

OGC Testbed-13
Data Quality Specification Engineering Report

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Chapter 1. Summary

With the proliferation of digital services that provide data for the Aeronautical Domain, a formalized definition of the quality of the data offered is needed. This responds to the needs of the following use cases:

- Service advertising: In this case, a service makes known to a potential client the quality of the data provided by the service. Based on this information, the client can determine whether the service meets its needs (that is, to determine if it is fit-for-purpose).
- Service validation: In this case, assurance is given that the quality of the data provided by a service is consistent with the quality that is explicitly defined in a service requirement or any kind of agreement that may exist between a service provider and the clients.

In practical terms, users will approach a catalog of aviation services such as the one provided by the United States Federal Aviation Administration (FAA) under the name of National Aerospace Standard (NAS) Service Registry and Repository (<https://nsrr.faa.gov/>) and will look for and compare information about the quality of the aviation data offered. The NSRR uses the Service Description Conceptual Model (SDCM) that provides a Service Description for aviation services (in other words, metadata about the aviation service) in a similar way to what GetCapabilities does for OGC services and ISO 19119 (now included in ISO 19115-1) does for geospatial services. Currently, none of the above mentioned service descriptions provide direct information about the data quality offered by the service. A set of the three Engineering Reports (ER) that this document is part of study some of the technical possibilities to include data quality information in aviation service descriptions. In particular:

- OGC 17-032 (Testbed-13 Abstract Data Quality Engineering Report) provides a taxonomy and a model for the fundamental concepts covered by the internationally agreed rules and regulations related with data quality in terms of accuracy, resolution and integrity (or equivalent assurance level), traceability, timeliness, completeness, and format. It maps these concepts to the International Organization for Standardization (ISO) Technical Committee (TC) 211 equivalent concept for consistency to the geospatial domain.
- OGC 17-018 (Testbed-13 Data Quality Specification Engineering Report) provides methods to quantify the quality concepts defined in OGC 17-032 and a way to include the quantifications in service descriptions. It extends QualityML quality metrics (that already includes ISO 19157) into the aviation domain. It lists a set of quantitative and conformance measurements that are specified in terms of quality measures, domains, and metrics (value types and units) and are appropriated for each quality type and data type. Secondly, it extends the SDCM to be able to encode and include the above mentioned quality information for each service in a interoperable way.
- OGC 17-025 (Testbed-13 Quality Assessment Service) provides a description of a service that is able to connect to other services and infer the data quality of them. To do that, it reads the data that the external service contains, applies a set of rules and procedures to determine the quality of that data and documents it on the service description metadata. The rules and procedures to apply may differ considerably from one data type to another. The service procedures are based on the measures, domains and metrics defined in OGC 17-018 and might require comparison with data that is considered ground truth, statistical analysis of repetitive measurements (e.g. weather forecast ensembles) or consistency checks. In the end, the results will be added to the

data quality section of the service description following the SDCM model.

1.1. Requirements

Upon successful completion of the abstract model in OGC 17-032, this ER develops a DataQuality Assessment Specification. This specification defines a set of data quality parameters as well as the methods and units of measure employed for measuring these parameters. This specification is information domain neutral, i.e., it specifies data quality characteristics and methods that can be applied to all aviation information domains: weather, flight, and aeronautical. This document also includes:

- An extension mechanism for the abstract model to be extended to address domain-specific requirements.
- A mechanism for augmenting the SDCM with classes/concepts for describing a service's data quality. This includes taxonomies that capture defined parameters, methods of measurement, and units of measure.
- Discussions of the relationships between Quality of Service (QoS) parameters already defined in the SDCM and data quality parameters proposed in this document.

1.2. Key Findings and Prior-After Comparison

Currently QualityML and ISO 19157 have abundant information on common quality measures that can be applied to the aviation domain. We will analyze how these measures adapt to aviation dataset(s) and will include new ones when needed.

Service Description for aviation services (SDCM), OGC ServiceMetadata response to GetCapabilities and ISO 19119 (now included in ISO 19115-1) describe several characteristics of the services and the data they provide but none of them directly include information about data quality (some data quality information can be indirectly found by getting access to the metadata describing the data in the service). This engineering report describes a possible way to do it in SDCM that is new and can open the possibility to include data quality in other service metadata standards improving the process of finding data that is fit for purpose.

1.3. What does this ER mean for the Working Group and OGC in general

The Aviation Domain Working Group (DWG) and the Data Quality DWG should be interested in this work for different reasons. For the Aviation DWG, it represents a way to complete the SDCM data model. For the Data Quality DWG, it brings the perspective of the aviation domain and contributes to increase the list of relevant quality measures known by the community.

1.4. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Contacts

Name	Organization
Alaitz Zabala	UAB-CREAF
Joan Maso	UAB-CREAF

1.5. Future Work

The work on this document can impact on OWS Common by adopting data quality descriptions in service metadata. The work on this document can impact the future evolution of SDCM. Future editions of the Testbed can experiment with implementations of the proposed approach in aviation services and catalogues.

1.6. Foreword

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

Chapter 2. References

The following normative documents are referenced in this document.

- [OGC 06-121r9, OGC® Web Services Common Standard](https://portal.opengeospatial.org/files/?artifact_id=38867&version=2) [https://portal.opengeospatial.org/files/?artifact_id=38867&version=2]
- [OGC 16-050, OGC® Imagery Quality and Accuracy ER](http://docs.opengeospatial.org/per/16-050.pdf) [http://docs.opengeospatial.org/per/16-050.pdf]
- OGC 17-032, OGC® Testbed-13 Abstract Data Quality ER
- ISO 19115-1:2014, Geographic information - Metadata - Part 1: Fundamentals
- ISO 19157:2013, Geographic information - Data quality
- ISO/TS 19115-3:2016, Geographic information - Metadata - Part 3: XML schema implementation for fundamental concepts
- AIXM, Aeronautical Information Exchange Model
- FIXM, Flight Information Exchange Model
- WXXM, Weather Information Exchange Model
- QualityML v1.0, [Quality Indicators Dictionary and Markup Language](http://www.qualityml.org/) [http://www.qualityml.org/]
- FAA SWIM Governance team, [SWIM Controlled Vocabulary \(v.1.1\)](https://www.faa.gov/nextgen/programs/swim/vocabulary/) [https://www.faa.gov/nextgen/programs/swim/vocabulary/]

Chapter 3. Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard [OGC 06-121r9](https://portal.opengeospatial.org/files/?artifact_id=38867&version=2) [https://portal.opengeospatial.org/files/?artifact_id=38867&version=2] shall apply. In addition, the following terms and definitions apply.

3.1. accuracy

closeness of agreement between a test result or measurement result and the true value.
[SOURCE: ISO 3534-2:2006, 3.3.1]

a degree of conformance between the estimated or measured value and true value.
[SOURCE: ICAO Annex 15]

3.2. conformance

fulfillment of specified requirements.
[SOURCE: ISO 19105:2000, 3.8]

3.3. integrity

a degree of assurance that an aeronautical data and its value has not been lost or altered since the data origination or authorized amendment.
[SOURCE: ICAO Annex 15]

3.4. data quality basic measure

generic data quality (4.21) measure used as a basis for the creation of specific data quality measures.
[SOURCE: ISO 19157:2013, 4.7]

3.5. dataset

identifiable collection of data
[SOURCE: ISO 19115-1:2014, 4.3]

3.6. feature

abstraction of real world phenomena
[SOURCE: ISO 19101:2002, 4.11]

3.7. lineage

provenance, source(s) and production process(es) used in producing a resource
[SOURCE: ISO 19115-1:2014, 4.9]

3.8. precision

The smallest difference that can be reliably distinguished by a measurement process.
[SOURCE: ICAO Annex 15]

3.9. provenance

organization or individual that created, accumulated, maintained and used records
[SOURCE: ISO 5127:2001, 4.1.1.10]

3.10. provider

supplier, organization that provides a product or a service
[SOURCE: ISO 9000:2015, 3.2.5]

3.11. quality

degree to which a set of inherent characteristics fulfills requirements.
[SOURCE: ISO 9000:2015, 3.6.2]

a degree or level of confidence that the data provided meets the requirements of the data user in terms of accuracy, resolution and integrity.
[SOURCE: ICAO Annex 15]

3.12. quality of service

A parameter that specifies and measures the value of a provided service.
[SOURCE: SWIM Controlled Vocabulary (v.1.1), #quality-of-service]

3.13. resolution

A number of units or digits to which a measured or calculated value is expressed and used.
[SOURCE: ICAO Annex 15]

3.14. service

capability which a service provider entity makes available to a service user entity at the interface between those entities
[SOURCE: ISO 19101:2002, 4.11]

distinct part of the functionality that is provided by an entity through interfaces
[SOURCE: ISO 19119:2005, 4.1]

A mechanism to enable access to one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description.
[SOURCE: SWIM Controlled Vocabulary (v.1.1), #service]

3.14.1. aeronautical information service (AIS)

A service established within the defined area of coverage responsible for the provision of aeronautical information/data necessary for the safety, regularity and efficiency of air navigation.

3.15. timeliness

Speed of dissemination of the data - i.e., the lapse of time between the end of a reference period (or a reference date) and dissemination of the data.
[OECD Glossary of Statistical Terms, 3090,
<https://stats.oecd.org/glossary/detail.asp?ID=3090>]

3.16. traceability

Ability to trace the history, application or location of that which is under consideration

[SOURCE: ISO 9000:2015, 3.6.13]

Chapter 4. Abbreviated terms

- AIM: Aeronautical Information Management
- AIS: Aeronautical Information Services
- AIXM: Aeronautical Information Exchange Model
- AQM: Abstract Quality Model
- FIXM: Flight Information Exchange Model
- ICAO: International Civil Aviation Organization
- ISO: International Organization for Standardization
- IWXXM: ICAO Meteorological Information Exchange Model
- NAS: National Aerospace Standard
- NSRR: NAS Service Registry/Repository
- O&M: Objects and Measurements
- QoD: Quality of Data
- QoS: Quality of Service
- QualityML: Quality Indicators Dictionary and Markup Language
- SDCM: Service Description Conceptual Model
- SWIM: System Wide Information Management
- UML: Unified Modeling Language
- UoM: Unit of Measurement
- WSDD: Web Service Description Document
- WSQM: Web Service Quality Model
- WXXM: Weather Information Exchange Model

Chapter 5. Overview

The scenario of rapidly growing geodata catalogues requires tools focused on facilitating the users choice of services and datasets. Quality of services in the context of System Wide Information Management (SWIM) has two major use cases, service advertising and service validation. To assess both use cases, the quality of the data provided by the service needs to be available in order for the user to determine if it meets its needs or that the data provided by a service is consistent with the service requirements. Thus, having populated quality fields in metadata using an unambiguous definition of the data quality concept and a set of measurable parameters is "a must" for QoS. Moreover, this would lead to a Data Quality Assessment Service (DQAS) that will evaluate the quality of data based on a set of criteria. In addition, having clear data quality concepts and a set of measure parameters allows other components (such as visualization, discovery, or comparison tools) to be quality-aware and interoperable.

This ER is related to the "FA001: Abstract Quality Model Engineering Report" that develops a conceptual model for data quality in the context of Service-Oriented Architecture (SOA) services in general and OGC-compliant services in particular. It is based on Service Description Conceptual Model (SDCM), ISO 19157, and QualityML to improve quality description in the metadata.

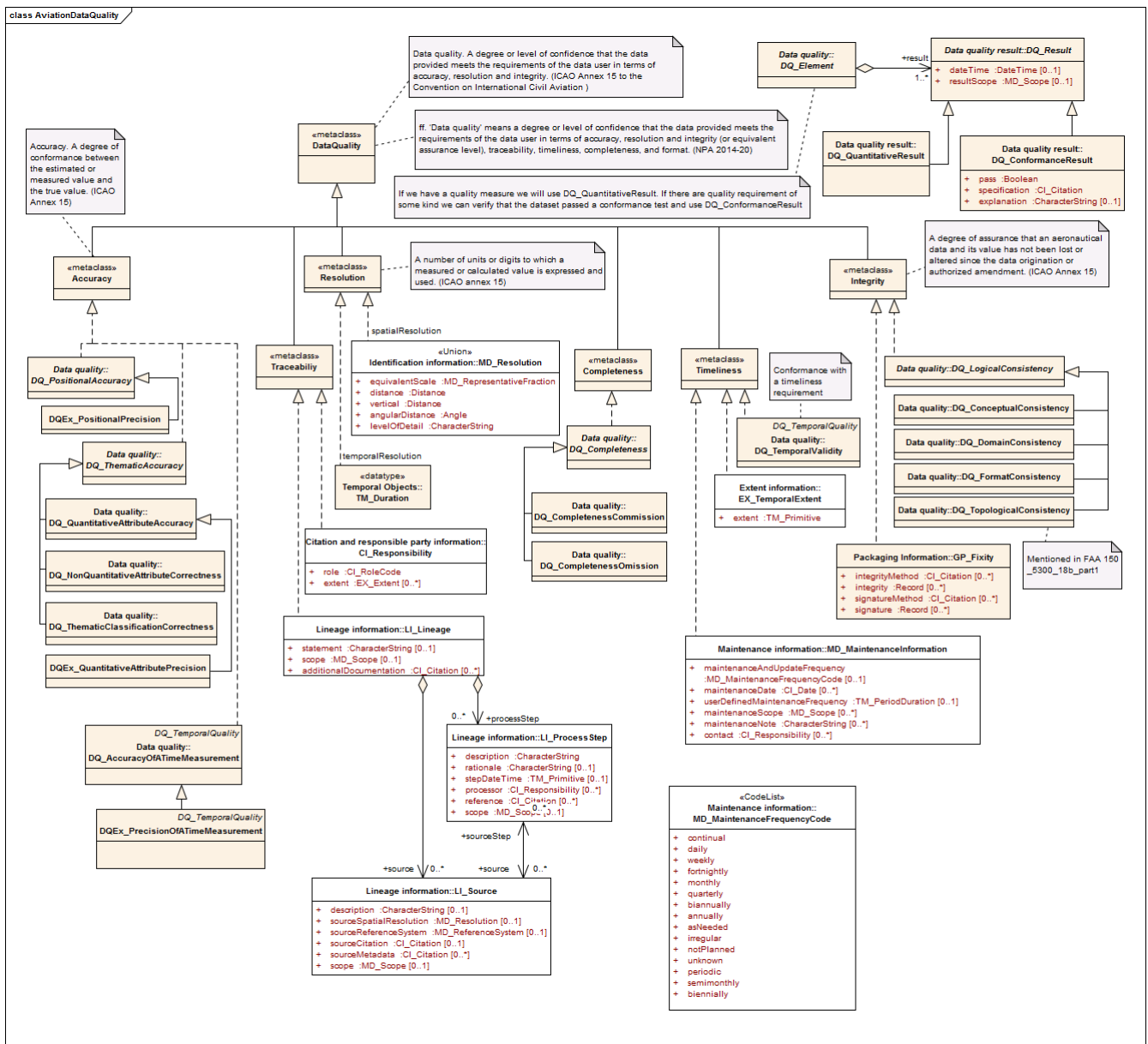


Figure 1. Abstract Quality Model Unified Modeling Language (UML) class diagram

The ER developed on this activity will be based on the previous one, and will develop a Data Quality Assessment Specification. It will define a set of data quality parameters dealing with completeness, logical consistency, positional accuracy, temporal accuracy and thematic accuracy. Moreover, this specification will review the common aviation information domains (weather, flight, and aeronautical), and will define the quality they require.

In particular, this document addresses:

- Definition of data and quality measures:** It is a common issue to confuse the spatial resolution of the data with the spatial accuracy. The spatial resolution is related to the pixel size chosen to encode the data in a raster format while the spatial accuracy refers to the deviance in the geographic position of the pixel from its real ground position. In many times, both are related but are not the same. This deliverable discusses how to encode both in a clear way. The same happens with the temporal extent and the temporal accuracy. The temporal extent indicates the interval of time (hours, dates, etc.) of data in the image while the temporal accuracy refers to the uncertainty in the individual time measurement. All these aspects will be recorded in the ER.

- **Define a set of data quality parameters** as well as the methods and units of measure employed for measuring these parameters. This description will be domain neutral, but will include extension mechanism to address domain-specific requirements.
- The use of **standard vocabularies and taxonomies** to describe data quality is mandatory in a QoS paradigm. In the 7th Framework Programme of the European Commission, the GeoViQua, a 3-year project, (UAB-CREAF were the coordinators) worked in different aspects of data quality and data visualization. One of the outcomes of the project was the QualityML vocabulary. This vocabulary is an extension of UncertML (the v1 of its community standard is a discussion paper in OGC). This vocabulary provides a common solution for all quality indicators described in the ISO 19157. It also proposes a clear encoding in XML metadata documents (see www.quality.org). QualityML was reviewed and extended in Testbed 12 DG003: Imagery Quality and Accuracy ER, ensuring the need of imagery and to meet A3C quality framework[2]. FA001: Abstract Quality Model Engineering Report and FA002: Data Quality Assessment Specification Engineering Report activities are suitable activities to apply or extend the QualityML vocabulary in order to describe new quality concepts and parameters (or adapt the existing ones) needed in the QoS framework. This links to the taxonomies requirement on the OGC Testbed 13 Call for Participation (CFP), capturing defined parameters, methods of measurements and units of measure.
- **Extends the SDCM** to be able to encode and include the above-mentioned quality information for each service in a interoperable way.
- Discussions of the relationships between **Quality of Service (QoS) parameters** already defined in the SDCM and **data quality parameters** proposed in the specification.

Chapter 6. Aviation Quality Measures

6.1. Introduction

An extension mechanism for the abstract model to be extended to address domain-specific requirements will be developed with regards to the following:

- Definition of data and quality measures
- Define a set of data quality parameters
- The use of standard vocabularies and taxonomies

In other words: "OGC 17-018 (Data Quality Specification Engineering Report) provides methods to quantify the quality concepts defined in OGC 17-032 and a way to include the quantifications in service descriptions. It extends QualityML quality metrics (that already includes ISO 19157) into the aviation domain. It lists a set of quantitative and conformance measurements that are specified in terms of quality measures, domains, and metrics (value types and units) and are appropriated for each quality type and data type."

6.2. Levels of granularity in quality measures

There are several levels of granularity of quality measures that will be covered in the next subsections, namely:

- Feature instance level
- Dataset level
- Service level

6.2.1. Feature instance level quality measures

Usually, feature instance level metadata and even attribute instance level metadata is allowed by adding fragments of metadata types to the other attributes in the data model of the feature types.

The exploration of the Aeronautical Information Exchange Model (AIXM) 5.1 reveals that there are some quality measures that have already been considered for some feature types.

Most feature types in AIXM are derived from basic geometric primitives or from the *elevated* version of them. Next figure shows as an example one feature type for each geometric *elevated* primitives.

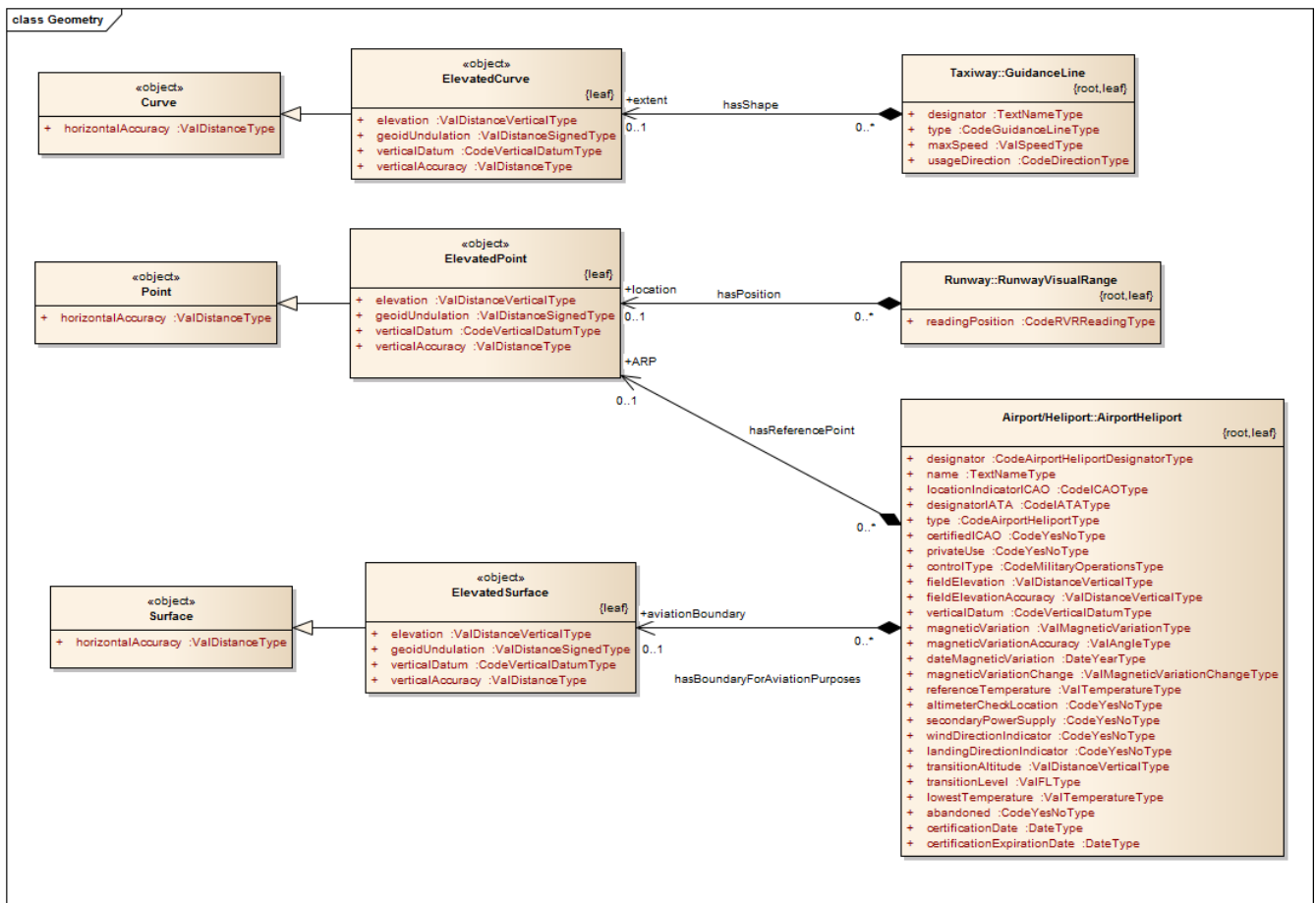


Figure 2. AIXM feature level quality examples

In addition to the horizontal and vertical accuracy, specific feature types for aviation objects can carry other quality elements for aspects other than positions. For example, Accuracy is included as an attribute of:

- AirportHeliport | Airport/Heliport | AirportHeliport: fieldElevationAccuracy + magneticVariationAccuracy
- Runway | NavaidEquipmentDistance | distanceAccuracy
- Runway | Runway: lengthAccuracy + widthAccuracy
- Runway | RunwayDeclaredDistanceValue: distanceAccuracy
- Runway | RunwayDirection: trueBearingAccuracy + elevationTDZAccuracy
- Geometry | Point & Geometry | Curve & Geometry | Surface: horizontalAccuracy
- Geometry | ElevatedPoint & Geometry | ElevatedCurve & Geometry | ElevatedSurface: verticalAccuracy
- Navaids Points | Navaids | Azimuth: trueBearingAccuracy
- Navaids Points | Navaids | Elevation: angleAccuracy
- Navaids Points | Navaids | GlidePath: angleAccuracy + rdhAccuracy
- Navaids Points | Navaids | Localizer: magneticVariationAccuracy + trueBearingAccuracy + widthCourseAccuracy
- Navaids Points | Navaids | NavaidEquipment: magneticVariationAccuracy

- Obstacle | VerticalStructurePart: verticalExtendAccuracy
- Surveillance | PrecisionApproachRadar: slopeAccuracy
- Surveillance | RadarEquipment: rangeAccuracy + magneticVariationAccuracy

There are also some other feature elements that can be somehow related to quality, for example the CodeIntegrityLevelILSBaseType, defined as "A coded value indicating the **quality** which relates to the **trust** which can be placed in the **correctness** of the information supplied by the ILS facility", is included in NavAids Points | NavAids | NavAid.

On the other hand, the Meteorological Community Exchange model METCE, within the Weather Information Exchange Model (WXXM), talks about resolution in Procedure | MeasurementContext: resolutionScale, defined as "The attribute 'resolutionScale' specifies the smallest change (e.g. the 'resolution') in property value of the 'measurand' that is intended to be measured within this procedure, using the unit of measure 'uom'. It shall be provided as a scaling factor, e.g. scale = -2 implies a precision of 100 units.."

In the models, there are currently no indications about other data quality aspects regarding quality facets such as timeliness, etc.

6.2.2. Dataset level quality

A dataset provided by a service can have quality measures attached. These quality measures will be quantitative aggregations of the quality of the individual features included in the dataset, as it is explained in the sections below.

6.2.3. Service level quality

Services that are providing data can provide an overall estimation of the data quality of the datasets available in the service.

6.3. Data models used in the aviation services

Service classifications depend on the aviation data standards they use:

- Aeronautical Information Exchange Model (AIXM) based: describe the AIS (e.g. the infrastructures, air spaces, etc) and its temporal modifications which are published through a Notice To Airmen (NOTAM). It is the more static one. It is distributed in "packs" and the quality measures should be at the feature and dataset level.
- Flight Information Exchange Model (FIXM) based: describe the flight and flow information of aircraft. It is used in navigation and flight. It is distributed in real time and each piece of information is generated by different agents in the flight route. Data quality measures should be at the feature level as different providers may have different quality on their data. Overall quality measures can be generated.
- Weather Information Exchange Model (WXXM) based: describe the current weather and its forecast. It is produced by weather centers that provide their own data quality measures associated to products.

6.4. Data quality measures that are appropriate for the data models used in aviation

Again, AIXM describes the AIS (e.g. the infrastructures, air spaces, etc) and its temporal modifications (NOTAMs). AIXM is therefore the more static of the above-listed data models. It is distributed in “packs” and the quality measures should be at the dataset level.

6.4.1. Accuracy and Precision: positional and thematic

Positional accuracy in the aviation context is concerned with the recorded position of each feature compared to its actual position. Note that this also includes a measurement of precision, a separate measure for the aviation domain.

Within AIXM models, feature positional description use 2D elements (Point, Curve and Surface) or its *elevated* versions (ElevatedPoint, ElevatedCurve and ElevatedSurface). All of them have horizontalAccuracy and the latter also have verticalAccuracy. Thus, elevation accuracy is decoupled from horizontal accuracy, so that pure 3D quality measures do not apply to this model.

All types of accuracy are described as quality elements in this quality of data model. Quality category is used to describe (in an enumeration basis) the different quality elements described in ISO such as positional accuracy, quantitative attribute accuracy and so on, as well as the new elements described in this document such as positional precision. The list of category values can be seen in the SDCM extension model explanation, in the next section.

Feature level horizontalAccuracy (for points, curves and surfaces) is defined in AIXM models as "The difference between the recorded horizontal coordinates of a feature and its true position referenced to the same geodetic datum expressed as a circular error at 95 percent probability".

Table 1. horizontalAccuracy for each point, curve or surface as reported by AIXM and described in ISO 19157 & QualityML

Model element	Content
Quality category	positional accuracy
Quality scope	dataset
Measure name	http://qualityml.geoviqua.org/1.0/measure/CircularMapAccuracy
Measure domain	http://www.qualityml.org/1.0/domain/DifferentialErrors2D
Measure metrics	http://www.qualityml.org/1.0/metrics/CircularError
Measure parameter name	level
Measure parameter value	0.95
Quantity value	0.2
Quantity unit of measure	m
Origin	ISO 19157 Id. 45

Feature level verticalAccuracy is defined as "The difference between the recorded elevation of a feature and its true elevation referenced to the same vertical datum expressed as a linear error at 95 percent probability".

Table 2. *verticalAccuracy* for each *elevatedPoint*, *elevatedCurve* or *elevatedSurface* as reported by AIXM and described in ISO 19157 & QualityML

Model element	Content
Quality category	vertical accuracy
Quality scope	dataset
Measure name	http://qualityml.geoviqua.org/1.0/measure/QuantitativeAttributeCorrectness
Measure domain	http://www.qualityml.org/1.0/domain/DifferentialErrors1D
Measure metrics	http://www.qualityml.org/1.0/metrics/Half-lengthConfidenceInterval
Measure parameter name	level
Measure parameter value	0.95
Quantity value	1
Quantity unit of measure	m
Origin	ISO 19157 Id. 71

There are two main features within the models, those representing actual phenomena on the Earth (e.g. tower), and those representing human conventions (e.g. delimitation of areas tagged as forbidden).

On the first group, a validation campaign may be done (sampling on the ground) to check the correspondence of the dataset position for these elements, and their real position. These differences may be aggregated to compute a dataset quality measure Circular Map Accuracy for the whole dataset. For example, an *AeronauticalGroundLight* (that is used for marking *TheSiteOf* within *AirportHeliport*) does have an *elevatedPoint* position that may include its 95% circular error (CE95) in the *horizontalAccuracy* element and an *elevationAccuracy* that may include its linear error at 95% (LE95). Several CE95 and LE95 values (for several *AeronauticalGroundLight* features) will be respectively used to compute the *dataset CE95 and LE95 values*.

Sometimes, it is not possible to provide a numerical value for a quality category as the quantitative uncertainty of the instrument used to do the measure is not available. Nevertheless, usually most instruments have a known order of magnitude precision, thus it is useful to provide the instrument name as an indication of this precision. For example the position of an aircraft can be measured using different instruments on board or other estimations in the positional precision element. Typical examples are: GPS, ADS-B (meters), *ADSBLostCoverageEstimation* or *TimeSpeedDistanceEstimation* (100km or more).

Table 3. *positionalPrecision* for position attribute (*FlightObject/Flight/EnRoute/Position/AircraftPosition*) as reported by AIXM and described in FA001 as a descriptive result stating the measurement mechanism limitations

Model element	Content
Quality category	positional precision
Quality scope	FlightObject/Flight/EnRoute/Position/AircraftPosition/position
Description	TimeSpeedDistanceEstimation
Origin	OGC 17-032

A descriptive result for a data quality element can also be used to describe the spatial distribution of data quality. For example, it could be good to have a way to state that horizontal accuracy of the elements next to or inside an Airport are defined in a more certain way than the obstacles around it. This is the typical use of a descriptive result as defined in ISO 19157.

Table 4. *positionalPrecision described as a descriptive result*

Model element	Content
Quality category	positional accuracy
Quality scope	dataset
Description	The relative positional accuracy has a higher value for features far from airports
Origin	TestBed 13

Thematic accuracy, is defined as the accuracy of attributes and it depends on the attribute type. In ISO it consists of three data quality elements: classification correctness, non-quantitative attribute correctness and quantitative attribute accuracy.

Regarding quantitative attributes, there are several relevant variables in the AIXM models covering angles (magnetic variations, bearing, slope), sizes (height, width) that are difficult in a single meaningful overall quality measurement. We suggest thematic accuracy is only provided for the dataset when it includes a coherent set of variables such as magnetic variations. The attribute that is being assessed should be defined in the scope of the quality element (or in the scope of the whole quality of data section if needed).

Table 5. *thematicAccuracy for a quantitativeAttribute, for example trueBearingAccuracy attribute (NavAids Points | NavAids | Azimuth) as reported by AIXM and described in ISO 19157 & QualityML*

Model element	Content
Quality category	quantitative attribute accuracy
Quality scope	NavAids Points/NavAids/Azimuth/trueBearingAccuracy
Measure name	http://qualityml.geoviqua.org/1.0/measure/QuantitativeAttributeCorrectness
Measure domain	http://www.qualityml.org/1.0/domain/DifferentialErrors1D
Measure metrics	http://www.qualityml.org/1.0/metrics/Half-lengthConfidenceInterval
Measure parameter name	level

Model element	Content
Measure parameter value	0.95
Quantity value	2
Quantity unit of measure	degree
Origin	ISO 19157 Id. 71

On the other hand, to cover classification correctness, the usual approach uses misclassification matrices to indicate thematic accuracy. An example of this can be giving the misclassification matrix for the attribute type in Routes/En-route/Route/type within AIXM Route feature:

Table 6. thematicAccuracy for classification correctness, for example route type attribute (Routes | En-route | Route), as reported by AIXM and described in ISO 19157 and QualityML

Model element	Content
Quality category	classification correctness
Quality scope	Routes/En-route/Route/type
Measure name	http://qualityml.geoviqua.org/1.0/measure/Misclassification/
Measure domain	http://www.qualityml.org/1.0/domain/predictedValues http://www.qualityml.org/1.0/domain/actualValues
Measure metrics	http://www.qualityml.org/1.0/metrics/ConfusionMatrix/
Measure parameter name	max
Measure parameter value	100
Measure parameter name	actualCategories
Measure parameter value	ATS NAT OTHER
Measure parameter name	predictedCategories
Measure parameter value	ATS NAT OTHER
Quantity value	87 1 12 5 88 7 8 11 81
Quantity unit of measure	percentage
Origin	ISO 19157 Id. 61

Moreover, as recognized in OGC 17-032, not only the usual misclassification indication but an indication about unclassified items may be helpful. This can be described using NodataAreas metrics in QualityML, understanding the percentage of unclassified items is similar to percentage of unclassified area in a classification image:

Table 7. thematicAccuracy for classification correctness (related to completeness omission), for example route type attribute (Routes | En-route | Route), as reported by AIXM and described in QualityML

Model element	Content
Quality category	completeness omission
Quality scope	Routes/En-route/Route/type
Measure name	http://www.qualityml.org/1.0/measure/NodataAreas/
Measure metrics	http://www.qualityml.org/1.0/metrics/items/
Measure parameter name	rate max
Measure parameter value	100
Quantity value	15
Quantity unit of measure	percentage
Origin	A3C - OGC 17-032

6.4.2. Resolution

The resolution class contains information about the resolution of a dataset including its positional (or spatial), vertical, temporal and attribute resolutions. ISO describes spatial resolution through the MD_Resolution class and temporal resolution through the TM_Duration class.

SDCM quality of data model describes a general Quantity class that can be used to describe the value and units of measure of any of these resolutions in a general way, and that is specified for each of the four resolution types. Positional resolution has also a equivalentScale element in order to be able to describe the most important elements in ISO (as distance, angularDistance and levelOfDetail can be described within positional resolution using the value and the needed units). For temporal resolution, the value and units are enough to describe the elements contained in ISO TM_Duration.

Table 8. *positionalResolution described as value and units*

Model element	Content
scope	<i>can be described if should be applied only to certain features</i>
Positional resolution value	1.5
Positional resolution unit of measure	m
Origin	OGC 17-018

Table 9. *temporalResolution for an specific feature attribute*

Model element	Content
scope	AirportHeliport/Surface Contamination/SurfaceContamination/observationTime
Positional resolution value	10
Positional resolution unit of measure	s
Origin	OGC 17-018

Regarding attribute resolution, the element resolutionScale in Procedure|MeasurementContext from the Meteorological Community Exchange model METCE (within WXXM) is another indication of resolution, and thus should be "translated" to resolution quality element within SDCM extension model. This is a direct translation as it is a scaling factor and thus the resolution value can be computed using the formula:

$$\text{resolution} = 10^{-\text{resolutionScale}}$$

And for example for a feature with a resolutionScale of -2, an attribute resolution with value 100 and attributes units of measure should be defined.

6.4.3. Traceability

Traceability describes the ability to trace the history, application or location of that which is under consideration. The closest match within ISO standards is Ll_lineage element. Information on the originator/person responsible should be included.

A first approach to lineage of a dataset would be given as a statement. This is a simple way to describe traceability but it is not the most recommended, as it does not easily state sources used and process steps related to the dataset history. According to ISO, a full flexible system is described where several options are possible:

- sources can be described including the process steps to generate each source
- process steps of the dataset can be described including the sources for each process step
- mixed situation can be defined

Even though the power of ISO schema should be recognized, allowing hierarchical definition of process steps and sources, creates a very flexible situation for each dataset of each service that would lead to a probably complex situation with hardly comparable datasets within a service or among services. Moreover, the originator of the data entity is also recognized in OGC 17-032 as relevant for traceability.

Thus, the proposal for SDCM extension described in this ER is to recommend to include a flat structure for sources, process steps and originator in the traceability section. To follow this aim, current elements on SDCM are reviewed in order to decide if they can be used to describe these elements, or if new elements are needed.

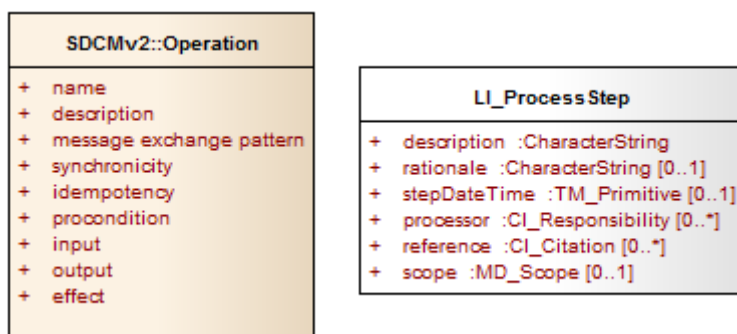


Figure 3. SDCM Operation element vs ISO process step element

SDCM Operation element may seem a good candidate to be reused (even if an extension is needed) to be mapped to ISO processStep element. Unfortunately, stepDateTime and processor are missing in SDCM operation class and these are important elements to describe traceability as describe *who* and *when*. Moreover, several Operation elements make no sense on a process step description. Thus, a new Process Step element in SDCM is created to fulfill the process step requirements, including process step description, date and time, organization carrying out the process and an optional reference to the process description. The processor description can be omitted if it is the same as the data originator (or even the service originator). The process step can refer to a process description document, similarly to the data description document from a data entity.

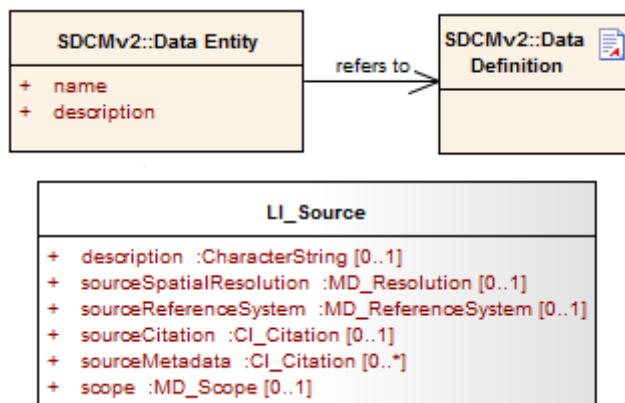


Figure 4. SDCM Data Entity element vs ISO source element

Regarding source descriptions for the lineage and traceability, it can be done reusing the "Data Entity" class within SDCM model and then describing the name and description of the Data entity and giving a reference document as well. The extended SDCM model includes a Quality of data section that is aggregated to Data Entity, the source description could also include its originator or its spatial resolution through Data quality sub-elements.

As an example, a service can provide a feature collection composed of an airport description, the approach and departure procedures, and obstacles around the airport. This feature collection conforms to a data entity delivered by one service. In the Quality of Data entity, the traceability of this feature collection can be stated as:

Table 10. traceability of a data entity combining three data sources

Model element	Model sub-element	Content
Statement		The feature collection is created by combining three original datasets into a feature collection, after a projection change to original datasets
Data source 1	name	Airport description
	definition	<i>a link to a data documentation may be described here</i>
	quality - traceability originator name	<i>it is not defined as it is the same than service provider</i>
	quality - positional resolution scaleDenominator	5000

Model element	Model sub-element	Content
Data source 2	name	Approach and departure procedures
	description	A series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing or to a point from which a landing may be made visually
	quality - traceability originator name	Aeronautical Information Management Modernization
	quality - traceability originator web page	https://www.faa.gov/air_traffic/flight_info/aimm/
	quality - positional resolution value	10
	quality - positional resolution units of measure	m
Data source 3	name	Obstacles
	description	http://www.qualityml.org/1.0/metrics/items/
	quality - traceability originator name	Aeronautical Information Management Modernization
	quality - traceability originator web page	https://www.faa.gov/air_traffic/flight_info/aimm/
	quality - positional resolution value	12
	quality - positional resolution units of measure	m
Process Step 1	description	A projection change is applied to each data source
	processor name	<i>it is not defined as it is the same than service provider</i>
Process Step 2	description	A confusion procedure is developed to generate a single feature collection with the selected information of each data source
	processor name	<i>it is not defined as it is the same than service provider</i>
Originator	name	<i>it is not defined as it is the same than service provider</i>
Origin	OGC 17-018	

A second example is related to gridded weather products such as the ones delivered by CSS-Wx Web Coverage Service (WCS), that enable National Airspace System (NAS) systems to access high-resolution aviation weather data to meet their individual needs and to support NAS operations.

Table 11. traceability of a data entity generated using interpolation methods

Model element	Model sub-element	Content
Statement	A gridded precipitation (VIL) dataset is created by fusion of weather data received from multiple radar and sensor systems	
Process Step 1	description	Interpolation of source data using linear method
	processor name	Aviation Weather & Aeronautical Services (AJM-33) Weather and Radar Processor
Originator	name	<i>it is not defined as it is the same than service provider</i>
Origin	OGC 17-018	

6.4.4. Completeness

Completeness describes the amount of data in a dataset according to a comparison with the expected data, it is described using a measure of commission and omission. Completeness may be described at a dataset level or at feature level, for example regarding omission and commission errors among categories in a classification.

Several measures are described in ISO 19157 to describe completeness. The measures they represent use mainly excess, duplicate and omission measures. QualityML groups and extends the list of measures in order to aggregate the same concept but different metric. All the measures related to the same quality measure are grouped and use a metric called items which results can be expressed as a boolean, count or rate. In fact ISO 19157 suggest several options, in this case for the rate elements, when states that "[Error rate / Correct items rate] can either be presented as percentage or as a ratio. The value unit in the quantitative result (see 7.5.4.2) can be used to specify that the result is presented in percentage or as a ratio". To standardize these options for the rate as well as to combine the other two options (boolean and count), QualityML describe the Items metrics as a choice among "indicator" (for boolean), "count" or "rate". For the last one a parameter is described in order to include the maximum value of the rate. Thus, a value of 100 in this attribute will be used to express that the value is a percentage. Default value for this attribute is 1, representing a pure ratio.

Moreover, usually measures based on errors and on correct items are described in ISO 19157. Both definitions are exactly the same, the only difference being "which elements" the measure is counting. This, in QualityML is described by the Domain of the Quality measure, allowing then a higher aggregation schema relating several ISO measures to the same QualityML measure with several metrics and domains:

- Commission:
 - [measure/Excess](http://qualityml.geoviqua.org/1.0/measure/Excess) [http://qualityml.geoviqua.org/1.0/measure/Excess]: [domain/NonConformance](http://www.qualityml.org/1.0/domain/NonConformance) [http://www.qualityml.org/1.0/domain/NonConformance] + [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/

metrics/items]

- [measure/Duplicate](http://qualityml.geoviqua.org/1.0/measure/Duplicate) [http://qualityml.geoviqua.org/1.0/measure/Duplicate]: [domain/NonConformance](http://www.qualityml.org/1.0/domain/NonConformance) [http://www.qualityml.org/1.0/domain/NonConformance] + [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
- [measure/Misclassification](http://qualityml.geoviqua.org/1.0/measure/Misclassification) [http://qualityml.geoviqua.org/1.0/measure/Misclassification]:
[domain/predictedValues](http://www.qualityml.org/1.0/domain/predictedValues) [http://www.qualityml.org/1.0/domain/predictedValues] or
[domain/actualValues](http://www.qualityml.org/1.0/domain/actualValues) [http://www.qualityml.org/1.0/domain/actualValues] +
[metrics/CommissionError](http://www.qualityml.org/1.0/metrics/CommissionError) [http://www.qualityml.org/1.0/metrics/CommissionError] or
[metrics/FalsePositive](http://www.qualityml.org/1.0/metrics/FalsePositive) [http://www.qualityml.org/1.0/metrics/FalsePositive] or
[metrics/FalsePositiveRate](http://www.qualityml.org/1.0/metrics/FalsePositiveRate) [http://www.qualityml.org/1.0/metrics/FalsePositiveRate]
- Omission:
 - [measure/MissingItems](http://qualityml.geoviqua.org/1.0/measure/MissingItems) [http://qualityml.geoviqua.org/1.0/measure/MissingItems]:
[domain/NonConformance](http://www.qualityml.org/1.0/domain/NonConformance) [http://www.qualityml.org/1.0/domain/NonConformance] + [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
 - [measure/MissingClass](http://qualityml.geoviqua.org/1.0/measure/MissingClass) [http://qualityml.geoviqua.org/1.0/measure/MissingClass]: [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
 - [measure/NodataAreas](http://www.qualityml.org/1.0/measure/NodataAreas) [http://www.qualityml.org/1.0/measure/NodataAreas]: [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
 - [measure/FlagAreas](http://www.qualityml.org/1.0/measure/FlagAreas) [http://www.qualityml.org/1.0/measure/FlagAreas]: (used to flag elements that are detected as anomalous such as "cloud flag" or "snow flag") [metrics/items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
 - [measure/Misclassification](http://qualityml.geoviqua.org/1.0/measure/Misclassification) [http://qualityml.geoviqua.org/1.0/measure/Misclassification]:
[domain/predictedValues](http://www.qualityml.org/1.0/domain/predictedValues) [http://www.qualityml.org/1.0/domain/predictedValues] or
[domain/actualValues](http://www.qualityml.org/1.0/domain/actualValues) [http://www.qualityml.org/1.0/domain/actualValues] + [metrics/OmissionError](http://www.qualityml.org/1.0/metrics/OmissionError) [http://www.qualityml.org/1.0/metrics/OmissionError] or [metrics/FalseNegative](http://www.qualityml.org/1.0/metrics/FalseNegative) [http://www.qualityml.org/1.0/metrics/FalseNegative]

These measures are mainly related to a dataset level, as they describe the differences among the elements described in the dataset and the elements in the universe of discourse, finding those that are missing, duplicated or existing only in the dataset. As an example, for a dataset describing obstacles in an airport, an omission indicator may be described as:

Table 12. completenessOmission for obstacles as reported by AIXM and described in QualityML

Model element	Content
Quality category	completeness omission
Quality scope	obstacles dataset
Measure name	http://qualityml.geoviqua.org/1.0/measure/MissingItems
Measure metrics	http://www.qualityml.org/1.0/metrics/items/
Quantity value	3
Quantity unit of measure	obstacles
Origin	ISO 19157 Id 6.

6.4.5. Temporal Accuracy and Precision

Time is an essential aspect of the aeronautical information world, where change notifications are usually made well in advance of their effective dates. Aeronautical information systems are usually requested to store and to provide both the current situation and the future changes.

In order to satisfy the temporal requirements of aeronautical information systems, AIXM must include an exhaustive temporality model, which enables a precise representation of the states and events of aeronautical features. A general temporal model should be uniformly applied to all aeronautical feature types and the temporality concept should be abstracted from the task of modeling object properties. At the conceptual level, the model should describe the temporal evolution of the features, as they occur in the real world.

The *AIXM Temporality Model* describes two levels at which aeronautical feature instances are affected by time: 1) Every feature has a start of life and an end of life; and 2) The properties of a feature can change within the lifetime of the feature[3]. It is considered that any feature property may change in time, except for the global unique identifier. This is a key assumption of the AIXM Temporality model.

Within FIXM models, there are several elements describing time, such as *runwayTime* (in *FIXM 3.0.1.Base.Aerodrome.RunwayPositionAndTime.runwayTime*) or *standTime* (in *FIXM 3.0.1.Base.Aerodrome.StandPositionAndTime.standTime*). FIXM also includes the *Base.Time* schema that provides representations for time elements.

What AIXM temporality and FIXM models do not cover is the accuracy of a time measurement, that is fixed to 1 minute, as the *validTime* on the model is a date and time element. The accuracy time measurement or the precision of time measurement could be described for the whole dataset or for several temporal elements described in the AIXM or FIXM models.

When accuracy elements are described within AIXM and FIXM models, the selected measure is related to 95% probability (as explained for example for *trueBearingAccuracy* attribute in AIXM *NavAids Points|NavAids|Azimuth*). Thus, the recommendation to describe temporal accuracy is to use "accuracy of a time measurement" also with 95% probability, for example:

Table 13. temporalAccuracy defined generally for a dataset describing Aerodrome runways as described in ISO 19157 & QualityML

Model element	Content
Quality category	accuracy of a time measurement
Quality scope	dataset
Measure name	http://qualityml.geoviqua.org/1.0/measure/TimeAccuracy
Measure domain	http://www.qualityml.org/1.0/domain/DifferentialErrors1D
Measure metrics	http://www.qualityml.org/1.0/metrics/Half-lengthConfidenceInterval
Measure parameter name	level
Measure parameter value	0.95

Model element	Content
Quantity value	2.5
Quantity unit of measure	min
Origin	ISO 19157 Id. 57

A temporal precision element has been also added as a quality category as suggested by OGC 17-032.

6.4.6. Timeliness

Timeliness is a representation of the concepts of currency and fitness for purpose and is described including date and time of capture, maintenance date and time and maintenance frequency. Using these elements a dataset can be described in terms of when it was produced, and whether it is valid.

For a dataset that is updated quarterly, for example, capture date, last maintenance and maintenance frequency can be described.

Table 14. *timeliness of a data set*

Model element	Content
date and time of capture	2017-09-12 10:00
maintenance date and time	2017-09-25 10:00
maintenance frequency	quarterly
Origin	OGC 17-018

Moreover, for a service, an aggregated measure related to timeliness can be computed if a requirement on timeliness is defined, such as that this data should not be more than a certain number of days old. This could be described using a *Temporal validity* data quality category, using an 'item' metric (a boolean indicator, number of items or rate) and a domain requirement to define the time limit to consider and element to be conformant or not to this time requirement . To describe the conformance or non-conformance domain requirements, the domain can describe a range ("domain min" and/or "domain max" parameters) to define the requirement, as needed.

Using the [AIXM temporality model](#), several data quality measures can be computed to describe the temporal validity of the dataset, for example describing if there are elements that have already ended their lives (and thus, do not follow timeliness requirements).

For example, if the feature requirements considers that features older than 15 days are not current enough (so they do not conform to the rule), a quality indicator with a temporal validity category can report the rate of elements non conformant with the domain with an specific requirement as a parameter in the domain of the quality measure (3% in this example):

Table 15. *temporal validity for timeliness described in ISO 19157 and QualityML*

Model element	Content
Quality category	temporal validity

Model element	Content
Quality scope	dataset
Measure name	http://qualityml.geoviqua.org/1.0/measure/ValueDomain
Measure domain	http://www.qualityml.org/1.0/domain/NonConformance
Measure metrics	http://www.qualityml.org/1.0/metrics/items
Measure parameter name	domain min
Measure parameter value	2017-09-15 ¹
Measure parameter name	rate max
Measure parameter value	100
Quantity value	3
Quantity unit of measure	percentage
Origin	ISO 19157 Id. 18

¹ Features older than 15 days of the time intended for the data (i.e. older than 2017-09-15 if the day this measure is computed is 2017-10-01)

Within the WXXM model, there are also highly dynamic features that should be properly described in order to be able to assess its timeliness. Inside the model, there is an AIRMET package that reports the occurrence and/or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations, and of the development of those phenomena in time and space. These weather phenomena are reported as impacted regions of airspace.

This package contains candidate representations for eventual adoption by ICAO Meteorological Information Exchange Model (IWXXM). Representations are based upon ICAO Annex 3 Amendment 76 / WMO No. 49. These representations should be considered unofficial until incorporated into IWXXM. Each observation/forecast phenomenon includes its own period of validity for described meteorological conditions, which is represented as the O&M Observation validTime. These elements can be similarly used to compute aggregated measures such as percentage of features covering a certain time requirement (like the last example).

6.4.7. Integrity

Integrity describes the degree of assurance that can be given that the dataset has not been altered or lost since creation or update from the required body. There are several commonly used strategies to describe and ensure data integrity (some recognized in ICAO Annex 15 or other standards [5]), and those are included in the Integrity class in the model:

- cyclic redundancy check (CRC) values: electronic aeronautical data sets shall be protected by the inclusion in the data sets of a 32-bit cyclic redundancy check (CRC) implemented by the application dealing with the data sets
- designated level: demonstration of compliance of the quality management system applied shall be by audit. If nonconformity is identified, initiating action to correct its cause shall be determined and taken. All audit observations and remedial actions shall be evidenced and properly documented

- integrity faults: related to ICAO DIL classification: routine data (10^{-3} integrity level), essential data (10^{-5} integrity level), critical data (10^{-8} features,), described in aeronautical data quality requirements in appendix 7 in ICAO annex 15
- signature: as recognized by ISO 19165, not only integrity (such as crc values) are important but also signature and certification of data. This element allows for the identification of signature information.

Moreover, several quality elements can be described in order to include the audit results as well as other integrity parameters related to logical consistency elements in ISO (and its four types) and temporal consistency:

- Conceptual consistency: rules to conceptual schema. This may include the audit of datasets and if classification of integrity faults requirements are met.
- Domain consistency: check if feature attributes have the expected domains, for example: AIXM navaids features may be checked during quality control to see if the Navaids.Points.Navaids.Azimuth.trueBearing attribute is a value within the range [0,360].
- Format consistency: degree to which data is stored in accordance with the physical structure of the dataset
- Topological consistency: explicitly encoded topological characteristics of a dataset
- Temporal consistency: within AIXM temporality model, to check for a specific feature is there are chronological errors (i.e. feature/time slice start of life is later than end of life)

There are several qualityML measures and metrics that can be used to describe consistency quality parameters, all of them using [items](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items] measure metrics, for example:

Table 16. ISO 19157 and QualityML measures and metrics related to consistency (and thus to integrity)

Quality category	Measure name	Measure domain	Origin
Conceptual consistency	Conceptual schema [http://qualityml.geoviqua.org/1.0/measure/ConceptualSchema]	Conformance [http://www.qualityml.org/1.0/domain/Conformance]	ISO 19157: Id. 8 + Id. 9 (boolean), Id. 10 + GeoViQua (count), Id. 12 + Id. 13 (rate)
		Non conformance [http://www.qualityml.org/1.0/domain/NonConformance]	
	Invalid overlaps surfaces [http://qualityml.geoviqua.org/1.0/measure/InvalidOverlapsSurfaces]	Non conformance [http://www.qualityml.org/1.0/domain/NonConformance]	GeoViQua (boolean, rate), ISO 19157 Id. 11 (count)

Quality category	Measure name	Measure domain	Origin
Domain consistency	Value domain [http://qualityml.geoviqua.org/1.0/measure/ValueDomain]	Conformance [http://www.qualityml.org/1.0/domain/Conformance]	ISO 19157 Id. 14 + Id. 15 (boolean), Id. 16 + GeoViQua (count), Id. 17 + Id. 18 (rate)
		Non conformance [http://www.qualityml.org/1.0/domain/NonConformance]	
Format consistency	Physical structure conflicts [http://qualityml.geoviqua.org/1.0/measure/PhysicalStructureConflicts]	Non conformance [http://www.qualityml.org/1.0/domain/NonConformance]	GeoViQua (boolean), ISO 19157 Id. 119 (boolean), Id. 19 (count), Id. 20 (rate)
Topological consistency	Faulty point curve connections [http://qualityml.geoviqua.org/1.0/measure/FaultyPoint-curveConnections]	Non conformance [http://www.qualityml.org/1.0/domain/NonConformance]	GeoViQua (boolean), ISO 19157 Id. 21 (count), Id. 22 (rate)
	Missing connections due to undershoots [http://qualityml.geoviqua.org/1.0/measure/MissingConnectionsDueUndershoots]		GeoViQua (boolean, rate), ISO 19157 Id. 23 (count)
	Missing connections due to overshoots [http://qualityml.geoviqua.org/1.0/measure/MissingConnectionsDueOvershoots]		GeoViQua (boolean, rate), ISO 19157 Id. 24 (count)
	Invalid slivers [http://qualityml.geoviqua.org/1.0/measure/InvalidSlivers]		GeoViQua (boolean, rate), ISO 19157 Id. 25 (count)
	Invalid self intersects [http://qualityml.geoviqua.org/1.0/measure/InvalidSelfIntersects]		GeoViQua (boolean, rate), ISO 19157 Id. 26 (count)
	Invalid self overlaps [http://qualityml.geoviqua.org/1.0/measure/InvalidSelfOverlaps]		GeoViQua (boolean, rate), ISO 19157 Id. 27 (count)

6.5. NSRR service exploration

The FAA has a [National Airspace System \(NAS\) Service Registry and Repository](https://nsrr.faa.gov/) [https://nsrr.faa.gov/] that includes metadata describing around 80 services in several life cycle stage (Proposed, Verification, Definition, Deprecated, Production and Development). These services are categorized in several groups under several criteria, for example depending on the ATM service or the SWIM

product category, as seen in the next figure:

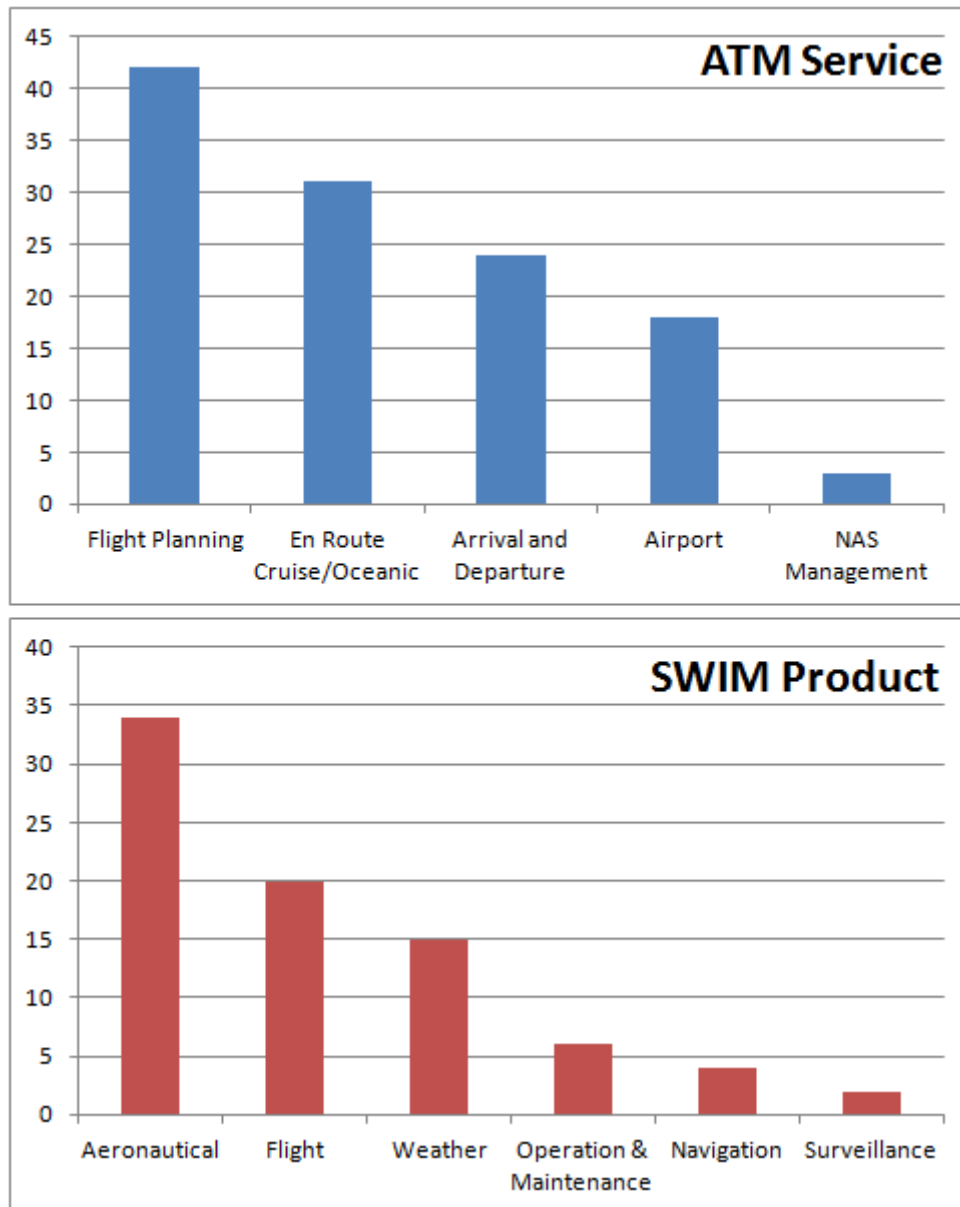


Figure 5. ATM services and SWIM product categories of NSRR services

Metadata for each service includes several sections, one of them describing the **Data** of the service. The Data section describes the nature, structure, and representation of the data that constitutes the body or payload of the service’s messages, i.e., the data shared between service providers and consumers. The Data section captures bibliographic and location information for relevant data definition documents, including XML Schemas, Data Model Diagrams, or other descriptive documents. Only 37 of the services described in the registry include some information on the Data section. Unfortunately, the data section is not always populated so a careful reading of some service description reveals more details about the data types involved. We also have to take into account that sometimes more than one service provides the same data in different formats, and we only need to consider this data once.

This information is a source list of different data used by these services and, thus, is interesting to check it in order to define quality measures related to most of the data available through the services. These can be grouped by model as seen in the next table:

Table 17. Data categories on NSRR

code	Name	Model	Data
acs-dqv2 [http://nsrr.faa.gov/services/acs-dqv2]	Aeronautical Common Services Data Query (ACS-DQ) V 2.0	AIXM	Special User Airspace (SUA), NOTAM
acs-gc [http://nsrr.faa.gov/services/acs-gc]	Aeronautical Common Services Geodetic Computation (ACS-GC)	AIXM	Magnetic declination
acs-wfsv2 [http://nsrr.faa.gov/services/acs-wfsv2]	Aeronautical Common Services Web Feature Service (ACS-WFS) v2.0	AIXM	Airports, navaids, obstacles, procedures, and NOTAMs
aim-saa-get [http://nsrr.faa.gov/services/aim-saa-get]	Get Static Special Activity Airspace (SAA)	AIXM	Special User Airspace (SUA)
enroute-ad-pub-v2 [http://nsrr.faa.gov/services/enroute-ad-pub-v2]	En Route Airspace Data Publication - v2.0, SWIM Flight Data Publication Service (SFDPS)	AIXM	route, sector, altimeter setting, and special activities airspace information
fns-notam-pub [http://nsrr.faa.gov/services/fns-notam-pub]	Federal NOTAM System (FNS) Publication	AIXM	NOTAM
navlean [http://nsrr.faa.gov/services/navlean]	Aeronautical Feature Data	AIXM	
oas-ds-wfs [http://nsrr.faa.gov/services/oas-ds-wfs]	Aeronautical Information Authoritative Source (AIAS) Data Service Web Feature Service (WFS)	AIXM	Obstacle Authoritative Source (OAS)
stds-adp [http://nsrr.faa.gov/services/stds-adp]	SWIM Terminal Data Distribution System (STDDS) Airport Data Service (APDS)	AIXM	Runway Visual Range (RVR) data: Runway visibility and trend for touchdown, midpoint and rollout. Edge and centerline light intensity settings
enroute-fd-pub-v2 [http://nsrr.faa.gov/services/enroute-fd-pub-v2]	En Route Flight Data Publication - v2.0 (SFDPS)	FIXM	flight plan, track

code	Name	Model	Data
stdds-sme [http://nsrr.faa.gov/services/stdds-sme]	STDDS Surface Movement Event (SMES)	FIXM	Surface movement events for all aircraft monitored at select towers. track positions for all aircraft and vehicles collected from towers
stdds-tais [http://nsrr.faa.gov/services/stdds-tais]	STDDS Terminal Automation Information Service (TAIS)	FIXM	Flight plan data, track data, sign-in / sign-out (SISO) data, alert data, Instrument Meteorological Conditions (IMC) data, traffic count data, and performance monitoring data
stdds-tde [http://nsrr.faa.gov/services/stdds-tde]	STDDS Tower Departure Event (TDES)	FIXM	Departure events for all flights
tbfm-mis [http://nsrr.faa.gov/services/tbfm-mis]	Time Based Flow Metering (TBFM) Publication (TBFM-MIS)	FIXM	TBFM Metering Status, TBFM Interface Status, TRACON Name, Gate Name, Arrival Airport Information, Airport Configuration, MRE Information, Arrival Airport Configuration Information, Airport Acceptance Rate Group, Terminal Radar Approach Control (TRACON) Acceptance Rate Group, Meter Point Acceptance Rate Group, Runway Acceptance Rate Group, Super Stream Class Configuration Group, Satellite Airport Configuration Group, Flight Plan Information, Estimated Times of Arrivals (ETA), Scheduled Times of Arrival (STA), Meter Reference Element (MRE) information, and Scheduling information.

code	Name	Model	Data
tbmf-rtcs [http://nsrr.faa.gov/services/tbmf-rtcs]	TBFM Release Time Coordination Service (TBFM-RTCS)	FIXM	Departure release time
tfdm-afis [http://nsrr.faa.gov/services/tfdm-afis]	Terminal Flight Data Manager (TFDM) Airport and Flight Information Service (AFIS)	FIXM	Airport's configuration, demand, delay, other airport information, and flight specific data and delay information.
tfm [http://nsrr.faa.gov/services/tfm]	Traffic Flow Management (TFM) Data	FIXM	Route information, entry/exit data for certain Traffic Management Initiatives (TMIs), Route Availability Planning Tool (RAPT) timeline data, National Traffic Management Log (NTML) restrictions
tfm-r13 [http://nsrr.faa.gov/services/tfm-r13]	TFM Data R13	FIXM	Route information, entry/exit data, Route Availability Planning Tool (RAPT) timeline data, Traffic restrictions
ciws-wcs [http://nsrr.faa.gov/services/ciws-wcs]	Corridor Integrated Weather System (CIWS) Data Distribution Service (CDDS) Web Coverage Service (WCS) Gridded Weather Products (CIWS WCS)	WXXM	Gridded - current Continental United States (CONUS) Vertically Integrated Liquid (VIL) Dataset, Forecast CONUS VIL Dataset, Current Echo Tops Dataset, Forecast Echo Tops Dataset and Current CONUS Satellite Dataset

code	Name	Model	Data
ciws-wfs [http://nsrr.faa.gov/services/ciws-wfs]	CDDS Web Feature Service (WFS) NonGridded Weather Products (CIWS WFS)	WXXM	Non- Gridded - Growth and Decay Trends, Storm Information – Echo Tops Tags, Storm Information – Leading Edges, Storm Information – Motion Vectors, Forecast Standard-Mode VIL Contours, Forecast Winter-Mode VIL Contours, Forecast Echo Tops Contours, Echo Tops Forecast Accuracy Scores, Standard-Mode VIL Forecast Accuracy Scores and Winter-Mode VIL Forecast Accuracy Scores.

code	Name	Model	Data
CSS-WX-WCS [http://nsrr.faa.gov/services/css-wx-wcs]	Common Support Services Weather (CSS-Wx) Web Coverage Service (WCS)	WXXM	Gridded weather products: Precipitation, Precipitation with Mask, Precipitation Forecast, Precipitation (VIL) Forecast with Mask, Echo Tops, Echo Tops Forecast, Precipitation (Base Reflectivity), Precipitation (Composite Reflectivity), Precipitation (Composite Reflectivity) with Mask, Surface Precipitation Phase, Surface Precipitation Phase Forecast, Precipitation (ASR), Precipitation (ASR AP Flagged), Icing Tops, Icing Tops Forecast, Icing Bottoms, Icing Bottoms Forecast, Icing Layer, Composite Icing, Icing Layer Forecast, Composite Icing Forecast, Turbulence Layer, Turbulence Layer Forecast, Composite Turbulence, Composite Turbulence Forecast, Convective Weather Avoidance Fields, Convective Weather, Avoidance Field Forecast, Satellite, Terminal Winds, NOAA Model Data (Rapid Refresh -RAP-, High-Resolution Rapid Refresh -HRRR-, Global Forecast System -GFS-)

code	Name	Model	Data
css-wx-wfs [http://nsrr.faa.gov/services/css-wx-wfs]	CSS-Wx Web Feature Service (WFS)	WXXM	Meteorological Terminal Aviation Routine Weather Report (METAR) and Terminal Aerodrome Forecast (TAF), Precipitation (VIL) Forecast Accuracy, Precipitation (VIL) Forecast Contours, Echo Tops Forecast Accuracy, Echo Tops Forecast Contours, Lightning, Airport Lightning Warning, Storm Information Hazard Text, Storm Information Leading Edges, Storm Information Motion Vectors, Fronts Forecast, Growth Trends, Decay Trends, Forecast Confidence, Convective Weather Avoidance Polygons, Wind Profiles, Tornado Detections, Jet Stream (WP2), Winds Aloft Forecast, Microburst, Gust Front, Gust Front Estimated Time to Impact, Tornado Alert, Tornado Warnings, Tornado Watches, Configured Alerts, Wind Shear ATIS Timers – Microburst, Wind Shear ATIS Timers – Wind Shear, Terminal Weather Graphics, Terminal Weather Text, Icing Layer Contours, Composite Icing Contours, Turbulence Layer Contours, Composite Turbulence Contours, Pilot Report (PIREP), ICAO Aircraft Report, Urgent Pilot Report (PIREP), Significant

code	Name	Model	Data
warp-pub [http://nsrr.faa.gov/services/warp-pub]	Weather and Radar Processor (WARP) Publication	WXXM	Weather information and radar product
warp-vendor-pub [http://nsrr.faa.gov/services/warp-vendor-pub]	WARP Vendor Weather Data Publication	WXXM	Weather information and radar product
wins-wcs [http://nsrr.faa.gov/services/wins-wcs]	National Weather Service (NWS) Weather Information Network Server (WINS). WCS Gridded data products	WXXM	Rapid Refresh (RAP), Global Forecast System (GFS), North American Mesoscale (NAM) (CONUS, Alaska and Puerto Rico domains), National Convective Weather Diagnostic (NCWD) and Current Icing Product (CIP). All of the data products are in netCDF-4 format and use Climate and Forecast (CF) metadata conventions.
wins-wfs [http://nsrr.faa.gov/services/wins-wfs]	NWS WINS WFS Non Gridded products	WXXM 1.1	National Convective Weather Forecast (NCWF), Airmen's Meteorological Information (AIRMETs), Significant Meteorological Information (SIGMETs), Meteorological Aviation Reports (METARs) and Meteorological Data Collection and Reporting System (MDCRS)
wmscr-ack-weather-rpt [http://nsrr.faa.gov/services/wmscr-ack-weather-rpt]	Acknowledge Weather Report, Weather Message Switching Center Replacement System (WMSCR)	WXXM 1.1	NOTAM, Pilot Reports (PIREPS), altimeter setting
wmscr-pub-alt [http://nsrr.faa.gov/services/wmscr-pub-alt]	Publish Altimeter Setting (WMSCR)	WXXM 1.1	altimeter setting
wmscr-pub-pirep [http://nsrr.faa.gov/services/wmscr-pub-pirep]	Publish PIREP (WMSCR)	WXXM 1.1	PIREP

code	Name	Model	Data
wmscr-rpt-retrieval [http://nsrr.faa.gov/services/wmscr-rpt-retrieval]	WMSCR Report Retrieval (WMSCR)	WXXM 1.1	PIREPs or Altimeter Setting

Chapter 7. SDCM Extension

The second version of the Service Description Conceptual model ([SDCM v2.0](https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.htm) [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.htm]) is extended in this ER in order to include new elements covering the quality information for each service in a interoperable way.

SDCM in its profile diagram, describes a Quality of Service class where requirements of the services can be included and added to the QoS class as a new property "parameter type" related to the taxonomy of parameters describing QoS (ex. timeliness, etc). This is shown in [figure 3](https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.2) [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.2] of SDCM v2.0.

Moreover, on the model diagram, SDCM has a Data class where quality of the data or basic metadata of the data may also be included. This is shown in [figure 4](https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.3) [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.3] of SDCM v 2.0.

7.1. Extension options

SDCM v2.0 model needs to be extended to include quality of the data. This can be done in several ways, as described in next sub-sections.

7.1.1. First option: quality of service for quality of data

The quality of service class could be applied directly to Quality of Data. This approach is the simplest one in the way that the model is only slightly modified, but no new classes or class modification would be needed. On the contrary, this approach maybe too simple to contain all the elements or to provide enough semantic information about the quality measures needed to describe aviation services in general, and specifically those registered that includes a Quality Element in NASS services.

7.1.2. Second option: new elements inspired on ISO 19115 and 19157 concepts

In this case, SDCM extensions are more important. The idea is to modify SDCM following ISO 19115 and 19157 concepts, but keeping as much as possible SDCM simplicity. Instead of directly adopting the ISO 19115 and 19157 classes, a reinterpretation (usually simplifying the ISO classes) is suggested.

A new "Quality of Data" class is created that includes several child elements:

- quality element
- positional, vertical, temporal and attribute resolution
- traceability
- timeliness
- integrity

The new element "Quality of Data" can be used to illustrate the level of granularity "dataset" or "service". Details are described in next sub-sections.

Dataset level

In this case, the suggestion is to extend the *model diagram* (figure 4 [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.3] of SDCM v 2.0) to attach the quality to each data *payload* responded by each *operation*. This has the benefit that provides quality at the dataset level permitting a quality report for each data type that a service can potentially provide; being able to give different reports for each dataset. The approach also has drawbacks. First, in case the same data type is provided by more than one operation, the data quality description will be repeated for each instance. Secondly, different service instances can serve the same data using different operation structures with different names and payload sets. This will make quality comparison among services more challenging.

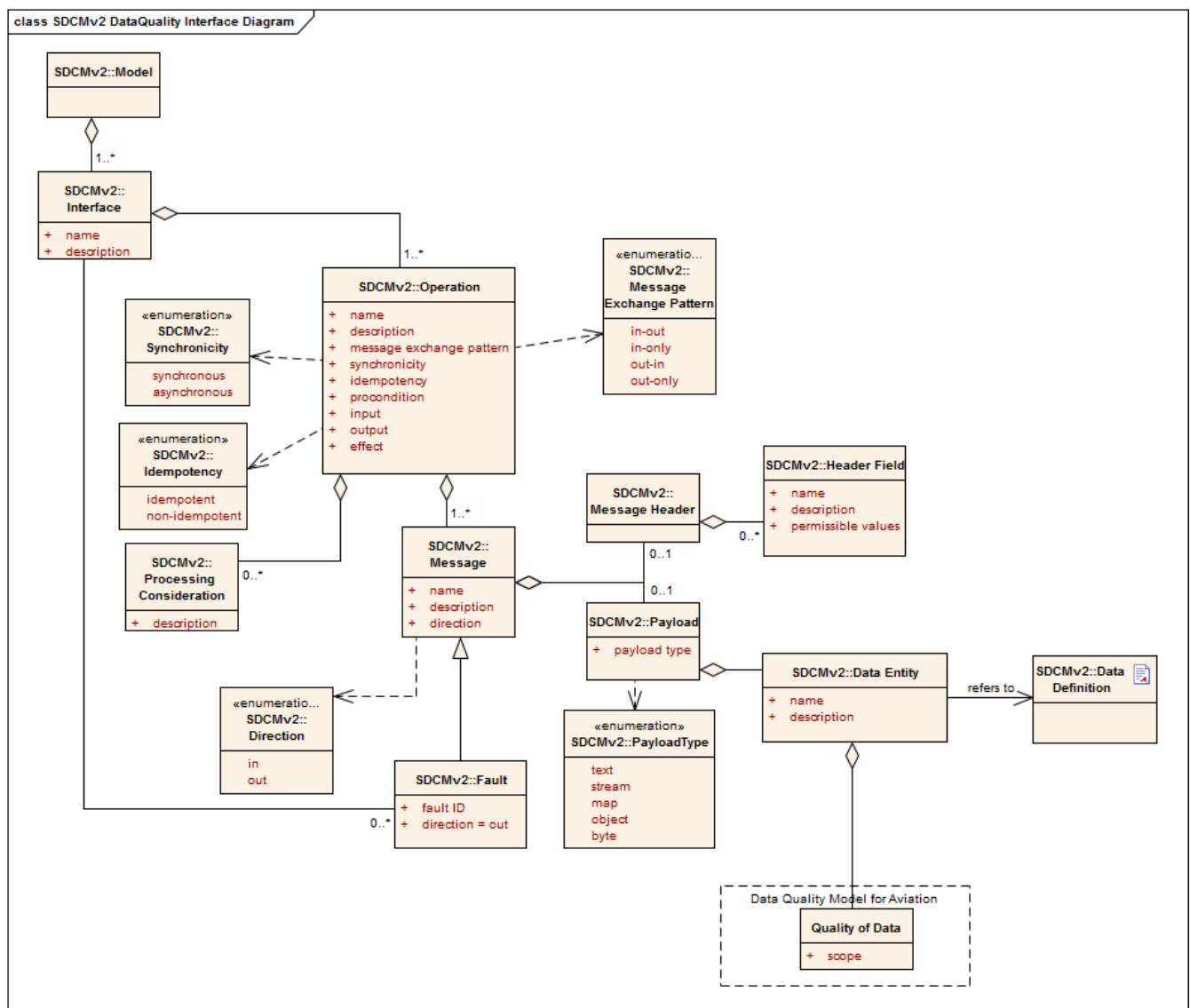


Figure 6. UML class diagram of SDCM extension for quality interface. Dataset level data quality

Service level

In this case, the suggestion is to extend the *profile diagram* (figure 3 [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#2.2] of SDCM v2.0) to attach an

overall quality report that summarizes the characteristics of all datasets in the service. This has the advantage of making the data quality more prominent in the model (at the same level as the Quality of Service), and allows the easy comparison of the data quality of several services.

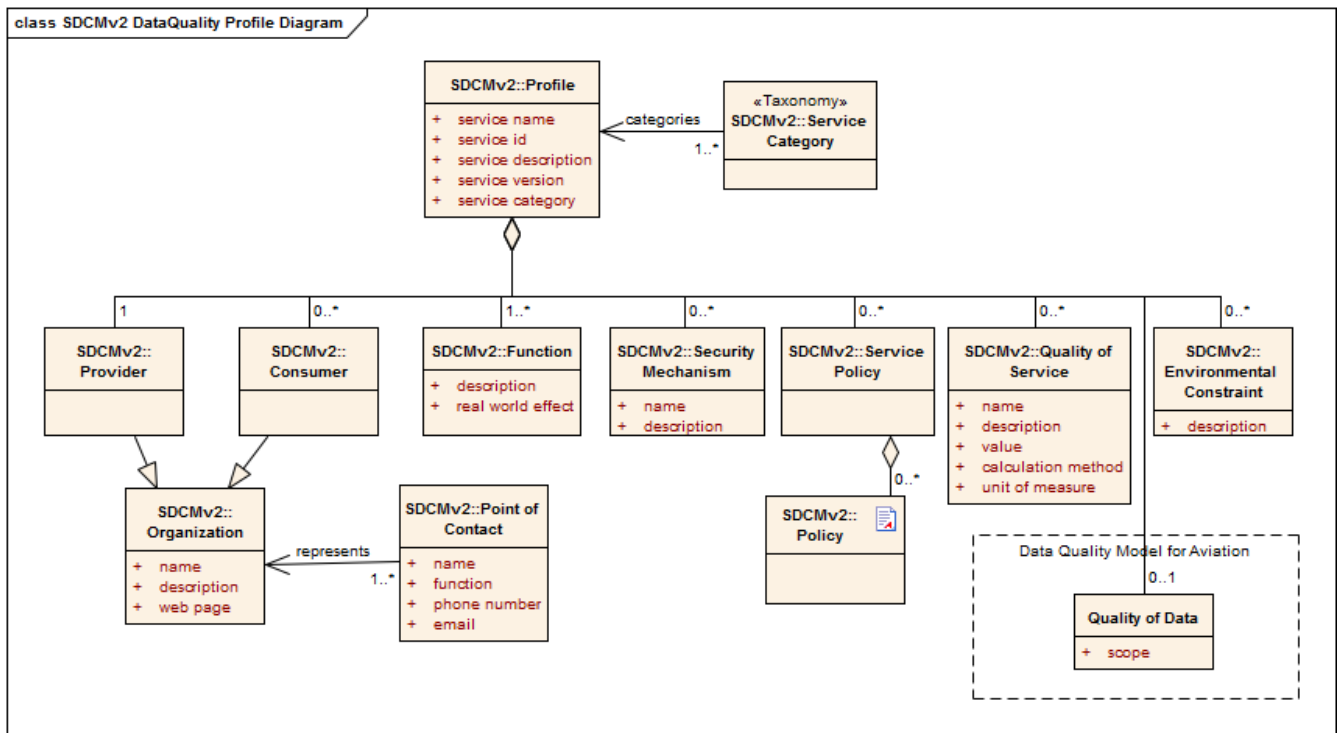


Figure 7. UML class diagram of SDCM extension for quality profile. Service level data quality

7.1.3. Third option: full MD_Metadata record

OGC 17-032, OGC® Testbed-13 Abstract Data Quality ER, explained how to describe aviation concepts using ISO elements. With this approach an XML file describing the full ISO metadata record for a dataset (or service) may be described.

SDCM v2.0 "Data Definition" element on "Data Entity class" could be used to link to the full MD_metadata class.

The drawback of this option is that ISO standards are quite complex and several mandatory information elements that would be required are potentially not relevant or it's harder to find that in a simplest model that will be more easily comparable.

7.1.4. Selected option: new elements inspired on concepts of ISO 19115 and 19157

The complete UML model for the SDCM is shown in the next figure.

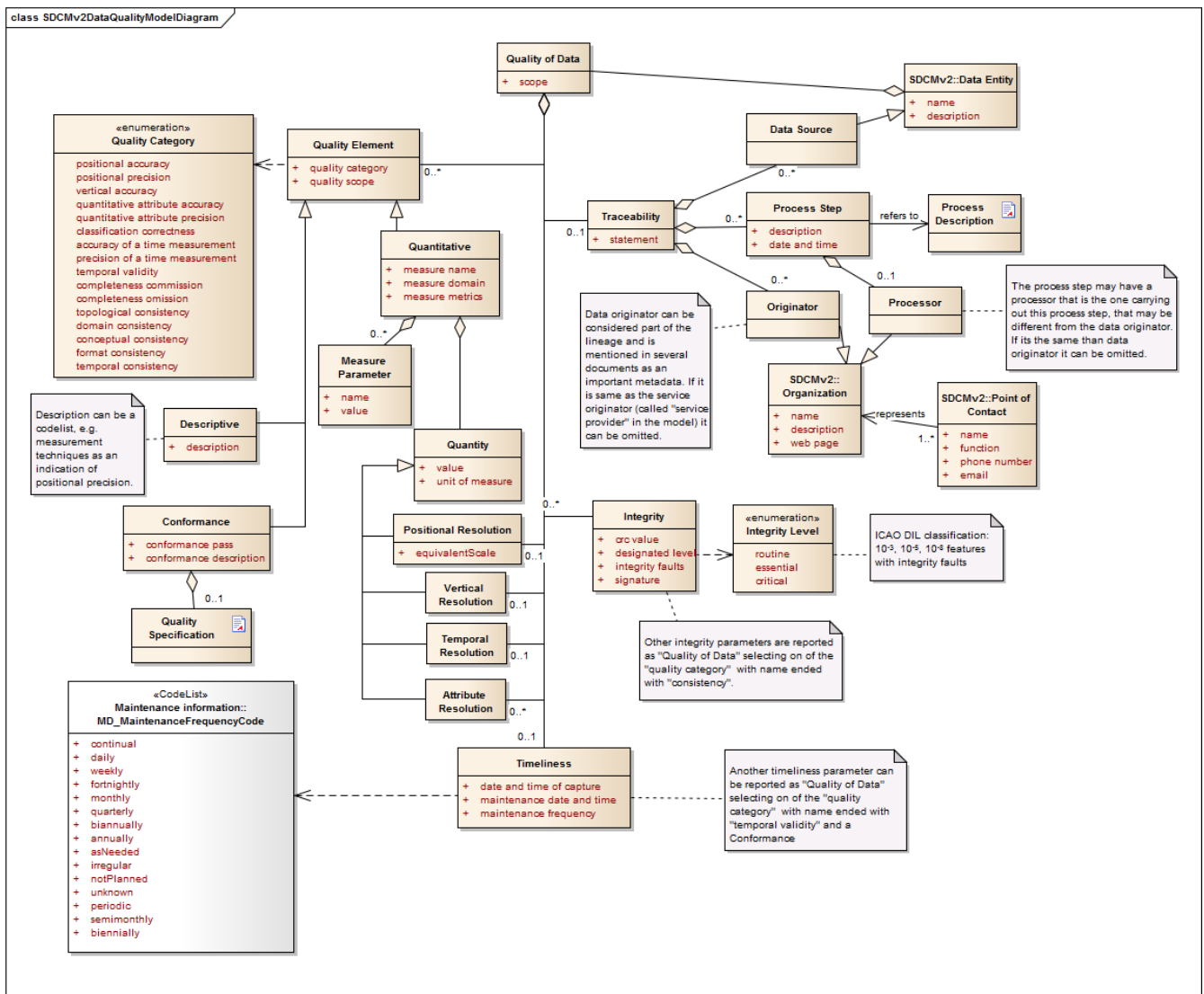


Figure 8. UML diagram of a SDCM extension to describe Data Quality

7.2. Model description

7.2.1. Scope

Within the new Quality of Data class, an element "scope" is defined. This element is intended to include the description of the scope of elements to whom this quality information should apply.

Typically, "dataset" level is the proper value if this quality report is describing the whole dataset, but sometimes an attribute or feature type may be specified if this quality report only applies to them, for example "FlightObject/Flight/EnRoute/Position/AircraftPosition/position".



Figure 9. UML Quality of Data class diagram (fragment of a SDCM extension)

7.2.2. Quality element

The first element inside Quality of Data is *Quality element*. This element is intended to describe

quality reports about the dataset, feature or attribute. It is inspired in ISO 19157 DQ_Element.

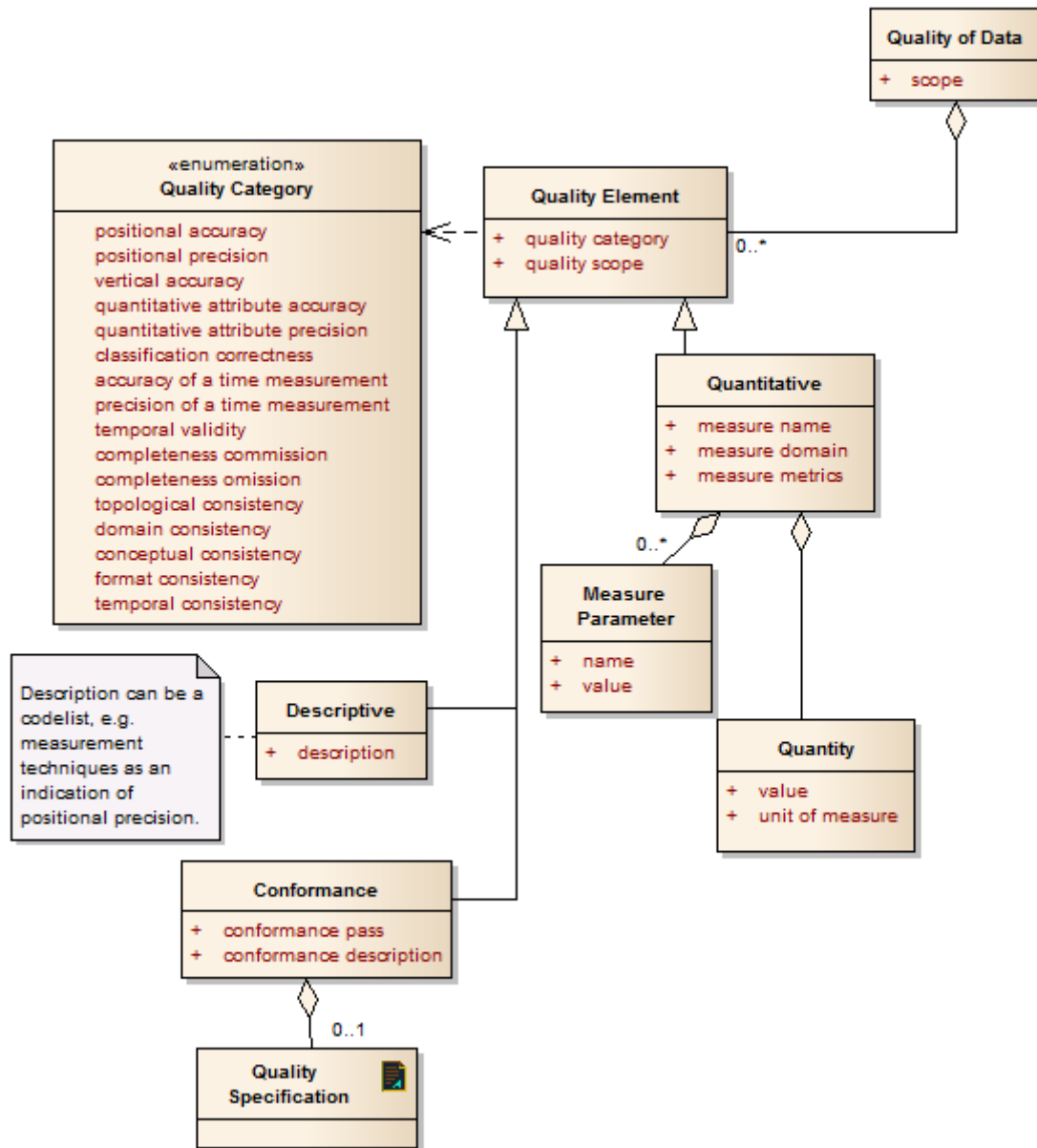


Figure 10. UML Quality Element class diagram (fragment of a SDCM extension)

The element contains a **quality category**, that should be selected from the namesake enumeration. Values for this enumeration come from ISO 19157 DQ_Elements subclasses, as well as from OGC 17-032 or this ER proposals:

- positional accuracy
- positional precision
- vertical accuracy
- quantitative attribute accuracy
- quantitative attribute precision
- classification correctness
- accuracy of a time measurement
- temporal validity

- completeness commission
- completeness omission
- topological consistency
- domain consistency
- conceptual consistency
- format consistency
- temporal consistency

The second element is quality scope. This only needs to be populated if its value is not the same as the one for the general "scope" element (described in the previous section). This allows, for example, the generation of a single "Quality of Data" section for the whole dataset, that includes "Quality elements" for the whole dataset (thus "quality scope" will be not defined) or other for specific features or attributes (and thus "quality scope" will be described for them).

The result of the quality element can be described as three options:

- descriptive result: it can be used to describe in a textual way the order of magnitude precision of the instrument used, for example GPS, ADS-B (meters), ADSBLostCoverageEstimation or TimeSpeedDistanceEstimation (100km or more) for positional accuracies. It can also be used, as typically used in ISO 19157, to describe the spatial distribution of data quality, for example to explain that horizontal accuracy of the elements next to or inside an Airport are defined in a more certain way than the obstacles around it.
- conformance result: describe if a certain specification is met or not. The result of the measure is described in the conformance pass element, the specification is described in the conformance description element, and a formal reference to the specification document can also be provided.
- quantitative result: numerical value

When a quantitative result is provided, several elements should be described:

- measure name: identification of the measure. When possible a link to an external and recognized description should be provided. This ER recommends to use links to QualityML concepts, that include ISO 19157, GeoViQua and A3C (after TestBed 12 efforts) proposals. For example: [Circular map accuracy in QualityML](http://qualityml.geoviqua.org/1.0/measure/CircularMapAccuracy) [http://qualityml.geoviqua.org/1.0/measure/CircularMapAccuracy] or [Value domain in QualityML](http://qualityml.geoviqua.org/1.0/measure/ValueDomain) [http://qualityml.geoviqua.org/1.0/measure/ValueDomain]
- measure domain: the selected measure can be applied to several value domains, for example [Differential errors 2D in QualityML](http://www.qualityml.org/1.0/domain/DifferentialErrors2D) [http://www.qualityml.org/1.0/domain/DifferentialErrors2D], [Differential errors 1D in QualityML](http://www.qualityml.org/1.0/domain/DifferentialErrors1D) [http://www.qualityml.org/1.0/domain/DifferentialErrors1D] or [Non conformance domain in QualityML](http://www.qualityml.org/1.0/domain/NonConformance) [http://www.qualityml.org/1.0/domain/NonConformance]
- measure metrics: a specific metric (numerical computation) may be used, for example [Circular error in QualityML](http://www.qualityml.org/1.0/metrics/CircularError) [http://www.qualityml.org/1.0/metrics/CircularError] or [items in QualityML](http://www.qualityml.org/1.0/metrics/items) [http://www.qualityml.org/1.0/metrics/items]
- measure parameter name: sometimes, to fully describe the domain or the metrics, or to set up a requirement on the domain, some parameters are needed. For example, level of confidence is needed when a differential error or a half-confidence interval is used. Another example is when

an item metrics is used is to provide the maximum value if a rate option for the metric is used. These parameters are described in the domain or metrics description in QualityML.

- measure parameter value: the value of the previous parameter, for example 0.95 for level of confidence or 100 to indicate that items rate is a percentage.
- quantity value: the value for the quantitative quality element
- quantity unit of measure: the units of measure for the value

More information on QualityML use to describe measure name, domain, metrics and values (including parameters when needed) can be found in OGC 16-050 Imagery Quality and Accuracy ER.

7.2.3. Positional, vertical, temporal and attribute resolution

The resolution classes contain information about the resolution of a dataset including its positional (or spatial), vertical, temporal and attribute resolutions.

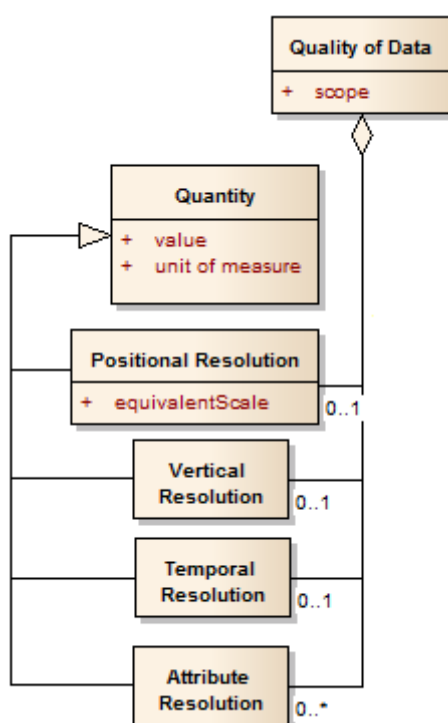


Figure 11. UML Resolution class diagram (fragment of a SDCM extension)

ISO describes spatial resolution through the MD_Resolution class and temporal resolution through the TM_Duration class.

All of them are specified from a general Quantity element, and thus include a value and a unit of measure. This is enough for vertical, temporal and attribute resolutions. For positional resolution, also an equivalentScale element is added in order to allow describing resolution in this approach, like ISO standards recognize. Note that other options described by ISO, such as distance, angularDistance and levelOfDetail can be described using the general Quantity class, describing the proper units.

7.2.4. Traceability

The traceability class includes a first textual element, statement, to describe in a general way the

lineage of the element it is describing (usually a dataset). Moreover, traceability class has three elements that can be described:

- data source
- process step
- originator

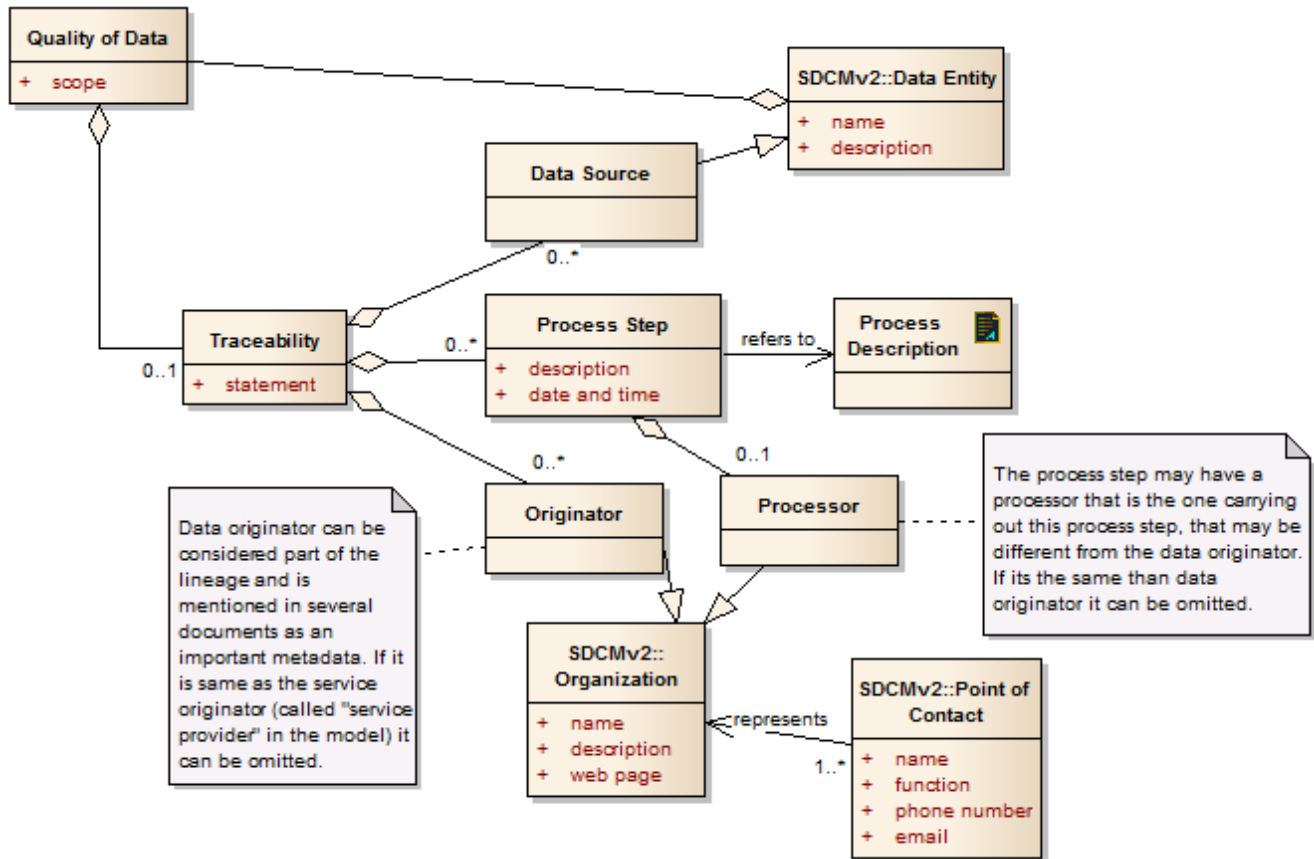


Figure 12. UML Traceability class diagram (fragment of a SDCM extension)

Several data sources can be described as being part of the dataset creation. The data source is a specified class from Data Entity class, and thus it may have, if necessary a quality of data section to describe its traceability or other quality elements.

Several process steps describing the algorithms or processes that had been applied to obtain the dataset can be described. A description and date-time of execution needs to be described for each process step. Moreover, the organism carrying out the process (processor) may be described. It can be omitted if it is the same than the data originator (or even the service originator). A process description document can be also referenced.

Finally, the originator of the dataset may also be described as a part of the lineage. It can be omitted if it is the same than the service provider.

Both originator and processor classes are specified from the SDCM Organization class and thus can be described with a name, description and website, and at least one point of contact.

7.2.5. Timeliness

Timeliness class on SDCM extension is intended to describe the data and time of the information, the date and time of its maintenance and also its expected maintenance frequency. Possible values for the last element are the ones in the ISO MD_MaintenanceFrequencyCode codelist.

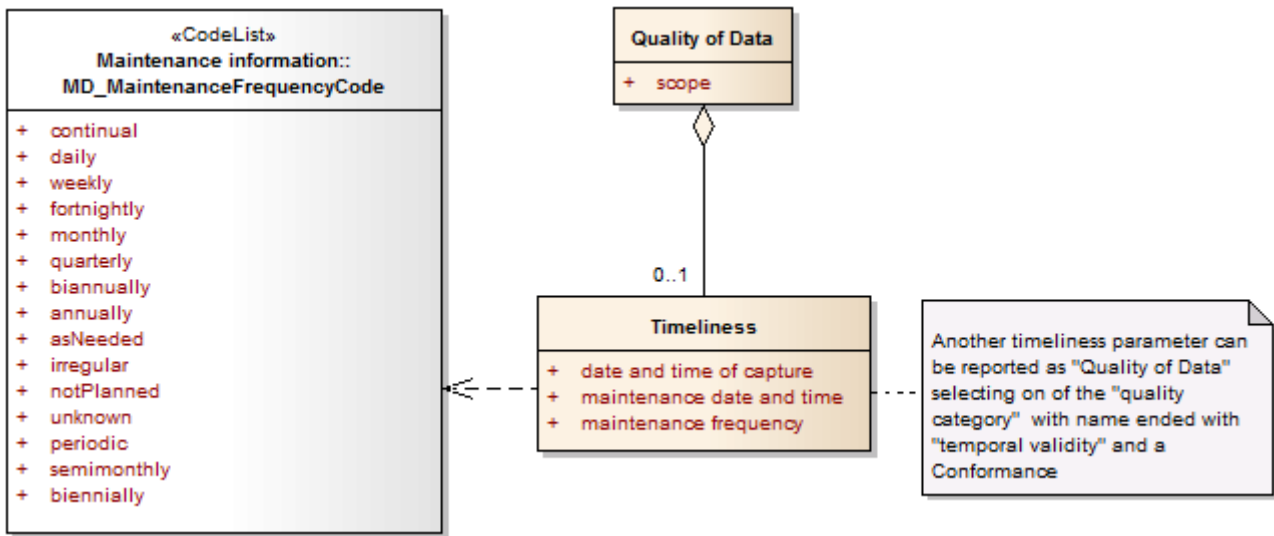


Figure 13. UML Timeliness class diagram (fragment of a SDCM extension)

Moreover, and also very important especially for dataset and service comparison, timeliness is related to quality elements categorized with time validity.

7.2.6. Integrity

Integrity class includes several elements to certify integrity of the data and data authorship, following ICAO and widely used rules:

- crc value
- designated level
- integrity faults (routine, essential or critical levels)

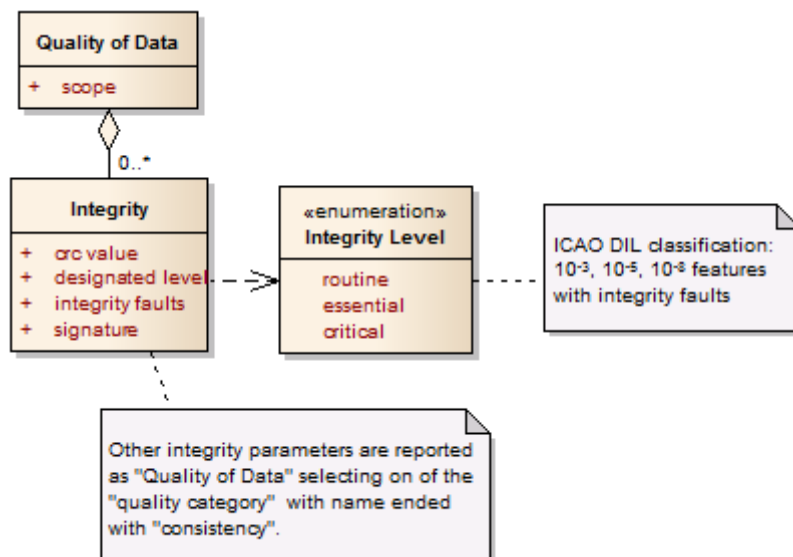


Figure 14. UML Integrity class diagram (fragment of a SDCM extension)

Moreover, and also very important especially for dataset and service comparison, integrity is related to quality elements categorized with several consistency categories, i.e. conceptual consistency, domain consistency, format consistency, topological consistency and temporal consistency.

Chapter 8. Quality of Service parameters related to Quality of Data

8.1. Introduction

SDCM, in its current version, contains a Quality of Service (QoS) class that allows service providers to describe quality parameters of their services within the Web Service Description Documents (WSDD). Nevertheless, no list of such parameters are listed on the SDCM document where only a couple of names for these parameters are given (Table 3.13 1 Quality of Service Attributes [https://www.faa.gov/nextgen/programs/swim/governance/servicesemantics/media/SDCM_v2.0/SDCM_v2.0.html#3.13]: *Examples include: capacity, response time, etc.*).

On the other hand, on the document Preparation of Web Service Description Documents [https://www.faa.gov/nextgen/programs/swim/governance/standards/media/FAA-STD-065A%2007012013%20FINAL.pdf] (FAA-STD-065A, 2013), a list of examples of QoS parameters is given on its Appendix D [4]. This appendix recognizes that WSDD developers may reuse these parameters or provide their own, as well as their own values or range of values.

8.2. FAA-STD-065A parameters

The list of QoS parameters listed on this document are:

Table 18. Examples of Quality of Service (QoS) Parameters provided by "Preparation of Web Service Description Documents" (FAA-STD-065A)

Name	Definition	Method	Unit of Measure	Value or Range of Values
Accuracy	Number of errors produced by the service over a period of time.	Simple count. Measurements are taken daily and apply to the preceding 24-hour period	Whole positive number	250
Availability	Probability that the service is present or ready for immediate use	100 * ((24 – Total Outage Time in Hours) / 24). Measurements are taken daily and apply to the preceding 24-hour period.	Percentage, accurate to 3 decimal places	Greater than or equal to 99.900%
Capacity	Number of service requests that the service can accommodate within a given time period	Simple count	Whole positive number, per period of time	25 per minute

Name	Definition	Method	Unit of Measure	Value or Range of Values
Mean Time Between Critical Failure (MTBCF)	The average time between hardware or software component failures that result in the loss of the service	The sum of the individual times between critical failures divided by the number of critical failures	Hours	Greater than or equal to 3000
Mean Time Between Failure (MTBF)	Average time between hardware or software component failures that do not result in the loss of the service	The sum of the individual times between noncritical failures divided by the number of noncritical failures	Hours	Greater than or equal to 5000
Mean Time To Restore (MTTR)	Average time required to localize a component failure, remove and replace the failed component, and to perform tests to confirm operational readiness of the component	The sum of the individual times to repair divided by the number of repairs	Hours	Less than or equal to 0.5
Response Time	Maximum time required to complete a service request	Measured from the time the provider agent receives the request to the time the service provider transmits the response	Seconds	10

None of these parameters have relation with the quality of the data that is provided by this server. New proposals of QoS parameters are given in the next section as examples of this relation.

8.3. New parameters

The description of these QoS parameters is done using the same structure that is in the FAA-STD-065A document that, in fact, describes the elements of the QoS class in SDCM. The only element that is not provided is a reference value to compare to, as it will be used as a quantitative value to establish an order in service comparison. Moreover, specific values for describing suitable or non suitable services will depend on the application and will be defined by the user (as each application

has certain data requirements). These two group of parameters are complimentary as the first one allows to better understand and better compare values of the second one for different services.

8.3.1. Describing completeness about the quality of the data documentation

The first set of quality parameters refer to the completeness of the server and datasets documentation, taking into account how many datasets of the service provide a specific data quality element.

A similar approach was previously used in GeoViQua project on the description of the [GeoLabel](http://www.geoviqua.org/GeoLabel.htm) [http://www.geoviqua.org/GeoLabel.htm], that is a graphic representation (i.e., a static image) which generated for each dataset based on the quality information that is available for that dataset. This idea evolved and has been later used as a voluntary label part of GEO Data branding strategy to give visibility to the effort data providers put into making their processes conformant with the [Data Management Principles \(DMP\)](http://www.geolabel.info/facets.htm) [http://www.geolabel.info/facets.htm] in the intergovernmental Group on Earth Observations (GEO).



Figure 15. Original GeoViQua GeoLabel (left) and GeoLabel as DMP representation in GEO (right)

In the same line, NOAA defined and uses the [Completeness Rubric](https://geo-ide.noaa.gov/wiki/index.php?title=Completeness_Rubric) [https://geo-ide.noaa.gov/wiki/index.php?title=Completeness_Rubric] in addition to ISO compliance, to provide an extra level of assessment to help metadata authors provide more thorough information about their data [12].

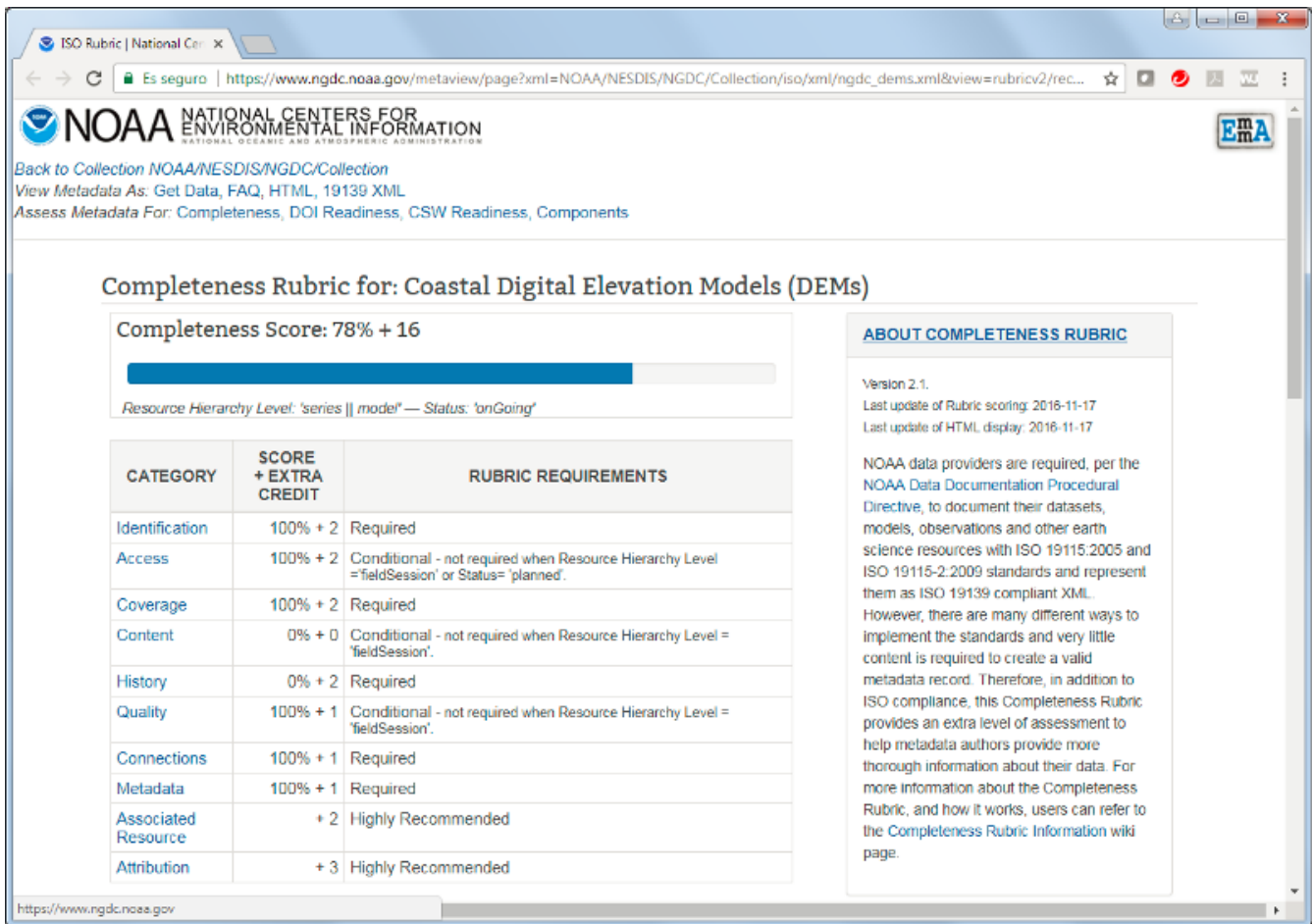


Figure 16. NOAA Completeness Rubric. *Coastal Digital Elevation Models* [https://www.ngdc.noaa.gov/metaview/page?xml=NOAA/NESDIS/NGDC/Collection/iso/xml/ngdc_dems.xml&view=rubricv2/recordHTML] example

Next table describes proposed Quality of Service parameters based on Quality of Data parameters and describing completeness about the quality of the data documentation. There are several parameters that describe completeness of different aspects of the SDMC data quality extension. One table is presented below for each aspect of the data quality extension.

Table 19. Examples of Quality of Service (QoS) Parameters describing service **documentation for Quality elements**

Name	Definition	Method	Related QoD information	Unit of Measure
Quality Category Completeness	Percentage of datasets provided by this service including some quality elements describing a certain quality category ¹	The number of datasets ² including any kind of quality elements describing a certain quality category divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to the selected quality category: <i>Quality Element</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Quantitative Quality Category Completeness	Percentage of datasets provided by this service including a quantitative quality element describing a certain quality category ¹	The number of datasets ² including quantitative quality elements describing a certain quality category divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to the selected quality category and a quantitative result: <i>Quality Element > value</i>	percentage

¹ Possible *quality categories* are: positional accuracy, positional precision, vertical accuracy, quantitative attribute accuracy, quantitative attribute precision, classification correctness, accuracy of a time measurement, temporal validity, completeness commission, completeness omission, topological consistency, domain consistency, conceptual consistency, format consistency, temporal consistency.

² Note that the parameters account for *number of datasets*, not number of quality elements with the explained requirements within the dataset. In other words, a single dataset with more than one quality element for an specific parameter should be counted only once.

Table 20. Examples of Quality of Service (QoS) Parameters describing service **documentation for Resolution**

Name	Definition	Method	Related QoD information	Unit of Measure
Resolution Completeness	Percentage of datasets provided by this service including some resolution information	The number of datasets including any kind of resolution information divided by the number of datasets provided by the service, and multiplied by 100	<i>Positional Resolution, Vertical Resolution, Temporal Resolution and/or Attribute Resolution</i>	percentage
Certain Resolution Completeness	Percentage of datasets provided by this service including some resolution information describing a certain kind of resolution	The number of datasets including a certain kind of resolution information divided by the number of datasets provided by the service, and multiplied by 100	<i>Positional Resolution, Vertical Resolution, Temporal Resolution or Attribute Resolution</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Quantitative Positional Resolution Completeness	Percentage of datasets provided by this service including quantitative positional resolution information	The number of datasets including quantitative positional resolution information divided by the number of datasets provided by the service, and multiplied by 100	<i>Positional resolution > value</i>	percentage ¹
Equivalent Scale Positional Resolution Completeness	Percentage of datasets provided by this service including equivalent scale positional resolution information	The number of datasets including equivalent scale positional resolution information divided by the number of datasets provided by the service, and multiplied by 100	<i>Positional resolution > equivalentScale</i>	percentage ¹

¹ Note that this two percentages may sum up more than 100% as some datasets can have both quantitative and equivalent scale positional resolution described.

Table 21. Examples of Quality of Service (QoS) Parameters describing service **documentation for Traceability**

Name	Definition	Method	Related QoD information	Unit of Measure
Traceability Completeness	Percentage of datasets provided by this service including some traceability information	The number of datasets including any kind of traceability information divided by the number of datasets provided by the service, and multiplied by 100	Traceability elements: <i>Traceability > statement, Data Source, Process Step and/or Originator</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Traceability Data Sources Completeness	Percentage of datasets provided by this service including traceability data sources information	The number of datasets including traceability data sources information divided by the number of datasets provided by the service, and multiplied by 100	<i>Traceability > Data Source</i>	percentage
Traceability Process Step Completeness	Percentage of datasets provided by this service including traceability process steps information	The number of datasets including traceability process steps information divided by the number of datasets provided by the service, and multiplied by 100	<i>Traceability > Process Steps</i>	percentage
<i>Traceability Originator Completeness</i>	<i>Originator not being described on a traceability element does not mean that it is unknown, as in this case it is assumed to be the service provider. Thus, it makes not many sense to include a completeness indicator on this element.</i>			

Table 22. Examples of Quality of Service (QoS) Parameters describing service **documentation for Timeliness**

Name	Definition	Method	Related QoD information	Unit of Measure
Timeliness Completeness	Percentage of datasets provided by this service including some timeliness information	The number of datasets including any kind of timeliness information divided by the number of datasets provided by the service, and multiplied by 100	Timeliness elements: <i>Timeliness > date and time of capture, maintenance date and time, maintenance frequency, and/or Quality Element with quality category equal to time validity</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Date and Time of Capture Completeness	Percentage of datasets provided by this service including date and time of capture information	The number of datasets including date and time of capture information divided by the number of datasets provided by the service, and multiplied by 100	<i>Timeliness > date and time of capture</i>	percentage
Maintenance Date and Time Completeness	Percentage of datasets provided by this service including maintenance date and time information	The number of datasets including maintenance date and time information divided by the number of datasets provided by the service, and multiplied by 100	<i>Timeliness > maintenance date and time</i>	percentage
Maintenance frequency Completeness	Percentage of datasets provided by this service including maintenance frequency information	The number of datasets including maintenance frequency divided by the number of datasets provided by the service, and multiplied by 100	<i>Timeliness > maintenance frequency</i>	percentage
Time validity Completeness	Percentage of datasets provided by this service including some quality elements describing time validity quality category	The number of datasets including any kind of quality element describing time validity quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element with quality category equal to time validity</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Quantitative Time validity Completeness	Percentage of datasets provided by this service including quantitative quality elements describing time validity quality category	The number of datasets including quantitative time validity quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to time validity and a quantitative result: <i>Quality Element > value</i>	percentage

Table 23. Examples of Quality of Service (QoS) Parameters describing service **documentation for Integrity**

Name	Definition	Method	Related QoD information	Unit of Measure
Integrity Completeness	Percentage of datasets provided by this service including some integrity information	The number of datasets including any kind of integrity information divided by the number of datasets provided by the service, and multiplied by 100	Integrity elements: <i>Integrity > crc value, designated level, integrity faults, signature, and/or Quality Element</i> with quality category equal to topological, domain, conceptual, format or temporal consistency	percentage
Crc value Completeness	Percentage of datasets provided by this service including crc value information	The number of datasets including crc value information divided by the number of datasets provided by the service, and multiplied by 100	<i>Integrity > crc value</i>	percentage
Designated level Completeness	Percentage of datasets provided by this service including designated level information	The number of datasets including designated level information divided by the number of datasets provided by the service, and multiplied by 100	<i>Integrity > designated level</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Integrity faults Completeness	Percentage of datasets provided by this service including integrity faults information	The number of datasets including integrity faults information divided by the number of datasets provided by the service, and multiplied by 100	<i>Integrity > integrity faults</i>	percentage
Signature Completeness	Percentage of datasets provided by this service including signature information	The number of datasets including signature information divided by the number of datasets provided by the service, and multiplied by 100	<i>Integrity > signature</i>	percentage
Consistency Completeness	Percentage of datasets provided by this service including some quality elements describing any kind of consistency quality category	The number of datasets including any kind of quality element describing any kind of consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to topological, domain, conceptual, format or temporal consistency	percentage
Quantitative Consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing any kind of consistency quality category	The number of datasets including a quantitative quality element describing any kind of consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to topological, domain, conceptual, format or temporal consistency and a quantitative result: <i>Quality Element > value</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Topological consistency Completeness	Percentage of datasets provided by this service including some quality elements describing topological consistency quality category	The number of datasets including any kind of quality element describing topological consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to topological consistency	percentage
Quantitative Topological consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing topological consistency quality category	The number of datasets including quantitative topological consistency quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to topological consistency and a quantitative result: <i>Quality Element > value</i>	percentage
Domain consistency Completeness	Percentage of datasets provided by this service including some quality elements describing domain consistency quality category	The number of datasets including any kind of quality element describing domain consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to domain consistency	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Quantitative Domain consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing domain consistency quality category	The number of datasets including quantitative consistency quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to domain consistency and a quantitative result: <i>Quality Element > value</i>	percentage
Conceptual consistency Completeness	Percentage of datasets provided by this service including some quality elements describing conceptual consistency quality category	The number of datasets including any kind of quality element describing conceptual consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to conceptual consistency	percentage
Quantitative Conceptual consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing conceptual consistency quality category	The number of datasets including quantitative conceptual consistency quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to conceptual consistency and a quantitative result: <i>Quality Element > value</i>	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Format consistency Completeness	Percentage of datasets provided by this service including some quality elements describing format consistency quality category	The number of datasets including any kind of quality element describing format consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to format consistency	percentage
Quantitative Topological consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing format consistency quality category	The number of datasets including quantitative format consistency quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to format consistency and a quantitative result: <i>Quality Element > value</i>	percentage
Temporal consistency Completeness	Percentage of datasets provided by this service including some quality elements describing temporal consistency quality category	The number of datasets including any kind of quality element describing temporal consistency quality category divided by the number of datasets provided by the service, and multiplied by 100	<i>Quality Element</i> with quality category equal to temporal consistency	percentage

Name	Definition	Method	Related QoD information	Unit of Measure
Quantitative Temporal consistency Completeness	Percentage of datasets provided by this service including quantitative quality elements describing temporal consistency quality category	The number of datasets including quantitative temporal consistency quality category description divided by the number of datasets provided by the service, and multiplied by 100	Quality elements with quality category equal to temporal consistency and a quantitative result: <i>Quality Element > value</i>	percentage

Of course, a high value on these indicators it is not *per se* an indicator that the datasets served by a server are better than others, as the *presence* of documentation has nothing to do with its value (for example a higher or lower attribute accuracy) or its usefulness (having a process step description that says "unknown" or an unintelligible character string identifying a process in a certain software may not be very informative). This needs to be complemented with some quantitative parameters (next section), when possible.

8.3.2. Quantitatively describing service and its datasets

The second set of quality parameters are those quantitatively describing services and their datasets. Several measures can be computed using dataset values for a certain quality parameter, in order to give some insight on how to compare services regarding the quality of its datasets.

For many of the parameters a set of summary statistics (or metrics) can be provided, each of them bringing its approach to the measure. The most common value to summarize is the average (or arithmetic mean) but the count of values is also meaningful to know how many elements this value is representing. The median is also interesting as it may differ from the average depending on the data distribution. Minimum value and maximum value are helpful in order to describe the maximum range of the values for this variable in a certain service. Finally, the standard deviation is also representative as a dispersion measure and, thus, to obtain confidence intervals centered on the average (if a normal distribution is assumed).

As this set of parameters can be used for several quality parameters, its definition is presented once in the next table and then referred to from the table describing the QoS parameters proposed:

Table 24. Summarizing metrics that can be applied to data quality in order to derive Quality of Service (QoS) Parameters

Metrics	Method	Lineal positional accuracy example
Count	Number of datasets that have this information ¹ defined	Number of datasets with a lineal positional accuracy defined
Average	The arithmetic mean (typically just the mean) is what is commonly called the average. The sum of values divided by the number of datasets that have this value defined	The sum of individual lineal positional accuracies divided by the number of datasets that have this value defined

Metrics	Method	Lineal positional accuracy example
Median	The median is described as the numeric value separating the higher half of a sample (or population) from the lower half. The median of a finite list of numbers can be found by arranging all the observations from lowest value to highest value and picking the middle one. If there is an even number of observations, then there is no single middle value, then the average of the two middle values is used. The median is also the 0.5 quantile, or 50th percentile.	The median individual lineal positional accuracies
Minimum	Minimum value of the datasets that have this value defined	The minimum value of individual lineal positional accuracies
Maximum	Maximum value of the datasets that has this value defined	The maximum value of individual lineal positional accuracies
Standard deviation	The standard deviation of a distribution or population is the square root of its variance. The standard deviation is a widely used measure of the variability or dispersion since it is reported in the natural units of the quantity being considered.	The standard deviation of individual lineal positional accuracies

¹ These *summarizing metrics* will be applied to a certain information, for example to quality elements of a certain type (as lineal positional accuracy in the third column in this table), to traceability elements or to resolution elements. The concrete element summarized each time is described in the cent tables in the *Related QoD information* column.

The next table describes proposed Quality of Service parameters based on Quality of Data parameters and describing summary metrics about the quality of the data within a service:

Table 25. Examples of Quality of Service (QoS) Parameters describing service **quantitative parameters for Quality elements**. Each row represents six metrics from the table above.

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
positional accuracy	Circular Error Positional Accuracy	Quality elements with quality category equal to positional accuracy, a quantitative result and a linear or angular unit of measure: <i>Quality Element > value</i>	Measure name: Circular Map Accuracy [http://www.qualityml.org/1.0/measure/CircularMapAccuracy] Measure domain: Differential Errors 2D [http://www.qualityml.org/1.0/domain/DifferentialErrors2D] Measure metrics: Circular Error [http://www.qualityml.org/1.0/metrics/CircularError]	meters or degrees ²

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
vertical accuracy	Half-length Confidence Interval Vertical Accuracy	Quality elements with quality category equal to vertical accuracy, a quantitative result and a linear or angular unit of measure: <i>Quality Element > value</i>	Measure name: Quantitative Attribute Correctness [http://www.qualityml.org/1.0/measure/ QuantitativeAttributeCorrectness] Measure domain: Differential Errors 1D [http://www.qualityml.org/1.0/domain/DifferentialErrors1D] Measure metrics: Half-length Confidence Interval [http://www.qualityml.org/1.0/metrics/ alflengthConfidenceInterval]	meters or degrees ²
quantitative attribute accuracy	Half-length Confidence Interval Quantitative Attribute Accuracy	Quality elements with quality category equal to quantitative attribute accuracy, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element > value</i>	Measure name: Quantitative Attribute Correctness [http://www.qualityml.org/1.0/measure/ QuantitativeAttributeCorrectness] Measure domain: Differential Errors 1D [http://www.qualityml.org/1.0/domain/DifferentialErrors1D] Measure metrics: Half-length Confidence Interval [http://www.qualityml.org/1.0/metrics/ alflengthConfidenceInterval]	units of measure depending on the measured attribute, described in the Quality Scope
classification correctness	Confusion Matrix Classification Correctness	Quality elements with quality category equal to classification correctness, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element > value</i>	Measure name: Misclassification [http://www.qualityml.org/1.0/measure/Misclassification] Measure domain: Predicted Values [http://www.qualityml.org/1.0/domain/predictedValues] and Actual Values [http://www.qualityml.org/1.0/domain/actualValues] Measure metrics: Confusion Matrix [http://www.qualityml.org/1.0/metrics/ConfusionMatrix] ⁴	dimensionless, in percentage or per unit

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
accuracy of a time measurement	Half-length Confidence Interval Temporal Accuracy	Quality elements with quality category equal to accuracy of a time measurement, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Time Accuracy [http://www.qualityml.org/1.0/measurement/TimeAccuracy] Measure domain: Differential Errors 1D [http://www.qualityml.org/1.0/domain/DifferentialErrors1D] Measure metrics: Half-length Confidence Interval [http://www.qualityml.org/1.0/metrics/halflengthConfidenceInterval]	temporal units of measure ²
temporal validity	Temporal validity non conformance	Quality elements with quality category equal to temporal validity, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Value Domain [http://www.qualityml.org/1.0/measurement/ValueDomain] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items] Optional measure parameter: temporal requirement can be set ⁵	temporal units of measure ²
completeness commission	Excess Items completeness commission	Quality elements with quality category equal to completeness commission, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Excess [http://www.qualityml.org/1.0/measurement/Excess] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
	Duplicate Items completeness commission	Quality elements with quality category equal to completeness commission, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Duplicate [http://www.qualityml.org/1.0/measurement/Duplicate] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
completeness omission	Missing completeness omission	Quality elements with quality category equal to completeness omission, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Missing Items [http://www.qualityml.org/1.0/measure/MissingItems] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
	Nodata Areas completeness omission	Quality elements with quality category equal to completeness omission, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Nodata Areas [http://www.qualityml.org/1.0/measure/NodataAreas] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
conceptual consistency	Conceptual schema compliance	Quality elements with quality category equal to conceptual consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Conceptual Schema [http://www.qualityml.org/1.0/measure/ConceptualSchema] Measure domain: Conformance [http://www.qualityml.org/1.0/domain/Conformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
	Conceptual schema non compliance	Quality elements with quality category equal to conceptual consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Conceptual Schema [http://www.qualityml.org/1.0/measure/ConceptualSchema] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
domain consistency	Value Domain compliance	Quality elements with quality category equal to domain consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Value Domain [http://www.qualityml.org/1.0/measure/ValueDomain] Measure domain: Conformance [http://www.qualityml.org/1.0/domain/Conformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
	Value Domain non compliance	Quality elements with quality category equal to domain consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Value Domain [http://www.qualityml.org/1.0/measure/ValueDomain] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
format consistency	Physical structure conflicts	Quality elements with quality category equal to format consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Physical Structure Conflicts [http://www.qualityml.org/1.0/measure/PhysicalStructureConflicts] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit
topological consistency	Faulty point-curve connections	Quality elements with quality category equal to topological consistency, a quantitative result, the same <i>Quality Scope</i> ³ , and units of measure: <i>Quality Element</i> > <i>value</i>	Measure name: Faulty Point-curve Connections [http://www.qualityml.org/1.0/measure/FaultyPoint-curveConnections] Measure domain: Non Conformance [http://www.qualityml.org/1.0/domain/NonConformance] Measure metrics: Items [http://www.qualityml.org/1.0/metrics/items]	dimensionless, in percentage or per unit

Quality Category	Parameter Name	Related QoD information	Measure, domain & metric ¹	Unit of Measure
<p>¹ Documentation of several datasets may use different measure and <i>measure metrics</i>. To compute a meaningful value, values should be only summarized over the same measure and measure metrics. Moreover, if the <i>metrics has parameters</i>, they should also be the same value to be summarized, for example: Circular error or Half-Lenght Confidence interval with the same probability (encoded in "level" parameter for each metric), or Items with the same max parameter (percentage or per unit)</p> <p>² Documentation of several datasets may use different lineal/angular/temporal <i>units of measure</i>. To compute a meaningful value, either values are only summarized over the same UoM or internal unit transformations are computed by the system</p> <p>³ The <i>Quality Scope</i> allows describing the scope of a certain quality element: the dataset, or a certain feature attribute is described with each quality element, for example: FlightObject/Flight/EnRoute/Position/AircraftPosition/position, NavAids Points/NavAids/Azimuth/trueBearingAccuracy, Routes/En-route/Route/type, etc.</p> <p>⁴ <i>Confusion Matrix</i> metrics can not be summarized if predicted and actual values are not the same, but presumably they would be the same if they are representing the same feature attribute.</p> <p>⁵ <i>Temporal requirement</i> can be set as a parameter of the measure, as explained in previous sections (temporal validity for timeliness).</p>				

Table 26. Examples of Quality of Service (QoS) Parameters describing service **quantitative parameters for Resolution**. Each row represents six metrics from the table above.

Name	Related QoD information	Unit of Measure
Certain resolution summary	Certain resolution element with a quantitative result and the same units of measure: <i>Positional Resolution, Vertical Resolution, Temporal Resolution</i> and/or <i>Attribute Resolution > value</i>	certain units of measure ¹
Equivalent scale positional resolution summary	Positional resolution with an Equivalent scale information <i>Positional Resolution > equivalenScale</i>	dimensionless
<p>¹ Documentation of several datasets and certain resolution types may use different <i>units of measure</i>. To compute a meaningful value, either values are only summarized over the same UoM or internal unit transformations are computed by the system</p>		

Table 27. Examples of Quality of Service (QoS) Parameters describing service **quantitative parameters for Timeliness**. Each row represents six metrics from the table above.

Name	Related QoD information	Explanation
Date and time of capture	<i>Timeliness > date and time of capture</i>	For a service, statistics can be summarized using date and time of capture to describe its minimum value (older dataset), maximum value (most current dataset), its average, etc

Name	Related QoD information	Explanation
Maintenance date and time	<i>Timeliness > maintenance date and time</i>	For a service, statistics can be summarized using maintenance date and time to describe its minimum value (dataset updated the less recently), maximum value (dataset updated the most recently), its average, etc
Maintenance frequency mode	<i>Timeliness > maintenance frequency</i>	In this case, as this is a categorical metadata element, the mode can of several datasets for a service can be described
Maintenance frequency histogram	<i>Timeliness > maintenance frequency</i>	Moreover, even an histogram showing how many datasets of each maintenance frequency are distributed within a service can be provided

Appendix A: Unified Modeling Language (UML) model

The Unified Modeling Language (UML) model including SDMC extension described this ER is included in a ZIP file on the UML folder of the ER repository on GitHub, and can be found in the [OGC® Public Engineering Report Repository](http://docs.opengeospatial.org/per/17-018.zip) [http://docs.opengeospatial.org/per/17-018.zip]. The following figure presents the UML diagram of the SDMC extension for describing Data Quality.

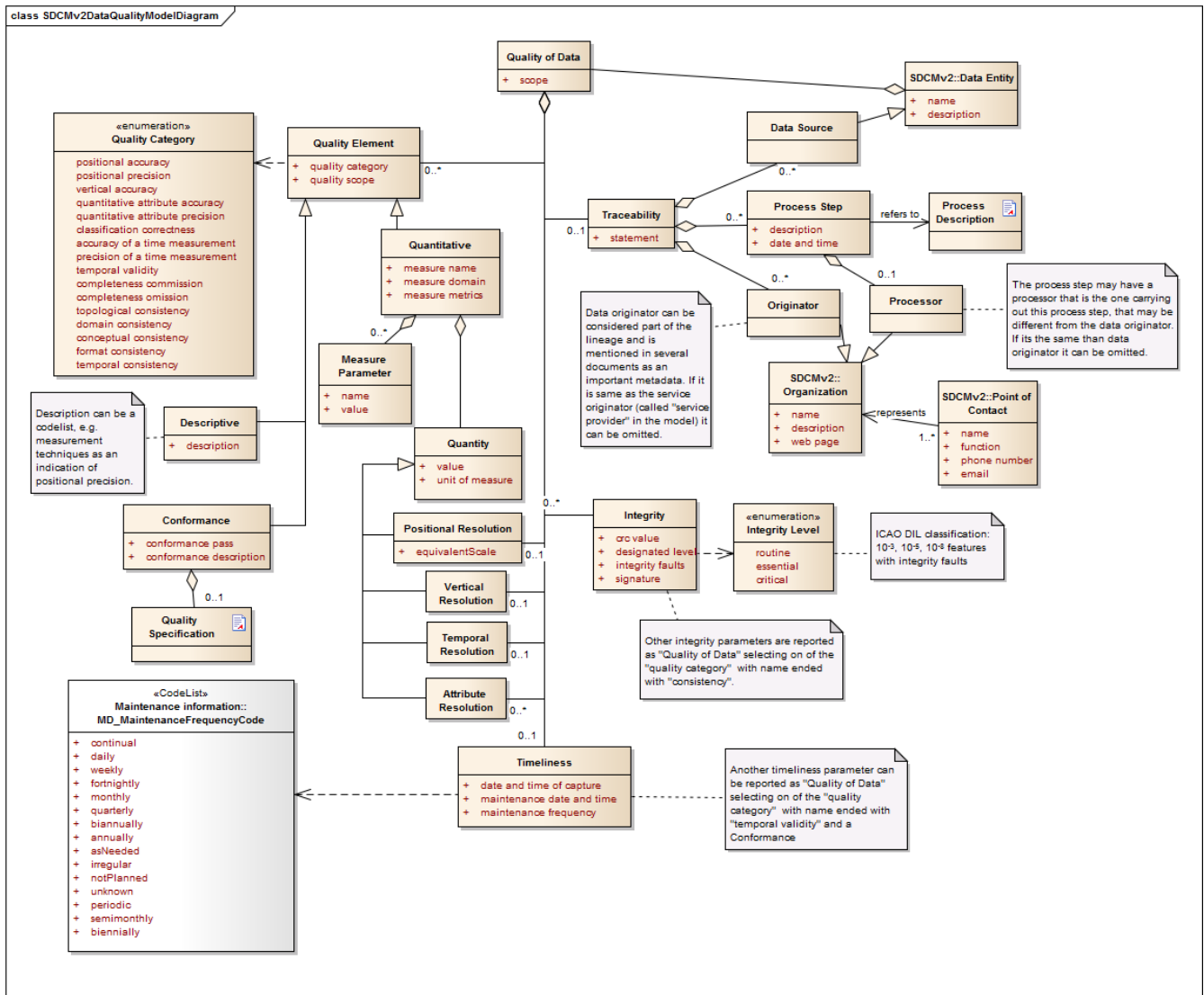


Figure 17. UML diagram of a SDMC extension to describe Data Quality

Appendix B: Revision History

Revision History

Date	Release	Editor	Primary clauses modified	Descriptions
June 30, 2017	A. Zabala	0.1	all	initial version
September 30, 2017	A. Zabala	0.7	various	final content for most sections
October 19, 2017	A. Zabala	0.8	various	preparation for publication (section 8: some content is left, main structure and general ideas described)
October 25, 2017	A. Zabala	0.9	various	Greg Buehler comments included, section 8 improved
October 31, 2017	A. Zabala	1.0	various	Final version for all sections. Gobe Hobona comments included.

Appendix C: Bibliography

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