected shape element having a defect as an attribute of **shape_data_quality_inspection_report_item** representing individual defect information against a specific criterion on shape data quality. The **inspected_shape_element_select** select type represents inspected geometric and topological elements defined in ISO 10303-42. These shape elements shall be elements of **shape_representation** identified in (B).

(D) Location of defect detected by inspection

An entity in the selection represents the location where a defect exists in the inspected shape element. **shape_data_quality_inspection_report_item** as described above has **extreme_instances** representing the individual detected quality defect. Its attribute **location_of_extreme_value_select** select type represents the information on the location of defect. When the location of the defect is represented using a shape element such as a point, for example in the case of **point_on_edge_curve**, the shape element is created within the product shape data quality data but its underlying shape element (in this case, **edge_curve**) and its coordinate system shall be defined in the shape element of the inspected product shape data identified in (C).

6.3 Two methods of using PDQ-S

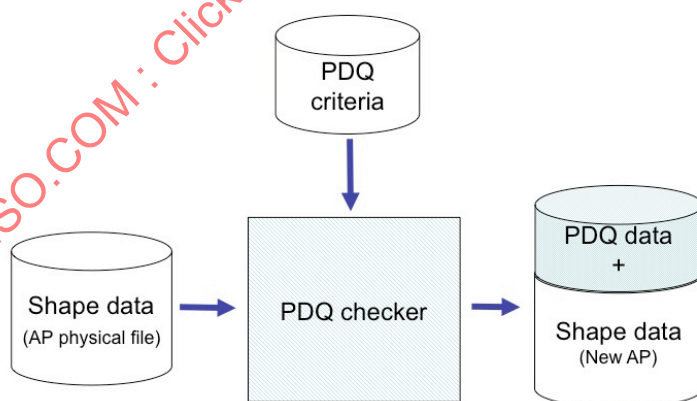


Figure 5 — An approach to modifying existing APs in order to make them PDQ-S conformant

We have investigated two methods for modifying existing ISO 10303 APs in order to make them PDQ-S conformant. Figure 5 illustrates the addition of product data quality information to the inspected product model data. The shape data to be inspected is represented using an existing AP. However, a newly defined AP is required to represent the shape data with additional shape data quality information.

Subclause 6.4 describes how to modify existing modular APs in order to make them PDQ-S conformant by using Application Modules (AMs).

In the second method, product data quality information is created as a separate file independent from the inspected product data with the necessary external reference between the two files. An external reference mechanism is necessary for referring to product data represented in an AP from a separate PDQ-S conformant product data quality information file. If such a reliable external reference mechanism is established, existing APs can be made PDQ-S conformant without any change.

6.4 Modifying existing APs in order to make them PDQ-S conformant

6.4.1 General

This clause describes development of a new AP by adding shape data quality information defined in PDQ-S to an existing AP that includes the shape model. Extension of an existing AP using PDQ-S modules, is described together with some detailed information on PDQ-S modules.

6.4.2 Extension of an existing AP with PDQ-S modules

As described in 6.2.2, PDQ-S refers to three types of data in the product model data: product_definition, shape_representation and shape elements. As information included in the AP other than these entities is not relevant to shape data quality, such information can be used as it is in the original AP. Figure 6 shows the conceptual scheme how to create a new AP by extending the original AP by adding PDQ-S modules.

The AP module that is the topmost module for the existing AP is modified to include PDQ-S modules in addition to the modules used in the original AP module. The new AP with shape data quality information is created based on this new AP module. PDQ-S modules have been constructed using PDQ-S and some shape related modules.

6.4.3 PDQ-S modules

PDQ-S modules cover the same scope of information as PDQ-S. The following principles have been applied for the development:

- the modules with one-to-one correspondence with the five schemas of PDQ-S;
- the application reference model (ARM) of each module is to be structured in the same way as the model of PDQ-S;
- entities defined in PDQ-S are copied to corresponding Application Objects of module ARMs;
- for an Application Object that corresponds to the entities but is not defined in PDQ-S, an existing Application Object appropriate for the purpose is used.

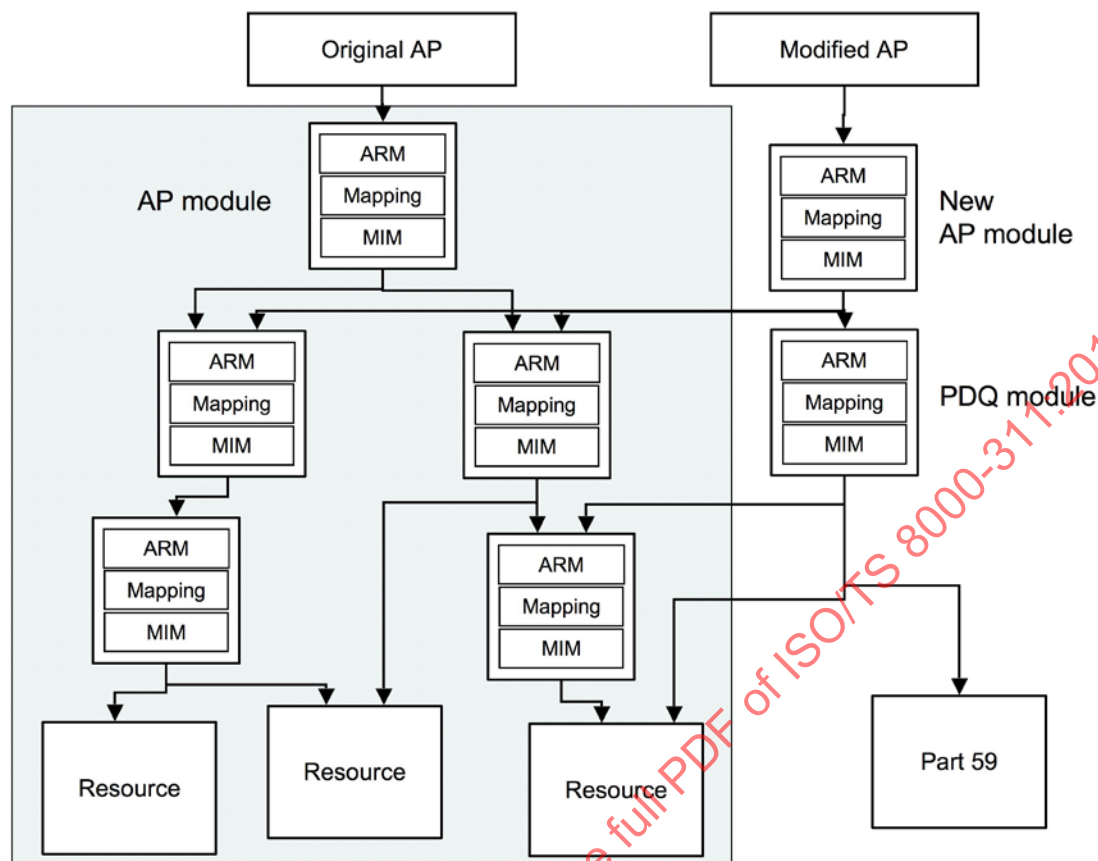


Figure 6 — Conceptual scheme of extension of AP using PDQ-S module

The PDQ-S modules are

- ISO/TS 10303-1520 Product data quality definition
- ISO/TS 10303-1521 Product data quality criteria
- ISO/TS 10303-1522 Product data quality inspection result
- ISO/TS 10303-1523 Shape data quality criteria
- ISO/TS 10303-1524 Shape data quality inspection result

6.4.4 Proposed procedure for creating a PDQ-S conformant AP

The following procedure is proposed for creating a PDQ-S conformant AP

- a) Identify shape information in the existing AP that conform to the scope of PDQ-S
- b) Create a new AP by adding representation of shape data quality in the scope statement.
- c) Create a new AP module by adding representation of shape data quality in its scope. Use PDQ-S modules in addition to the existing modules.

The relationship between product data and its data quality information described in 6.2.2 is based on resource entities. PDQ-S modules use the following application modules and ARM objects to establish the links with product data.

(A) Product data quality definition and product definition

product_view_definition in ISO/TS 10303-1019 *Product view definition* is used in ISO/TS 10303-1520 *Product data quality definition* to represent product data that is mapped to **product_definition** defined in ISO 10303-41. Additionally, ISO/TS 10303-AM1520 *Product data quality definition* uses ISO/TS 10303-1014 *Date time assignment* and ISO/TS 10303-1013 *Person organization assignment* to represent management information.

(B) Inspection result of product shape data quality and product shape

geometric_model in ISO/TS 10303-1004 *Elemental geometric shape* is used in ISO/TS 10303-1524 *Shape data quality inspection result* to represent shape model information that is mapped to **shape_representation** defined in ISO 10303-41.

(C) Inspected shape element violating a requirement on shape data quality

The following ARM objects are used in ISO/TS 10303-1524 *Shape data quality inspection result* to represent inspected shape elements that may appear as items in the **inspected_shape_element_select** select type.

- **Axis_placement** and **Direction** defined in ISO/TS 10303-1004 *Elemental geometric shape*
- **Curve**, **Surface** and **point_select** defined in ISO/TS 10303-1652 *Basic geometry*
- **Vertex_point**, **Edge_curve** and **Face_surface** defined in ISO/TS 10303-1323 *Basic geometric topology*
- **Edge_loop** and **Connected_face_set** defined in ISO/TS 10303-1005 *Elemental topology*
- **Composite_curve** defined in ISO/TS 10303-1651 *Basic curve*
- **Rectangular_composite_surface** defined in ISO/TS 10303-1525 *Composite surface*
- **B_spline_curve** and **B_spline_surface** defined in ISO/TS 10303-1801 *B spline geometry*
- **Open_shell** defined in ISO/TS 10303-1509 *Manifold surface*
- **Closed_shell** and **Manifold_solid_brep** defined in ISO/TS 10303-1514 *Advanced boundary representation*

(D) Location of data quality defect detected by inspection

- To represent location of data quality defect detected by inspection, the following ARM objects are used in ISO/TS 10303-1524 *Shape data quality inspection result* in addition to ARM objects listed in (C).
- **Oriented_edge** and **Face_bound** defined in ISO/TS 10303-1005 *Elemental topology*
- **Point_on_curve** and **Point_on_surface** defined in ISO/TS 10303-1652 *Basic geometry*

These ARM objects and modules are required for PDQ-S functions to be installed in the target AP. Create a link from an appropriate ARM object in the AP to **Data_quality_definition** in ISO/TS 10303-1520 *Product data quality definition* that is the root entity of PDQ-S from which any PDQ-S ARM objects can be traced.

To show how the instances of PDQ-S data are composed, examples are provided in Annex D with diagrams. Note that they are shown in expanded lists or “long forms” with resource entities. However, readers may easily identify ARM objects of PDQ-S modules because most of them are developed as duplicates of entities of PDQ-S.

Annex A

(normative)

Information object registration

A.1 Document identification

To provide for unambiguous identification of an information object in an open system, the object identifier

```
{ iso standard 8000 part(311) version(-1) }
```

is assigned to ISO/TS 8000-311. The meaning of this value is defined in ISO/IEC 8824-1, and is described in ISO 10303-1.

Annex B

(informative)

Technical discussion

B.1 Background

Increase of the use of engineering systems (CAD, CAM, CAE and CG systems) in product development has revealed the significance of product data quality as a key issue for realizing successful collaborative product development based on product data.

A recent report (see reference [18]) estimated that one billion dollars per year saving would be realized by full use of STEP in US transportation industries (aerospace, automotive and shipbuilding). Improvement of PDQ could realize further cost savings through the elimination of rework.

Establishing a widely acceptable method for guaranteeing appropriate quality of product model data is critically important in terms of drastically raising effectiveness of the use of 3D engineering systems and decreasing economic loss.

SASIG took the initiative in developing the automotive PDQ guidelines as a substantive response to this critical issue. But, PDQ is not specific to the automotive industry, instead being common to all manufacturing industries, even if the specific urgency, applicable PDQ criteria and acceptable threshold values could vary slightly from one industry to the next.

Additionally, standardization of PDQ approaches is expected to encourage IT vendors to develop better systems with regard to product data quality.

B.2 Definition of product data quality

Although the importance of product data quality has been widely recognized, it is not yet clearly defined what is “product data quality”. In the discussion of “product data quality”, we have to distinguish quality of the “product data” from that of the “product” itself and the “product model”, because these three types of qualities are often mixed up in conventional context.

The “product” is a manufactured physical body, and the “product model” is a mathematical model to represent the “product” on computers. The “product data” are numerical data that represent product information in accordance with the “product model.”

“Product quality” is defined as the degree of satisfaction of requirements on its functionality, performance, appearance and so on. Existing research and associated developments has extensively explored the meaning of “product quality.” The standard ISO 9000 provides for the management of “product quality.”

In contrast, not even a basic definition exists for “product model quality.”

Since “product data” depends on the “product model”, it is currently difficult to give a rigorous or theoretical definition of “product data quality”.

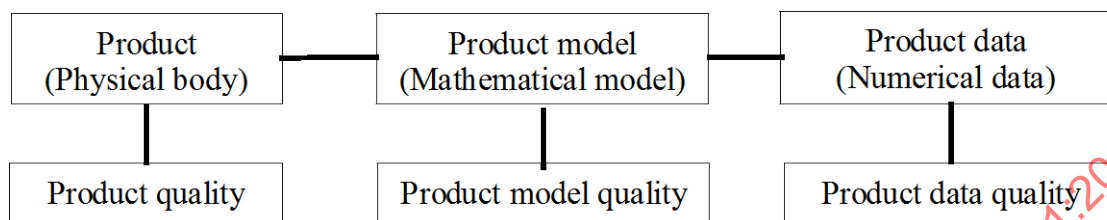


Figure B. 1 — Quality of product, product model and product data

For this reason, this Technical Specification adopts the following pragmatic approach to “product data quality.”

Identify two categories of issue that hinder successful sharing or exchange of product data: erroneous data and inapt data. Each category includes issues specific to either geometry, topology, combined geometry and topology or geometric model.

Annex C

(informative)

Comparison of ISO 10303-59 and ISO/PAS 26183

C.1 Similarity

Based on the understanding that low quality numerical data representing three dimensional shape, which necessitates considerable time and cost in receiver side for data repair, is the major reason of enormous economic loss and considerable delay of product development, both ISO/PAS 26183 and ISO 10303-59 enumerate concrete measures to eliminate low quality product shape data. Geometry related criteria of ISO/PAS 26183 are already replaced by PDQ-S.

C.2 Difference

C.1.1 Representation method

Specifications in ISO/PAS 26183 are expressed in a natural language but the core entities and functions of ISO 10303-59 are expressed in formal specification description language: EXPRESS similar to other standards developed by ISO TC184/SC4. Formal description has advantages such as unambiguous understanding of the specification and ease of implementation by computer programs.

C.1.2 Target industry

ISO/PAS 26183 has been developed to resolve today's critical quality related problems in automotive industry. It naturally targets automotive industry, whereas ISO 10303-59 targets all manufacturing industries including automotive, aerospace, commercial electric/electronic, precision mechanical industry, etc.

However, given that there are relatively few industry type specific quality problems, the difference between the contents of ISO 10303-59 and those of ISO/PAS 26183 is not significant.

C.1.3 Target data type

ISO/PAS 26183 mainly targets three dimensional shape data, but it also deals with some types of non-geometry attributes, CAE data and management data. PDQ-S deals with three dimensional shape data in detail and provides general schemas for enabling extension of the standard to cope with quality of non-shape product data. Using the general schemas, it is under development to extend the standard to deal with externally conditioned data quality criteria and quality of GD&T data.

Annex D

(informative)

Instantiation examples

D.1 General

This annex provides some example instantiations of PDQ-modules and PDQ-S. Firstly, a graphical notation for the presentation of instances is explained that is a customization of EXPRESS-G for ease of understanding. Two practically important criteria, **short_length_edge** and **gap_between_edge_and_base_surface**, are selected as examples. Example instances are generated for the three scenarios, consisting of the requirements or declaration of data quality, assurance of data quality and data quality information for use in quality improvement.

D.2 Graphical notation for instances

The graphical notation for the presentation of instances used in this clause includes some extensions to conventional EXPRESS-G:

- Multiple instances can be presented for a model entity.
- Actual values can be presented using call-outs.
- An instance for a group of entities with inheritance relationships is shown by circumscribed broken lines.

Figure D.1 illustrates an example usage of the notation. Three instances created for the EXPRESS-G model on the left, are shown on the right. The diagram shows three instances of **person**, namely John, Mary and their son Mike.

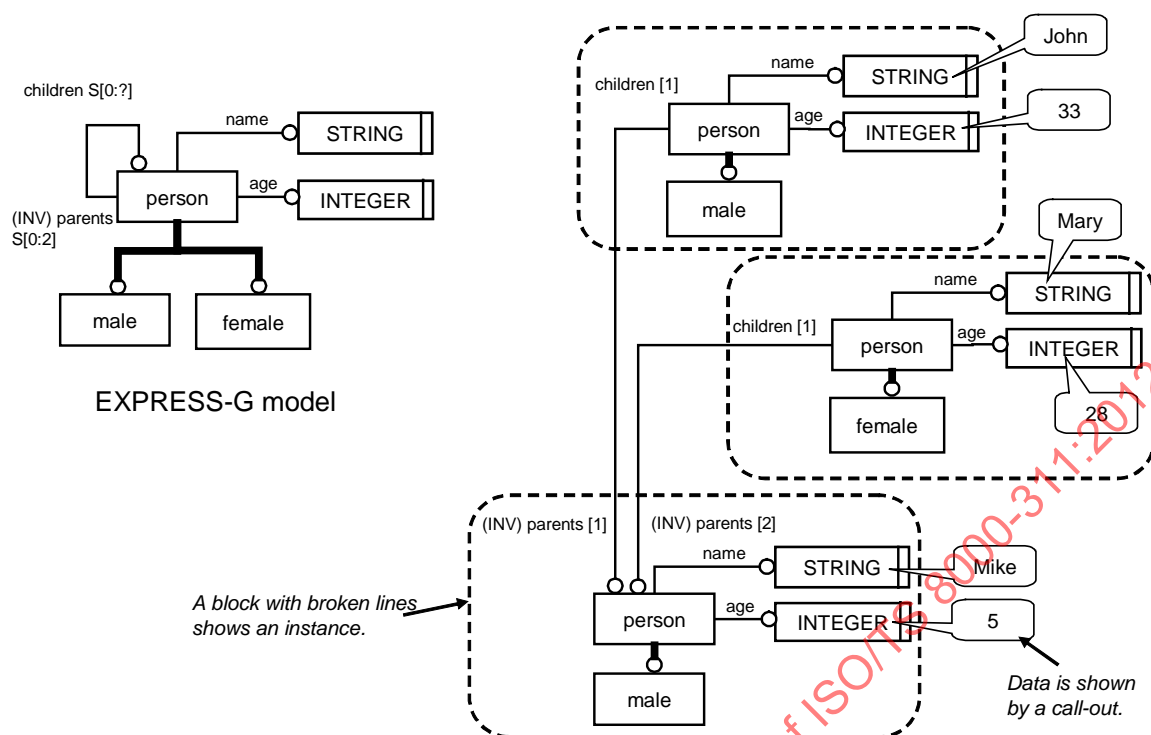


Figure D.1 — Example usage of the notation

D.3 Instances for short_length_edge

Examples are expanded to each of the following scenarios.

- 1) Representation of requirements for data quality
- 2) Representation of a declaration of data quality
- 3) Representation of assurance of data quality
- 4) Representation of data quality information for use in quality improvement

Since the same data are required for scenario 1) and 2), three kinds of examples are shown below.

The first example criterion is **short_length_edge**. If this criterion is identified as a concern, the PDQ checking system shall inspect the target shape model and shall detect any edge whose length is shorter than the given threshold. The definition of the entity **short_length_edge** is shown in ISO 10303-59:2008, 7.4.88. A typical example of short length edge is shown in Figure D.2.

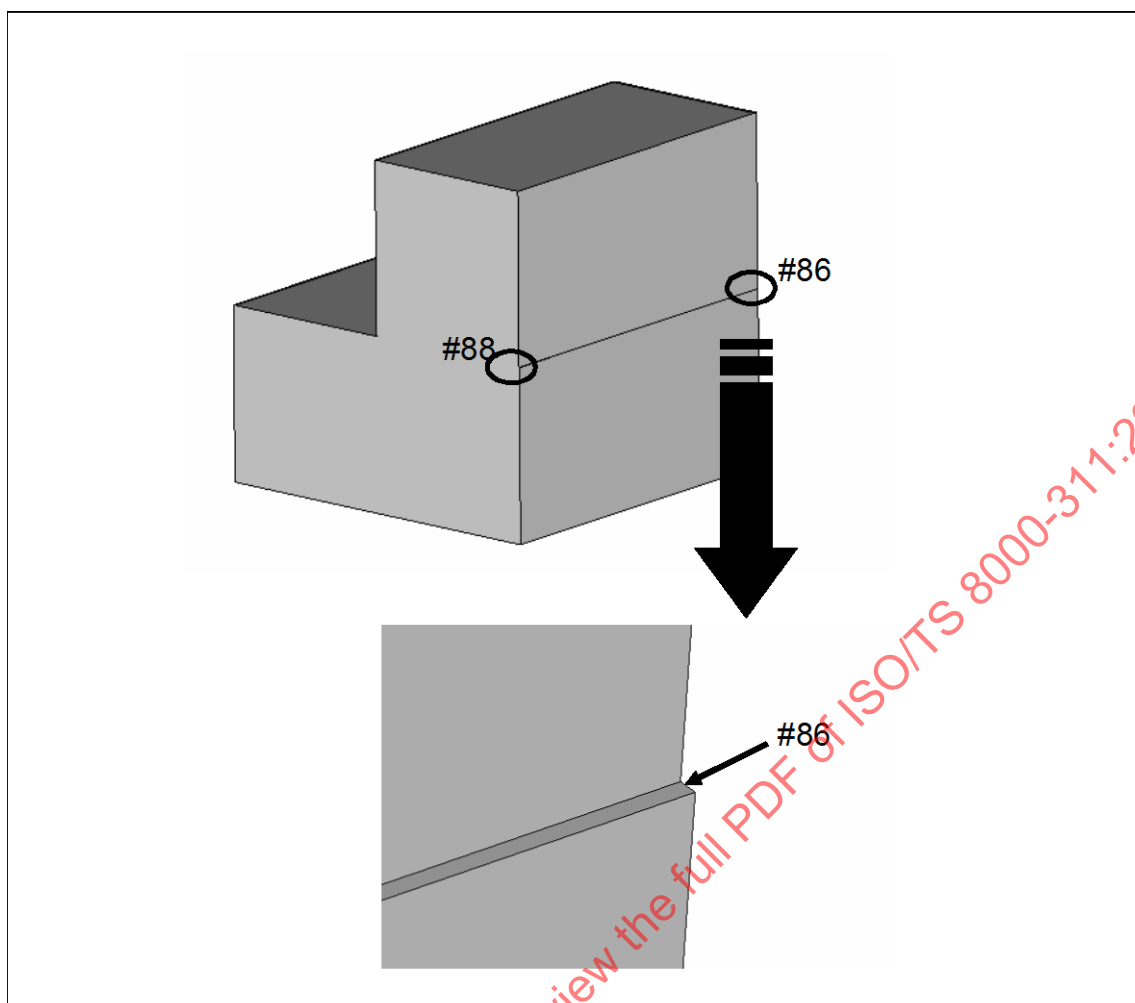


Figure D.2 — A typical example of short length edge

(1) Requirements or declaration of quality for **short_length_edge**.

The first scenario is requirements for data quality or a declaration of data quality. If ordering a design job from some company, then this type of quality information indicates to the company receiving the order the basis on which created product data will satisfy applicable requirements. Creators of product data can use this type of quality information for explicitly declaring the quality level satisfied by a product model data. When creating this type of quality information through the use of ISO 10303-59, selecting a set of criteria captures the scope of the requirement. The detail of the requirement is set of the values of threshold for each criterion and, if necessary, the accuracy of the corresponding measurement. No reference is made to individual product data in the 'requirement' case, although for the 'declaration' case, it is possible to attach the associated product data. At most two assigned **data_quality_report_requests** to represent the kind of required report.

As an example of quality information for this scenario, the following data is assumed for the criterion **short_length_edge**.

- The threshold for the detection of **short_length_edge** is smaller than or equal to 0.01mm.
- Two types of report are required; a summary report that shows the number of inspected instances and the number of instances detected as having quality defects; and a report on the edge instances that are shorter than the given threshold.

-

The instances to be created for this scenario are shown in Figure D.3, Figure D.4 and Figure D.5.

NOTE 1 Management information such as the approving person for the criterion and the approval date are attached to **data_quality_definition** as shown in Figure D.3. These data are defined in related modules.

NOTE 2 Instances whose name is shown in italics differ depending upon the criterion. In this case, the criterion **short_length_edge** requires **shape_data_quality_assessment_by_numerical_test** as its assessment requirement, which in turn requires **shape_data_quality_upper_value_limit** as the threshold.

NOTE 3 Four instances shown in Figure D.5 depict units used in general. If no other unit is specified for the specific criterion or measurement requirement, these units are applied.

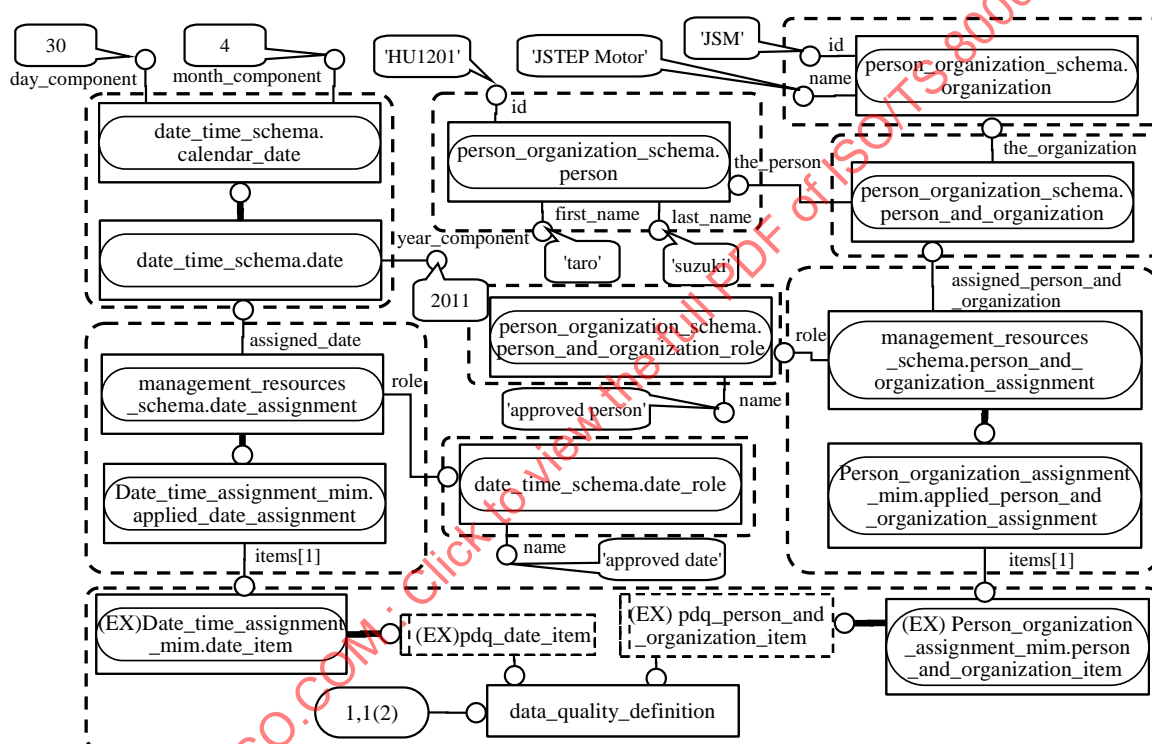


Figure D.3 — Example instances of quality information for use in requirement or declaration of **short_length_edge** without specified accuracy (1 of 3)

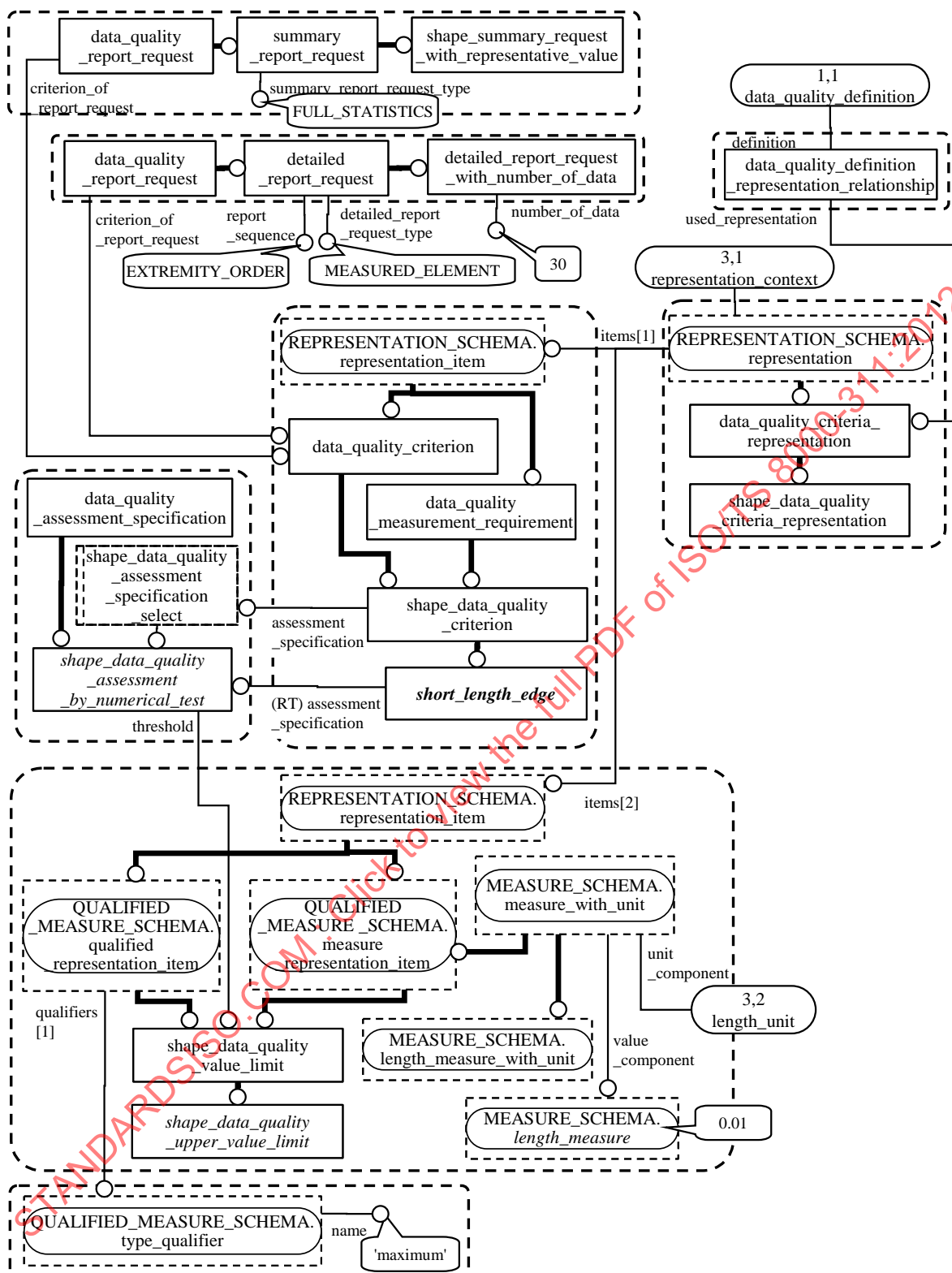


Figure D.4 — Example instances of quality information for use in requirement or declaration of `short_length_edge` without specified accuracy (2 of 3)

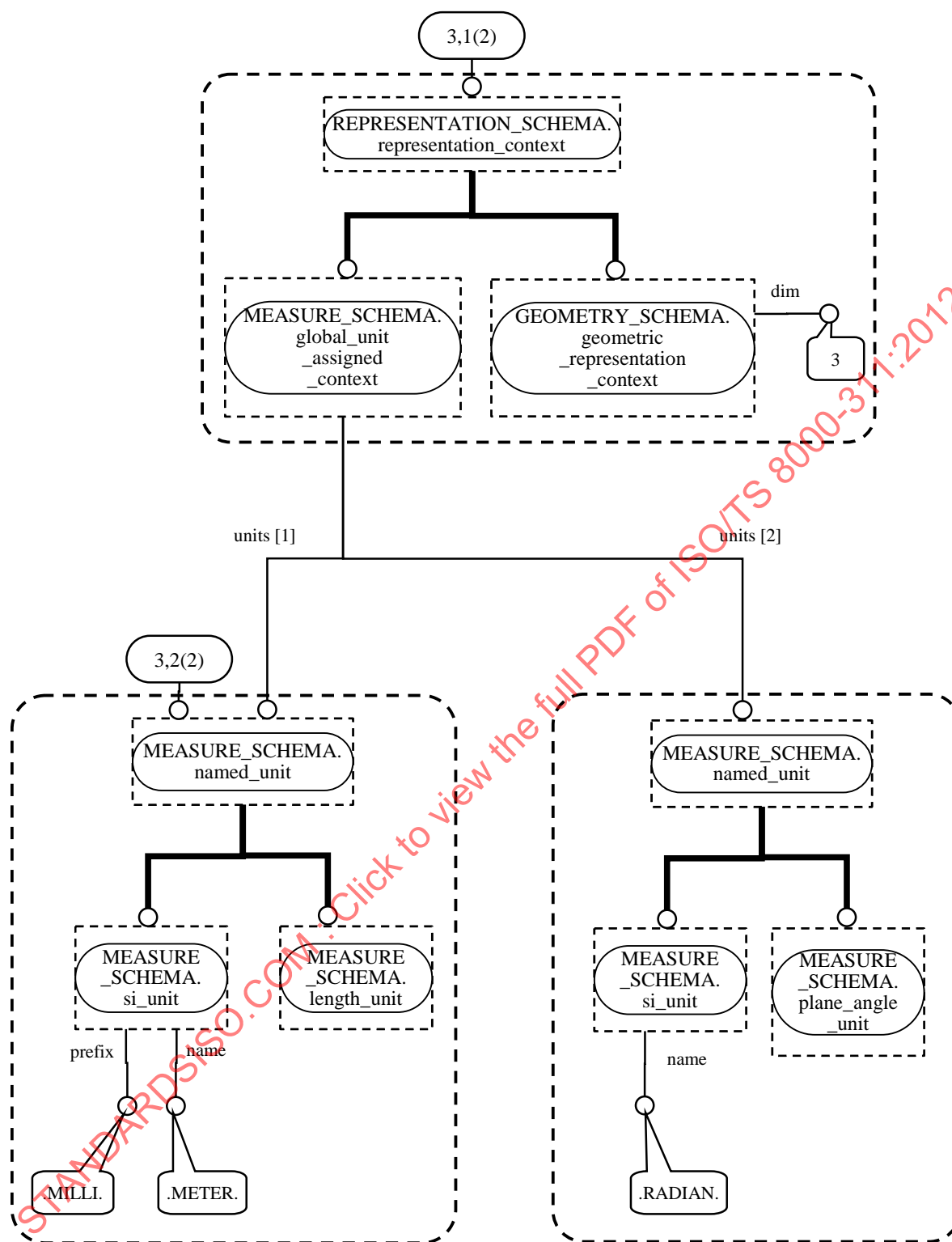


Figure D.5 — Example instances of quality information for use in requirement or declaration of `short_length_edge` without specified accuracy (3 of 3)

The data for this example described with the format defined in ISO 10303-21 is as follows.

```

DATA;
#1= DATA_QUALITY_DEFINITION('No short edge is required.');
```

#2= APPLIED_DATE_ASSIGNMENT(#6,#4,(#1));

#4= DATE_ROLE('approved date');

#5= DESCRIPTION_ATTRIBUTE('',#4);

#6= CALENDAR_DATE(2011,30,4);

#7= APPLIED_PERSON_AND_ORGANIZATION_ASSIGNMENT(#11,#9,(#1));

#9= PERSON_AND_ORGANIZATION_ROLE('approved person');

#10= DESCRIPTION_ATTRIBUTE('',#9);

#11= PERSON_AND_ORGANIZATION(#12,#13);

#12= PERSON('HU1201','suzuki','taro',\$,\$,\$);

#13= ORGANIZATION('JSM','JSTEP Motor',\$);

#14= DESCRIPTION_ATTRIBUTE('',#11);

#15= NAME_ATTRIBUTE('',#11);

#16= DATA_QUALITY_DEFINITION_REPRESENTATION_RELATIONSHIP('',#1,#17);

#17= SHAPE_DATA_QUALITY_CRITERIA_REPRESENTATION(
 'short_length_edge_example1',(#26,#30),#22);

#18= ID_ATTRIBUTE('',#17);

#19= DESCRIPTION_ATTRIBUTE('',#17);

#20= (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));

#21= (NAMED_UNIT(*)PLANE_ANGLE_UNIT()SI_UNIT(\$,.RADIAN.));

#22= (GEOMETRIC_REPRESENTATION_CONTEXT(3)GLOBAL_UNIT_ASSIGNED_CONTEXT((#20,
 #21))REPRESENTATION_CONTEXT('','));

#26= SHORT_LENGTH_EDGE('',#29);

#27= SHAPE_SUMMARY_REQUEST_WITH_REPRESENTATIVE_VALUE('',#26,
 .FULL_STATISTICS.);

#28= DETAILED_REPORT_REQUEST_WITH_NUMBER_OF_DATA('',#26,
 .MEASURED_ELEMENT...EXTREMITY_ORDER.,30);

#29= SHAPE_DATA_QUALITY_ASSESSMENT_BY_NUMERICAL_TEST('threshold:0.01mm',
 #30);

#30= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
 MEASURE_WITH_UNIT(LENGTH_MEASURE(0.01),#20)
 QUALIFIED_REPRESENTATION_ITEM((#31))REPRESENTATION_ITEM('upper limit')
 SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
 SHAPE_DATA_QUALITY_VALUE_LIMIT());

#31= TYPE_QUALIFIER('maximum');

ENDSEC;

(2) Assurance of quality for **short_length_edge**.

The second scenario is assurance of data quality. When the consideration is quality assurance, this type of quality information enables representation of the results of quality inspection of particular product model data. To create this type of quality information by using ISO 10303-59, create inspection results with references to both requirements and the inspected product data. The relevant schema in the standard requires each inspection result to correspond to exactly one identified criterion. Each inspection result is of the type of report specified by **data_quality_report_request**.

An example for this scenario presented below is based on the following assumptions.

- The requirement is to detect edges shorter than or equal to 0.01mm and to output summary report of the inspection. The accuracy in general is 0.001mm and the accuracy specific to this criterion is 10^{-5} mm.
- The inspection is performed against the shape data of a product model. The ID of the product model is P#1 and the ID of the shape representation is P#12.
- As the result of inspection, 24 edges are inspected and two edges are found to be within the given threshold. The length of the shortest edge detected is 0.009mm. The accuracy actually applied to this inspection is 10^{-5} mm for this criterion. The general accuracy applied is 10^{-3} mm.

The data for this example described with the format defined in ISO 10303-21 is as follows.

```
DATA;
#1= PRODUCT_DEFINITION('target product data',$,#3,#11);
#2= NAME_ATTRIBUTE('P#1',#1);
#3= PRODUCT_DEFINITION_FORMATION('target data1',$,#4);
#4= PRODUCT(' ','',$(#6));
#6= PRODUCT_CONTEXT(' ',#7,'mechanical');
#7= APPLICATION_CONTEXT('automotive_design');
#9= ID_ATTRIBUTE(' ',#7);
#10= DESCRIPTION_ATTRIBUTE(' ',#7);
#11= PRODUCT_DEFINITION_CONTEXT(' ',#7,'design');
#12= SHAPE_REPRESENTATION('target shape_representation',(#86,#88),#17);
#13= ID_ATTRIBUTE('P#12',#12);
#14= DESCRIPTION_ATTRIBUTE(' ',#12);
#15= (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
#16= (NAMED_UNIT(*)PLANE_ANGLE_UNIT()SI_UNIT($,.RADIAN.));
#17= (GEOMETRIC_REPRESENTATION_CONTEXT(3)
GLOBAL_UNIT_ASSIGNED_CONTEXT((#15,#16))REPRESENTATION_CONTEXT(' ',''));
#20= PRODUCT_DEFINITION_SHAPE(' ','',#1);
#21= ID_ATTRIBUTE(' ',#20);
#22= SHAPE_DEFINITION_REPRESENTATION(#20,#12);
#23= DESCRIPTION_ATTRIBUTE(' ',#22);
#24= NAME_ATTRIBUTE(' ',#22);
#30= POINT(' ');
#31= VERTEX_POINT(' ',#30);
#32= POINT(' ');
#33= VERTEX_POINT(' ',#32);
```



```

#34= POINT('');
#35= VERTEX_POINT('',#34);
#36= POINT('');
#37= VERTEX_POINT('',#36);
#40= CURVE('');
#41= CURVE('');
#86= EDGE_CURVE('P#86',#31,#33,#40,.T.);
#88= EDGE_CURVE('P#88',#35,#37,#41,.T.);
#101= DATA_QUALITY_DEFINITION(
    'Short edge is detected with the accuracy 0.00001.');
```

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```

#102= APPLIED_DATE_ASSIGNMENT(#106,#104,(#101));
#104= DATE_ROLE('approved date');
#105= DESCRIPTION_ATTRIBUTE('',#104);
#106= CALENDAR_DATE(2011,30,4);
#107= APPLIED_PERSON_AND_ORGANIZATION_ASSIGNMENT(#111,#109,(#101));
#109= PERSON_AND_ORGANIZATION_ROLE('approved person');
#110= DESCRIPTION_ATTRIBUTE('',#109);
#111= PERSON_AND_ORGANIZATION(#112,#113);
#112= PERSON('HU1201','suzuki','taro',$,$,$);
#113= ORGANIZATION('JSM','JSTEP Motor',$);
#114= DESCRIPTION_ATTRIBUTE('',#111);
#115= NAME_ATTRIBUTE('',#111);
#116= APPLIED_DATE_ASSIGNMENT(#120,#118,(#101));
#118= DATE_ROLE('check date');
#119= DESCRIPTION_ATTRIBUTE('',#118);
#120= CALENDAR_DATE(2011,20,5);
#121= APPLIED_PERSON_AND_ORGANIZATION_ASSIGNMENT(#125,#123,(#101));
#123= PERSON_AND_ORGANIZATION_ROLE('check person');
#124= DESCRIPTION_ATTRIBUTE('',#123);
#125= PERSON_AND_ORGANIZATION(#126,#127);
#126= PERSON('HU6436','soma','jiro',$,$,$);
#127= ORGANIZATION('JNC','JNC inc.',$);
#128= DESCRIPTION_ATTRIBUTE('',#125);
#129= NAME_ATTRIBUTE('',#125);
#130= PRODUCT_DATA_AND_DATA_QUALITY_RELATIONSHIP('',#1,#101);
#131= DATA_QUALITY_DEFINITION_REPRESENTATION_RELATIONSHIP('',#101,#135);
#132= (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
#133= (NAMED_UNIT(*)PLANE_ANGLE_UNIT()SI_UNIT($,.RADIAN.));
#134= ID_ATTRIBUTE('',#135);
#135= SHAPE_CRITERIA_REPRESENTATION_WITH_ACCURACY('',
    (#141,#144,#149,#154),#137,(#147));
#136= DESCRIPTION_ATTRIBUTE('',#135);
#137= (GEOMETRIC_REPRESENTATION_CONTEXT(3)
    GLOBAL_UNIT_ASSIGNED_CONTEXT((#132,#133))
    REPRESENTATION_CONTEXT('',''));
#141= SHORT_LENGTH_EDGE('',#143);
#142= SHAPE_SUMMARY_REQUEST_WITH_REPRESENTATIVE_VALUE('',#141,
    .FULL_STATISTICS.);
```

```

#143= SHAPE_DATA_QUALITY_ASSESSMENT_BY_NUMERICAL_TEST('threshold:0.01mm'
    ,#144);
#144= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
    MEASURE_WITH_UNIT(LENGTH_MEASURE(0.01),#132)
    QUALIFIED_REPRESENTATION_ITEM((#145))
    REPRESENTATION_ITEM('upper limit')
    SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
    SHAPE_DATA_QUALITY_VALUE_LIMIT());
#145= TYPE_QUALIFIER('maximum');
#147= SHAPE_MEASUREMENT_ACCURACY('General length accuracy 0.001mm',
    #149);
#149= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
    MEASURE_WITH_UNIT(LENGTH_MEASURE(0.001),#132)
    QUALIFIED_REPRESENTATION_ITEM((#150))
    REPRESENTATION_ITEM('upper limit')
    SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
    SHAPE_DATA_QUALITY_VALUE_LIMIT());
#150= TYPE_QUALIFIER('maximum');
#152= SHAPE_DATA_QUALITY_CRITERION_AND_ACCURACY_ASSOCIATION(#153,#141);

#153= SHAPE_MEASUREMENT_ACCURACY('Specific length accuracy 0.00001mm',
    #154);
#154= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
    MEASURE_WITH_UNIT(LENGTH_MEASURE(1.0000000E-5),#132)
    QUALIFIED_REPRESENTATION_ITEM((#155))
    REPRESENTATION_ITEM('upper limit')
    SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
    SHAPE_DATA_QUALITY_VALUE_LIMIT());
#155= TYPE_QUALIFIER('maximum');
#157= SHAPE_INSPECTION_RESULT_REPRESENTATION_WITH_ACCURACY('sdqir-check1',
    (#163,#165,#172,#177),#17,#135,(#170));
#158= DATA_QUALITY_DEFINITION_REPRESENTATION_RELATIONSHIP('',#101,#157);
#159= SOFTWARE_FOR_DATA_QUALITY_CHECK('', 'hu_checker', '3.0',#158);
#160= SHAPE_DATA_QUALITY_INSPECTED_SHAPE_AND_RESULT_RELATIONSHIP('',',',
    #12,#157);
#161= ID_ATTRIBUTE('',#157);
#162= DESCRIPTION_ATTRIBUTE('',#157);
#163= (DATA_QUALITY_INSPECTION_RESULT(#141)
    DATA_QUALITY_INSPECTION_RESULT_WITH_JUDGEMENT(.T.)
    REPRESENTATION_ITEM('')SHAPE_DATA_QUALITY_INSPECTION_RESULT());
#165= SHAPE_DATA_QUALITY_INSPECTION_CRITERION_REPORT('',#163,(#167,#168)
    ,LENGTH_MEASURE(0.009));
#167= DATA_QUALITY_INSPECTION_CRITERION_REPORT_ITEM('',24,
    .NUMBER_OF_INSPECTED_INSTANCES.);
#168= DATA_QUALITY_INSPECTION_CRITERION_REPORT_ITEM('',2,
    .NUMBER_OF_QUALITY_DEFECTS_DETECTED.);
#169= DATA_QUALITY_REPORT_MEASUREMENT_ASSOCIATION('',',',#141,#165);
#170= SHAPE_MEASUREMENT_ACCURACY('General length accuracy 0.001mm',

```

```

#172);
#172= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
      MEASURE_WITH_UNIT(LENGTH_MEASURE(0.001),#15)
      QUALIFIED_REPRESENTATION_ITEM((#173))
      REPRESENTATION_ITEM('upper limit')
      SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
      SHAPE_DATA_QUALITY_VALUE_LIMIT());
#173= TYPE_QUALIFIER('maximum');
#175= SHAPE_INSPECTION_RESULT_ACCURACY_ASSOCIATION(#176,#163);
#176= SHAPE_MEASUREMENT_ACCURACY('Specific length accuracy 0.00001mm',
      #177);
#177= (LENGTH_MEASURE_WITH_UNIT()MEASURE_REPRESENTATION_ITEM()
      MEASURE_WITH_UNIT(LENGTH_MEASURE(1.0000000E-5),#15)
      QUALIFIED_REPRESENTATION_ITEM((#178))
      REPRESENTATION_ITEM('upper limit')
      SHAPE_DATA_QUALITY_UPPER_VALUE_LIMIT()
      SHAPE_DATA_QUALITY_VALUE_LIMIT());
#178= TYPE_QUALIFIER('maximum');
ENDSEC;

```

(3) Quality information for use in the improvement of quality for **short_length_edge**.

The third and final scenario concerns data quality information to be used in quality improvement. This scenario assumes that the detailed information obtained for detecting **short_length_edge** by a PDQ checking system will be used at a later stage for healing problem data by the use of some PDQ healing system, or by manual work. The PDQ checking system is required to generate the information on what quality defect is detected, to what extent and provide it as a detailed inspection result report at the geometric entity instance level. The requirement is for inspection results to be created for each measurement that identifies a detected quality defect.

An example for this scenario presented below is based on the following assumptions.

- The requirement is to detect edges shorter than or equal to 0.01mm. The accuracy in general is 0.001mm and the accuracy specific to this criterion is 10^{-5} mm.
- For the purpose of this scenario, it is necessary to generate the report showing the edges that are shorter in length than or equal to 0.01mm and their measured length. The reports should be created in extremity order.
- The summary report is the same as the example in (2).
- The detailed information on the two edges that are detected as **short_length_edge** is as follows.
 - ☆ edge_curve #86 has the length 0.009mm.
 - ☆ edge_curve #88 has the length 0.009mm.

The instances to be created for this scenario are shown in Figure D.6, Figure D.7, Figure D.8, Figure D.9, Figure D.10, Figure D.11 and Figure D.12.

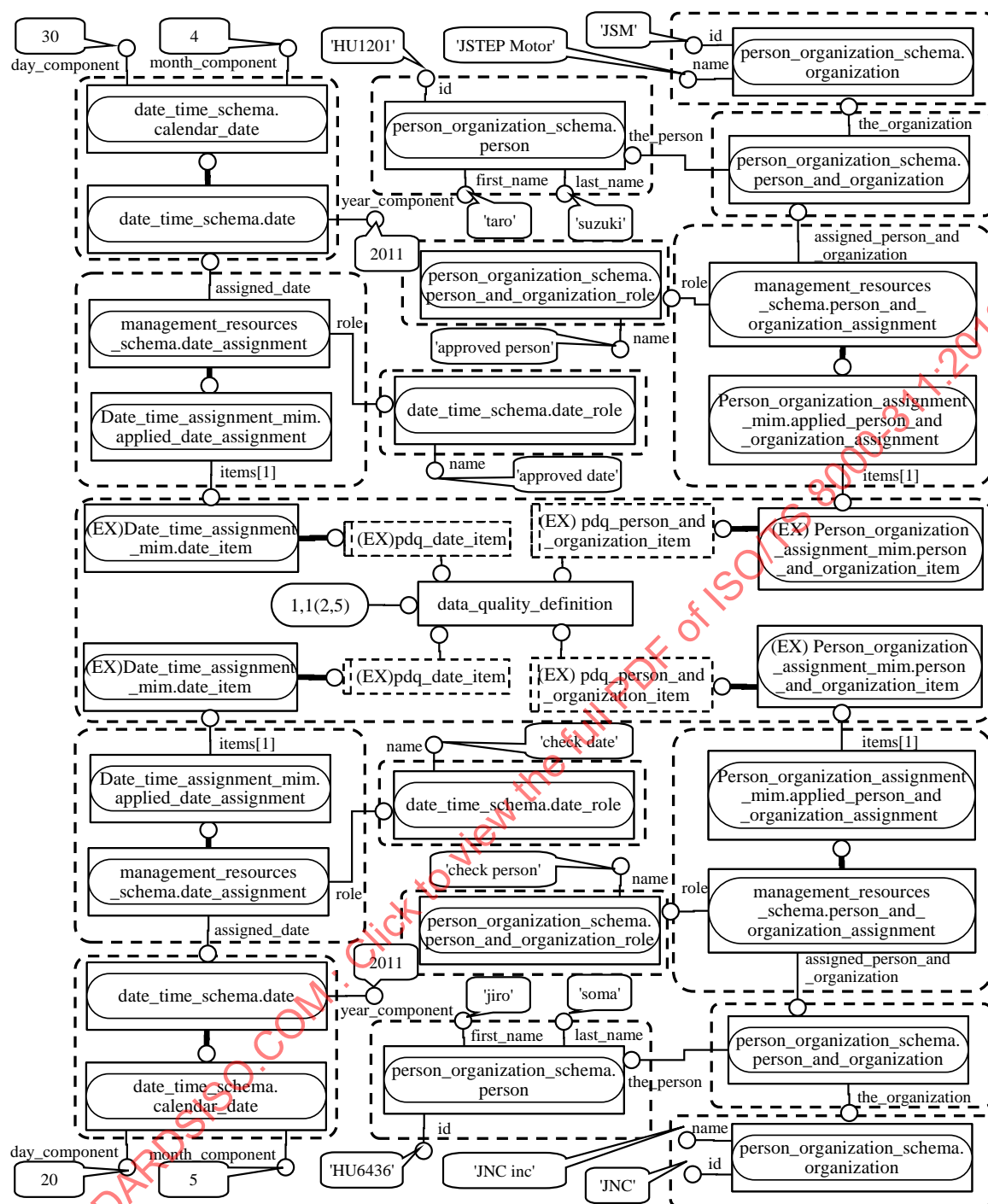


Figure D.6 — Example instances of quality information for use in the improvement of quality of short_length_edge (1 of 8)

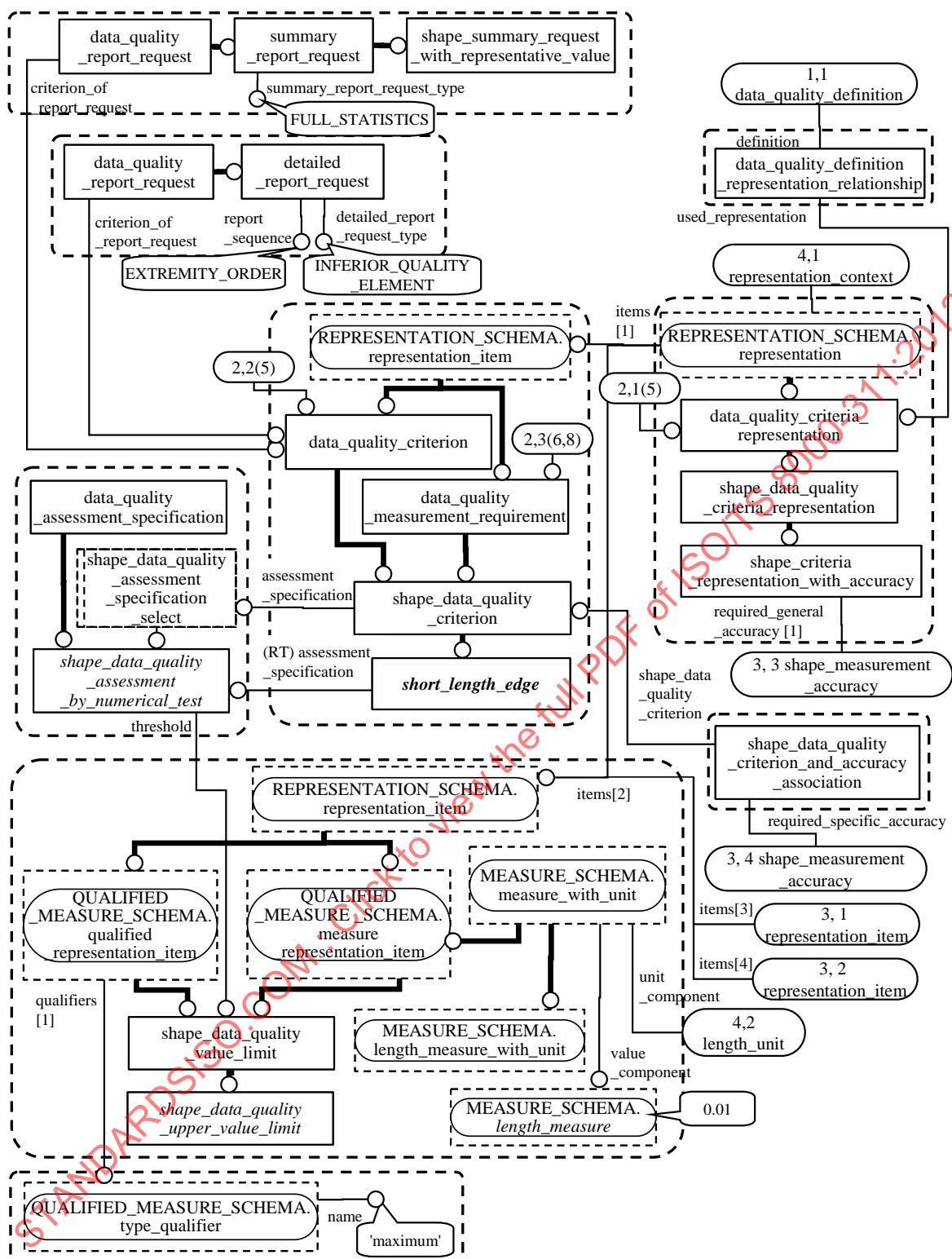


Figure D.7 — Example instances of quality information for use in the improvement of quality of *short_length_edge* (2 of 8)

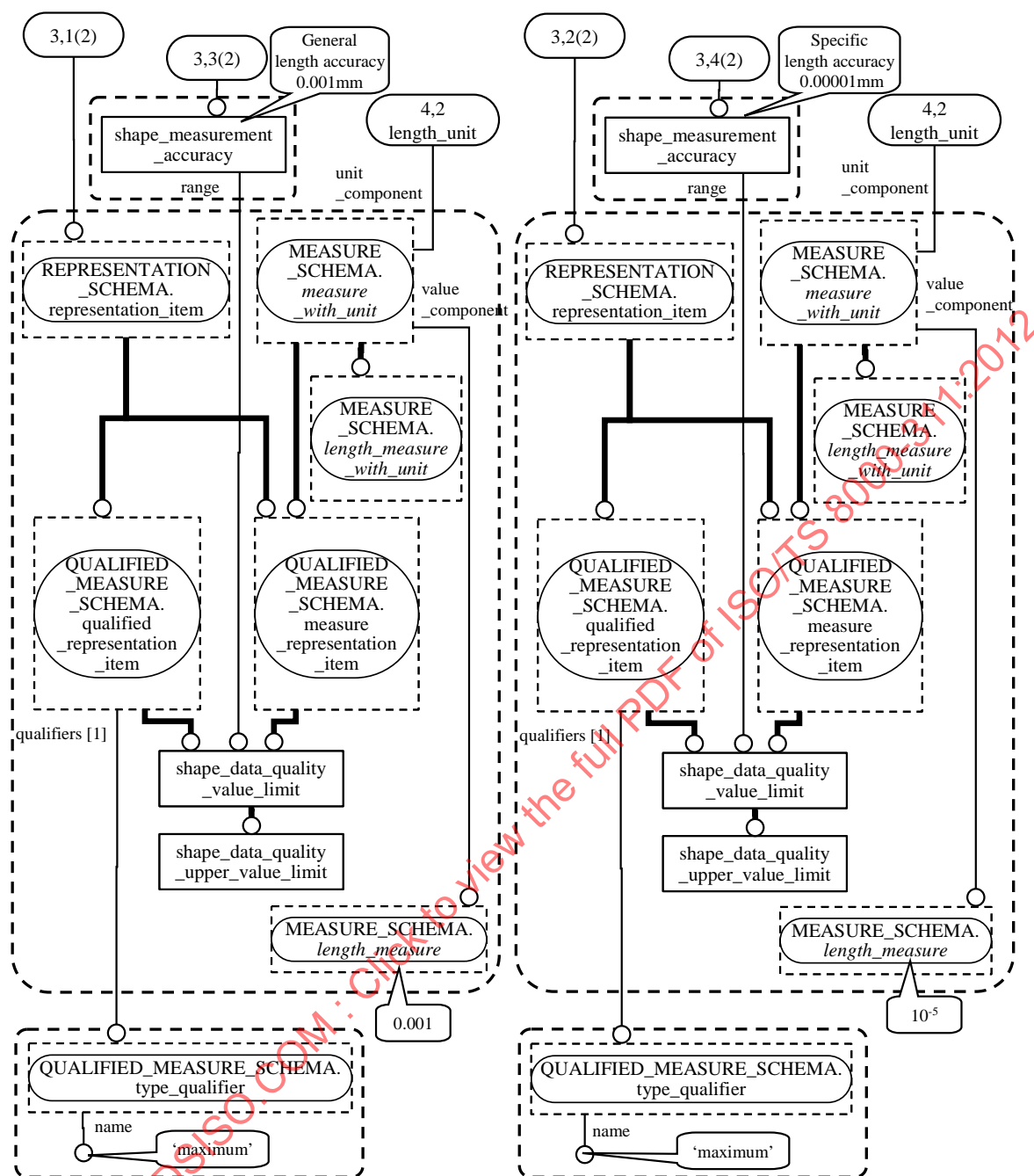


Figure D.8 – Example instances of quality information for use in the improvement of quality of short_length_edge (3 of 8)

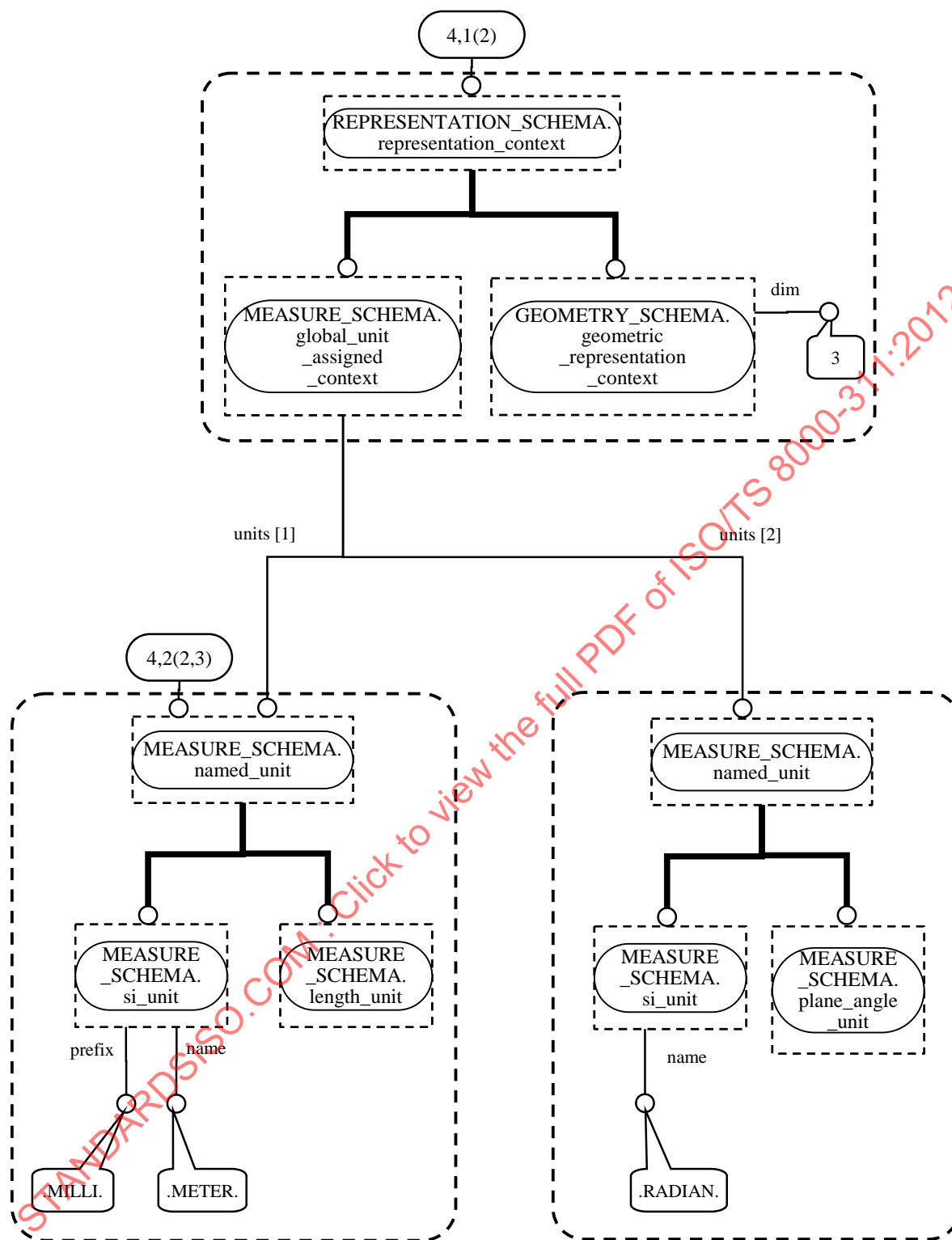


Figure D.9 — Example instances of quality information for use in the improvement of quality of short_length_edge (4 of 8)



Figure D.10 — Example instances of quality information for use in the improvement of quality of short length edge (5 of 8)