ETSI TR 104 180 V1.1.1 (2026-05)



TECHNICAL REPORT

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Development and identification of Data Quality Metrics

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Data Solutions (DATA).

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Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

The present document establishes a standardized framework for data quality assessment to ensure reliability in digital and AI ecosystems. It defines 18 Data Quality Metrics, providing formal definitions and mathematical formulas for quantitative measurement across intrinsic and contextual dimensions.

Through empirical case studies on Industrial IoT and Demographic data, the present document validates the applicability of these metrics while demonstrating that effective assessment relies heavily on domain-specific contexts and metadata availability.

Based on these findings, the present document recommends two key future standardization activities:

- Transitioning the definitions and descriptive examples into a normative TS to ensure interoperability.
- Developing standardized Test Methodologies and Test Formulas for automated and reproducible verification of data.

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1 Scope

The present document introduces quality metrics for data for future standardization. It focuses on identifying key properties of data quality including trustworthiness (e.g. completeness, accuracy, bias, reliability, redundancy, source reliability and integrity) and formulating standardized methods to assess these properties.

The present document refers to developed standard specifications related to data quality and collaborates with standards bodies & groups working on data, security and AI trustworthiness (e.g. ETSI TC SAI, JTC 21).

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] ISO/IEC 25012:2008: "Software engineering — Software product Quality Requirements and Evaluation (SQuaRE) — Data quality model".

[i.2] Hitzler P, Zaveri A, Rula A, et al.: "Quality assessment for Linked Data: A Survey: A systematic literature review and conceptual framework". Semantic Web. 2015;7(1):63-93. doi:10.3233/SW-150175.

[i.3] Recommendation ITU-T E.800: "Definitions of terms related to quality of service".

[i.4] ISO/IEC 23988:2007: "Information technology — A code of practice for the use of information technology (IT) in the delivery of assessments".

[i.5] ISO/IEC 25010:2023: "Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Product quality model".

[i.6] ISO/IEC 16350:2015: "Information technology — Systems and software engineering — Application management".

[i.7] Recommendation ITU-T Y.3605: "Big data - Reference architecture".

[i.8] IEEE 610.12-1990™: "IEEE Standard Glossary of Software Engineering Terminology".

[i.9] ISO 19157-1:2023: "Geographic information — Data quality — Part 1: General requirements".

[i.10] IEEE 100™: "The Authoritative Dictionary of IEEE Standards Terms".

[i.11] Recommendation ITU-T X.1252: "Baseline identity management terms and definitions".

[i.12] ISO 8000-61:2016: "Data quality — Part 61: Data quality management: Process reference model".

[i.13] Recommendation ITU-T Y.3600: "Big data – Cloud computing based requirements and capabilities".

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[i.14] ISO/IEC 11179-1: "Information technology — Metadata registries (MDR) — Part 1: Framework".

[i.15] ISO/IEC 5259-4: "Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 4: Data quality process framework".

[i.16] Recommendation ITU-T X.1601: "Security framework for cloud computing".

[i.17] NIST SP 800-53: "Security and Privacy Controls for Information Systems and Organizations".

[i.18] ISO/IEC 20889:2018: "Privacy enhancing data de-identification terminology and classification of techniques".

[i.19] ISO/IEC 29100:2024: "Information technology — Security techniques — Privacy framework".

[i.20] ISO/IEC TR 24027:2021: "Information technology — Artificial Intelligence (AI) — Bias in AI Systems and AI aided decision making".

[i.21] ISO/IEC 27001:2022: "Information security, cybersecurity and privacy protection — Information security management systems — Requirements".

[i.22] IEEE 7003:2024™: "IEEE Standard for Algorithmic Bias Considerations".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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3.2 Symbols

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3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AI	Artificial Intelligence
BRCR	Business Rule Consistency Rate
CCR	Calculation Consistency Rate
CDE	Critical Data Element
CS	Consistency Score
CV	Coefficient of Variation
CVR	Consistency Violation Rate
DC	Duplicate Count
DIR	Disparate Impact Ratio
DRR	Duplicate Record Rate
DSR	Data Synchronization Rate
FCR	Format Consistency Rate
GDPR	General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
IIoT	Industrial Internet of Things
IoT	Internet of Things
LCR	Logical Consistency Rate
MAE	Mean Absolute Error
MDAR	Master Data Alignment Rate
ML	Machine Learning
MSE	Mean Squared Error
NIST	National Institute of Standards and Technology
PII	Personal Identifiable Information

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PIPA	Personal Information Protection Act
POS	Point of Sale
RAID	Redundant Array of Independent Disks
RICR	Referential Integrity Consistency Rate
RMSE	Root Mean Squared Error
RRR	Record Redundancy Ratio
SCE	Source Consistency Error
SLA	Service Level Agreement
TCR	Timeliness Compliance Rate
TS	Temporal Stability
US	Uniqueness Score

4 General Principles of Data Quality Metrics

This clause describes fundamental principles applicable to the definition and assessment of data quality metrics within the scope of the present document. These principles guide the development and application of data quality metrics to ensure they are meaningful, consistent, and actionable across different data contexts:

- Purpose: Metrics are defined and interpreted according to specific data usage scenarios, business needs or regulatory requirements. Relevance is context-dependent.
- Measurable: Every metric is accompanied by a clear, repeatable measurement approach, preferably with a quantitative formula or method to ensure objective assessment.
- Scalable: Metrics are applicable at various levels of granularity (attribute, record, dataset) and scalable to large or high-velocity data environments.
- Interpretable: Results are understandable to both technical and non-technical stakeholders, and indicate not only a score but also potential corrective actions.
- Metadata-aware: Many metrics rely on external information such as business rules, data definitions, and lineage. Dependencies on metadata are explicitly acknowledged.
- Ethical: Metrics related to bias, privacy and fairness need to be considered in the present document.
- Evolvable: The set of metrics and their definitions are better to be periodically reviewed and refined based on practical experience, technological changes, and evolving standards.
- AI/ML Training dataset: Metrics for data used in AI and ML can be considered with additional dimensions such as label quality, representational bias, as these directly impact model performance and fairness.

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5 Data Quality Metrics

5.1 Completeness

5.1.1 Definition

Completeness refers to the degree to which all required or expected data values are present and available for a given purpose. It quantifies the absence of missing information, ensuring that a dataset contains all the necessary attributes and records to adequately represent the phenomena it describes or to fulfil the requirements of a specific task (e.g. model training, validation, or inference). In the context of a feature set for an AI/ML model, completeness ensures that all relevant features for each observation are populated. For a time-series dataset, it pertains to the presence of data points at expected intervals.

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- ISO/IEC 25012:2008 [i.1]: Completeness refers to the degree to which subject data associated with an entity has values for all expected attributes and related entity instances in a specific context of use.
- Hitzler P et al. [i.2]: Completeness refers to the degree to which all required information is present in a particular dataset.

5.1.2 Measurement Formula

The completeness of a dataset can be measured at various granularities (e.g. attribute-level, record-level, or dataset-level). A common approach to quantify completeness for an attribute or a set of required attributes within a dataset is as follows:

- Let D be a dataset with N records (rows) and M attributes (columns).
- Let A_j be the j^{th} attribute in the dataset, where $j \in \{1,2,...,M\}$.
- Let I_{ij} be an indicator variable such that:
  - I_{ij}=1 if the value for record i and attribute j is present (not null/missing).
  - I_{ij}=0 if the value for record i and attribute j is missing (null/empty).

Attribute Completeness (C_A): The completeness of a specific attribute A_j is given by the ratio of present values for that attribute to the total number of records:

$$C_{Aj} = \frac{\sum_{i=1}^{N} I_{ij}}{N}$$

Record Completeness (C_R): The completeness of a specific record R_i (considering a set of K required attributes within that record) is given by the ratio of present values for the required attributes in that record to the total number of required attributes:

$$C_{R_i} = \frac{\sum_{j \in Required_Attributes} I_{ij}}{K}$$

Dataset Completeness (C_D): The overall completeness of the dataset, considering all N records and M attributes (or a subset of M_{req} required attributes), can be defined as the average attribute completeness or the total proportion of non-missing values:

$$C_D = \frac{\sum_{j=1}^{M_{req}} \sum_{i=1}^{N} I_{ij}}{N \times M_{req}}$$

Where M_{req} is the number of attributes deemed "required" for the dataset's intended use.

5.1.3 Example

Consider a dataset collected for a predictive maintenance model for industrial machinery, specifically focusing on pump performance. The dataset aims to predict potential failures based on operational parameters. Assume the following attributes are deemed required for each operational log record: `Timestamp`, `PumpID`, `Temperature_C`, `Vibration_mm_s`, `Pressure_kPa`.

A dataset snippet consisting of five operational log records for a single pump (`PumpID: P001`) is presented below.

Table 5.1.3-1: Example of a dataset for illustrating the Completeness property

Index	Timestamp	PumpID	Temperature_C	Vibration_mm_s	Pressure_kPa
1	2024-06-25 10:00:00	P001	45,2	1,5	500
2	2024-06-25 10:05:00	P001	45,8	1,7	505
3	2024-06-25 10:10:00	P001	46,1	NaN	510
4	2024-06-25 10:15:00	P001	NaN	1,6	508
5	2024-06-25 10:20:00	P001	47,0	1,8	NaN

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Here, N=5 records and M_{req}=5 required attributes.

Attribute Completeness Example:

1) Completeness of `Vibration_mm_s`:
   - Missing in Record 3
   - Present in 4 out of 5 records
   - $C_{Vibration_mm_s}$ = (4/5) × 100 % = 80 %
2) Completeness of `Temperature_C`:
   - Missing in Record 4
   - Present in 4 out of 5 records
   - $C_{Temperature_C}$ = (4/5) × 100 % = 80 %

Record Completeness Example:

1) Completeness of Record 3 (Required attributes: 5):
   - Vibration_mm_s is missing
   - Present values: 4 out of 5 records
   - C_{R3} = (4/5) × 100 % = 80 %
2) Completeness of Record 4 (Required attributes: 5):
   - Temperature_C: is missing
   - Present values: 4 out of 5 records
   - C_{R4} = (4/5) × 100 % = 80 %

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Overall Dataset Completeness Example (overall for required attributes):

- Total expected values ($N \times M_{req}$) = 5 × 5 = 25
- Total missing values: 3 (one in `Temperature_C`, one in `Vibration_mm_s` and one in `Pressure_kPa`)
- Total present values = 25 - 3 = 22
- C_D = 22/25 × 100 % = 88 %

5.2 Reliability

5.2.1 Definition

Reliability refers to the degree to which data can be trusted to be consistent, stable, and free from unexpected variations over time and across different sources. It measures the dependability of the data generation and collection processes, ensuring that the data produced is accurate, reproducible, and fit for its intended use under stated conditions. In the context of AI/ML systems, reliable data ensures that models are trained and evaluated on a consistent foundation, reducing the risk of performance degradation due to data drift or source inconsistencies.

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- Recommendation ITU-T E.800 [i.3]: Reliability refers to the probability that an item can perform a required function under stated conditions for a given time interval.
- ISO/IEC 23988:2007 [i.4]: Consistency with which an assessment measures.
- ISO/IEC 25010:2023 [i.5]: Capability of a product to perform specified functions under specified conditions for a specified period of time without interruptions and failures.
- ISO/IEC 16350:2015 [i.6]: Degree to which an object or an object's services provide agreed or expected functionality during a defined time period under specified conditions.

5.2.2 Measurement Formula

Reliability can be assessed through various lenses, such as source consistency, temporal stability, and reproducibility. A common approach involves measuring the variance or error rate from an expected baseline or across multiple sources.

Let *S* be a data source producing a stream of values for a specific attribute over time.

Let X_i be the value of the attribute at time *i*.

Let E_i be the expected or reference value for the attribute at time *i* (which could be a known ground truth, a value from a trusted source, or a predicted value from a stable model).

Source Consistency Error (SCE) for a single source over *N* observations can be measured as the Mean Absolute Error (MAE).

$$SCE_{MAE} = \frac{1}{N}\sum_{i=1}^{N}|X_i - E_i|$$

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Temporal Stability (TS) can be measured for a source by calculating the Coefficient of Variation (CV) for a specific attribute over a defined time window, indicating how much the data fluctuates relative to its average value:

$$TS_{CV} = \frac{\sigma\chi}{\mu\chi} \times 100\ \%$$

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Where:

- $\sigma\chi$ is the standard deviation of the attribute values over the time period.
- $\mu\chi$ is the mean of the attribute values over the time period.

A lower CV indicates higher temporal stability.

5.2.3 Example

Consider two sensors (Sensor A and Sensor B) measuring the temperature of a critical machine component every hour. The expected temperature, based on a calibrated laboratory standard, is also recorded.

Table 5.2.3-1: Example of a dataset for illustrating the Reliability property

Index	Time	Expected Temp (°C)	Sensor A (°C)	Sensor B (°C)
1	10:00	75,0	75,2	74,8
2	11:00	75,0	76,1	75,0
3	12:00	76,0	76,0	75,5
4	13:00	76,0	77,0	76,0
5	14:00	75,5	75,4	75,8

Source Consistency for Sensor A:

$$\boldsymbol{SCE_{MAE}} = \frac{1}{5}(|75{,}2 - 75{,}0| + |76{,}1 - 75{,}0| + |76{,}0 - 76{,}0| + |77{,}0 - 76{,}0| + |75{,}4 - 75{,}5|) = 0{,}48\ (°C)$$

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