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# Big Data Quality Assurance Through Data Traceability: A Case Study of the National Standard Reference Data Program of Korea

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**ABSTRACT** In the era of big data, the scientific and social demand for quality data is aggressive and urgent. This paper sheds light on the expanded role of metrology of verifying validated procedures of data production and developing adequate uncertainty evaluation methods to ensure the trustworthiness of data and information. In this regard, I explore the mechanism of the national standard reference data (SRD) program of Korea, which connects various scientific and social sectors to metrology by applying useful metrological concepts and methods to produce reliable data and convert such data into national standards. In particular, the changing interpretation of metrological key concepts, such as "measurement," "traceability," and "uncertainty," will be explored and reconsidered from the perspective of data quality assurance. As a result, I suggest the concept of "data traceability" with "the matrix of data quality evaluation" according to the elements of a data production system and related evaluation criteria. To conclude, I suggest social and policy implications for the new role of metrology and standards for producing and disseminating reliable knowledge sources from big data.

**INDEX TERMS** Big data, data quality, data traceability, metrology, standard reference data, uncertainty.

## I. INTRODUCTION

### A. OPPORTUNITIES AND CHALLENGES OF BIG DATA

Ever since Gartner analyst Doug Laney introduced the three dimensions of the challenges in big data (i.e., volume, velocity, and variety) in 2001,[1] a multitude of significant computational and information technologies have been developed to address these challenges, including cloud computing, Internet of Things (IoT), and various open-source software frameworks for data storage. With these technologies as a basis, advanced analytical techniques and methodologies, also known as 'data science,' show great potential in evolving from descriptive and predictable analytics to prescriptive analytics [1]. In particular, the emergence of machine learning and artificial intelligence (AI) generates new opportunities for specialized future applications of large-scale scientific and social big data in various fields.

Despite the evolution of data science, the ultimate goal of extracting actionable insight has yet to be fully realized due to the crucial challenges arising from uncertainties inherent in big data regarding inconsistency, incompleteness, accuracy, and reliability [2]. These uncertainties are commonly understood as matters of 'data quality' or the fourth dimension of big data, 'veracity,' without the biases, noise, and abnormality in data [3]–[5]. However, uncertainties of big data exist in every stage of data generation, data collection, data processing, data analytics, and data application [6]. For the transition from insights to values, the existing user-centered, top-down data quality management approach that is focused on 'produced data' (for example, ISO 8000 standards for data quality series)[2] is insufficient for the management of the uncertainties of big data. In order to be accepted for use as rigorous evidence in actionable decision-making, the measurement and collection of valid data are important. This requires an evaluation of the accuracy and reliability of the data

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[1]Laney D (2001) 3-d data management: controlling data volume, velocity and variety. META Group Research Note, Feb. 6. [Online] Available: https://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf

[2]ISO 8000, the international standard for data quality and enterprise master data, is being developed by ISO technical committee TC 184/SC 4 Industrial data. [Online] See https://www.iso.org/committee/54158.html

generation process [7]: Is the measurement value accurate? Are the data produced through accepted scientific protocols and methods? How is the data production process managed and supervised? Such process and methodology problems are linked to the matter of reproducibility, which indicates the quality and robustness of experimental or measurement data and protocols [8]. As such, confirming 'valid' data among 'available' big data becomes an important condition for both of data producers and consumers in terms of confidence in data for future application and usage.

### B. LOCATING METROLOGY AT THE CENTER OF THE BIG DATA ERA

The new role of metrology arises with the surge of the Fourth Industrial Revolution and digitalization to provide a metrological method to verify the accuracy and reliability of large quantities of data in various fields [9]–[12]. Here, metrology refers to expanded measurement activities that involve determining and documenting the accuracy and reliability of measurement data and disseminating that knowledge. For example, the recent issues of medical imaging big data have highlighted measurement matters in terms of accuracy and reliability during the conversion of unstructured medical images into quantitative imaging data. Quantification or measurement activities for the comparison and calculation of medical imaging calls for expanded metrological concepts and methods as a common language to manage uncertainties in medical imaging big data [13]. This is indispensable for the sharing of understandings on measurement subjects and methods as well as when coming to an agreement on measurement results [14]. However, the present challenges faced by regional and international metrology communities involve expansions in measurement area, scope, and the variety of measurement subjects. Beyond comparability work for data sharing and combining within the same domain, commensurability and interoperability work among heterogeneous measurement data of different disciplines becomes indispensable for the generation of meaningful insights for decision-making [15]. Global efforts for the unification of measurements extend from the realm of physical science to biomedical, behavioral, and social science fields, with the new task of measuring dynamic and heterogeneous quantities [16], [17].

References [18]–[21] argue that a new key role of metrology in the big data era is to ensure data reliability for efficient decisions in connection with uncertainty management. According to these studies, the new metrological function is to master the various factors of uncertainty 'at the right cost' by taking into account various uncertainty elements and calculating a conformity zone as required. Then, how can we decide what factors should be dropped or added to calculate the right cost? How can it assure the quality of the measurement data for each factor? In regard to this, [20] and [21] show an analytical model and method using the concept of measurement uncertainty to achieve reliable decision-making.

This paper examines the mechanism of the national standard reference data (SRD) program of Korea as an expanded metrological approach for data quality assurance. Drawing on the case of the Korean SRD program, I suggest the concept of data traceability, which refers to a documented auditable chain of a data production system with a comprehensive data uncertainty statement, and the matrix of data quality evaluation. The last section makes conclusions with the new role of metrology and standards to address the matter of big data quality.

## II. AN EXPANDED METROLOGICAL APPROACH TO CERTIFIED REFERENCE DATA

### A. THE DEFINITION AND ORIGIN OF SRD

The International Vocabulary of Metrology – basic and general concepts and associated terms (VIM), which is an international guide for metrology, defines SRD as ''data related to a property of a phenomenon, body, or substance, or a system of components of known composition or structure, obtained from an identified source, critically evaluated, verified for accuracy, and issued by a recognized authority'' [22]. However, the original concept and implementation examples can be found in legal documents of the United States and the Soviet Union in the mid-1960s. The United States and the Soviet Union began to institutionalize SRD through the 'Standard Reference Data Act' (11 July 1968, Public Law 90-396)[3] and 'Regarding Improvements in Standardization Activities Nationwide' (11 January 1965, Union of Soviet Socialist Republics Council of Ministers Decree 16),[4] respectively. The laws describe the definition and scope of SRD and state the authorized department and its integration and coordination activities for the collection, compilation, critical evaluation, publication, and sale of SRD. The Act and Decree were established so that the application of reliable, standardized scientific and technical reference data could result in reduced research periods and fewer repetitive experiments.

### B. NATIONAL SRD PROGRAM OF KOREA

In 1999, the Korean government legislated the legal framework for the development and promotion of national standards including standard reference data.[5] The enforcement ordinance of the Framework Act authorized the national metrology institute, Korea Research Institute of Standards and Science (KRISS), to be responsible for the collection, evaluation, and distribution of SRD using its metrological

[3][Online] Available: https://www.nist.gov/sites/default/files/documents/srd/publiclaw90-396.pdf

[4]The Russian National Standard Reference Data Service (NSRDS) was established in 1965 as per USSR Council of Minister Decree no.16 'Regarding Improvements in Standardization Activities Nationalwide'.

[5]Framework Act on National Standards 15643, Feb. 8, 1999. [Online] Available: http://www.law.go.kr/lsInfoP.do?lsiSeq=199522&chrClsCd=010203& urlMode=engLsInfoR&viewCls=engLsInfoR#0000

 

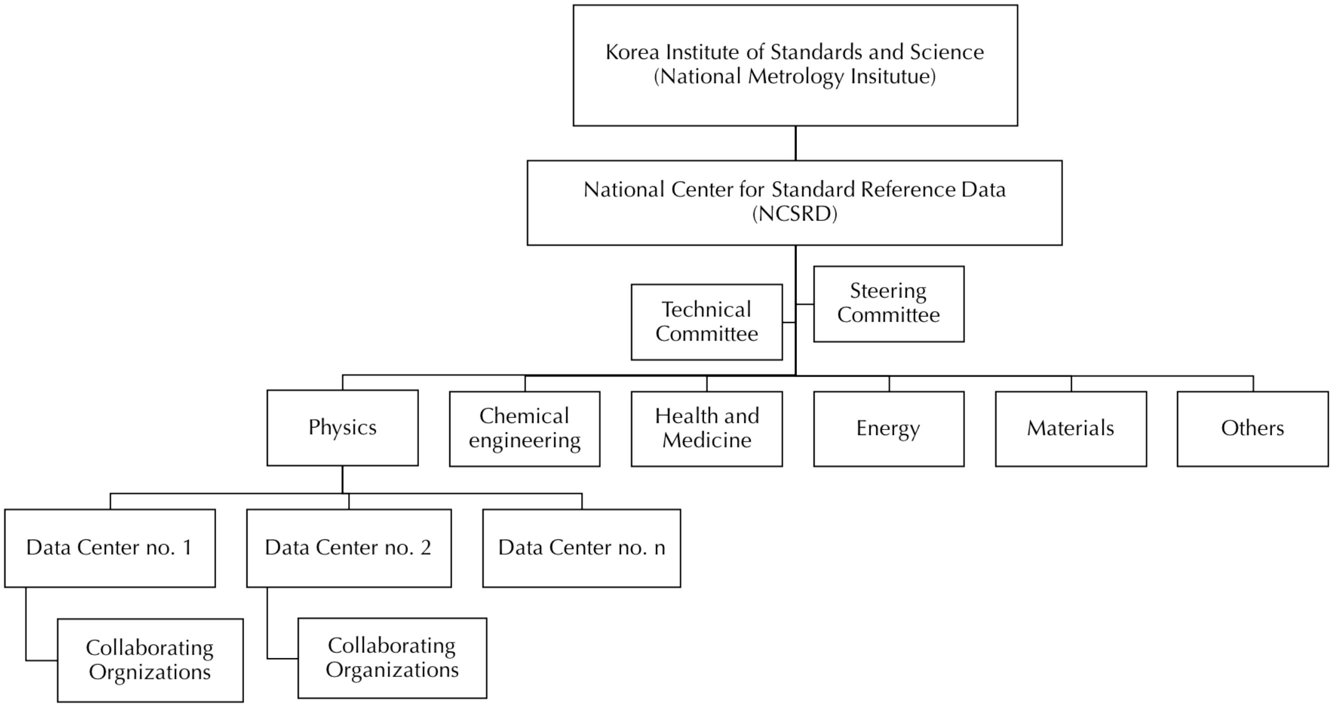


**FIGURE 1.** **Structure of the Korean standard reference data program.[9]**

expertise.[6] The institutionalization and implementation of SRD activities was initiated in 2006 with the establishment of the National Center for Standard Reference Data (NCSRD) within KRISS. On behalf of the government, NCSRD was placed in charge of the development and dissemination of SRD by producing data evaluation guidelines and fostering candidate national data centers for SRD production. As a result of a series of preliminary studies[7] by researchers of KRISS, the Code of SRD Development and Distribution (Ministry of Trade, Industry and Energy Public Notification 2006-86)[8] was created and proclaimed to implement a national SRD program. Fig. 1 describes the implementation structure of the SRD program, which is comprised of three parts: the steering committee that is the top decision-making body, the technical committees that deal with the technical issues of data-related matters, and data centers in charge of SRD production.

As a unique feature of the Korean SRD program, every technical committee should include metrologists in the subject field as uncertainty experts. This is to ensure that an internationally-accepted measurement uncertainty evaluation method is applied as a reference in various fields to ensure uniformity and objectivity. While there are no specific licenses or tests for such experts in Korea, KRISS researchers with adequate knowledge and experience on uncertainty provide related lectures to the general public and other domain experts. The role of uncertainty experts in data verification is not to develop new uncertainty formulas, but rather help data centers develop uncertainty evaluation methods and approve results by employing their metrological expertise. Thus, data centers can adapt the concept of measurement uncertainty to articulate and manage uncertainties in their data. By enlisting and collaborating with various social and industrial actors as data centers and committee members, KRISS expands the implementation fields and subjects to various types of measurement data and information.

### *C. RECONSIDERATION OF KEY METROLOGICAL CONCEPTS FOR DATA VERIFICATION*

For the past ten years, approximately 43,000 databases have been developed and registered as national SRD in the scientific, social, and industrial fields (see Fig. 2).

The core mechanism of the SRD program is to verify data accuracy and reliability by applying the concept of measurement uncertainty and traceability. For this, the Code of SRD applies major guides of metrology, VIM and GUM, as well as managerial and technical guides on measurement activities such as ISO 17025 and 9001 to create a rigorous yet effective pathway for developing certified national SRD.

[6]Enforcement Decree of the Framework Act on National Standards 29345, Jul. 29, 1999. [Online] Available: http://www.law.go.kr/lsInfoP.do?lsiSeq=205698&ancYd=20181211&ancNo= 29345&efYd=20181213&nwJoYnInfo=Y&efGubun=Y&chrClsCd=010202#0000

[7]Since publishing the first domestic policy report about SRD in 1982, KRISS annually conducted 'A Study on the Development of a National Standard Reference Data System' for three years to design a base model for the Korean national SRD system. The study results became a foundation for legal frameworks and the national code of SRD development and distribution.

[8][Online] Available: http://www.motie.go.kr/motie/ms/nt/gosi/bbs/bbsView.do?bbs_seq_n=15836& bbs_cd_n=5&currentPage=11&search_key_n=title_v&cate_n=&dept_v=&search_val_v=

[9][Online] Available: https://www.srd.re.kr:446/centerintro/intro.do

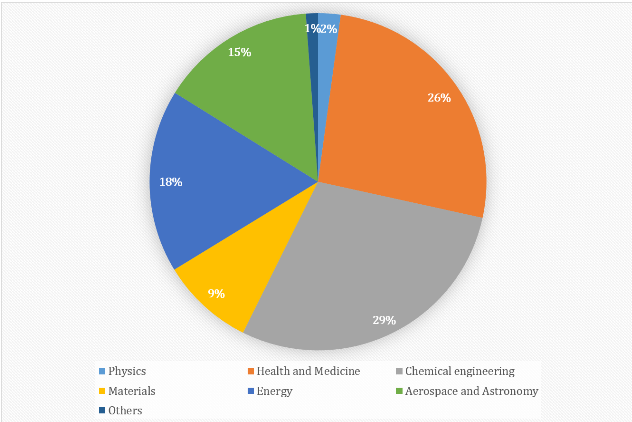


**FIGURE 2.** Distribution of standard reference data registration rate by discipline (as of December 2017).

In addition, NCSRD expands the original concept of SRD to cover not only measurement data of material properties, which are countable entities, but also observation data of nominal properties without magnitude, such as digital information and imaging data.

This new metrological approach for data verification is grounded upon the progressive expansion of the philosophies and descriptions of measurement, as shown by the changes in VIM. In particular, the 3$^{rd}$ edition of VIM (2008, 2012) has several distinctive features as summarized by chemist and metrologist Paul De Bièvre in his introduction article on VIM 3 [23]. According to De Bièvre, a notable change in VIM 3 was the description of an inclusive conceptual definition of metrology instead of a fixed terminological definition. Therefore, shared concepts can be translated into a similarly understood term in different languages. Second, the transition from an error approach to an uncertainty approach redefined the objective of measurement. In the uncertainty approach, the objective of measurement is not to determine 'a true value', but rather to assign 'an interval of reasonable values to the measurand' [22]. Third, VIM 3 describes its potential for application in various disciplines and cases as it includes the following definition: "metrology includes all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application" [22]. These changes in basic and general metrological concepts and methods promote NCSRD to expand the realm of measurement by encompassing a wide range of measurement purposes and areas.

For data accuracy and reliability, metrological concepts and methods provide important logic for data evaluation, but the general definitions of measurement, uncertainty, and traceability are reconsidered by expanding the subject and purpose of measurement. The SRD mechanism places its metrological focus on obtaining reliable reference data from verified sources of big data, which have various forms of experimental and interpretive observation values. For data verification, the Code of SRD suggests 10 technical evaluation criteria as follows:

1) Is the specification or identification of the measurement subject sufficient for the purpose?
2) Are the descriptions of the measurement method and procedure sufficient?
3) Has the adequacy of the measurement method been specified with a supporting basis?
4) Are factors that affect the measurement result being controlled?
5) Are the detailed measurement procedures and the conditions to reproduce the measurement specified?
6) Is the measurement method verified by uncertainty evaluation and metrological traceability?
7) Is the uncertainty estimation of the measurement results appropriate?
8) Do the measurement results agree with other values reported independently for the same measurand?
9) Is (measurement) data prediction through mathematical calculation or predictive modeling possible?
10) Have the results undergone comprehensive independent review by at least two members of third parties in the subject field?

The above criteria can be classified into two groups according to the evaluation purposes. Criteria 1, 2, 3, 4, 5, and 9 are evaluated by considering the candidate data provides sufficient and adequate information for data 'reproducibility'. Criteria 6, 7, 8, and 10 are for evaluating data 'comparability' and 'credibility' through expert reviews. Although the suggested technical criteria for data evaluation is derived from 'Data Evaluation Theory and Practice for Materials Properties' of NIST in 2003, it is targeted for various scientific, industrial, and social sectors, as described in Fig. 2. By emphasizing 'a documented traceable chain of a data production system' and allowing 'flexible interpretations of data evaluation criteria', the SRD program becomes a data certificate apparatus in Korea. In this sense, the function of the SRD mechanism can be understood as *a process of specifying and standardizing various types of data evaluation methods and criteria* according to the different data characteristics and various data application purposes.

However, the key concepts and related criteria of the present SRD mechanism should be refined to apply to big data quality management in various social and industrial fields.

## III. DATA TRACEABILITY AND DATA UNCERTAINTY STATEMENT

In this section, I suggest a further expanded interpretation about the original concepts of metrological traceability and measurement uncertainty for ensuring big data reliability.

First, I suggest the following term to provide a more appropriate definition of the scope of SRD quality verification activities:

*Data Traceability: The establishment of a common shared frame of references for the comparability of data quality within the defined data production system.*

Data traceability refers to the demonstration of a data production system[10] with verified references. According to [22], the establishment of metrological traceability requires a documented unbroken chain of calibrations that relates the measurement result to a reference. A reference can be a definition of a measurement unit (through practical realization), reference procedures, and a measurement standard such as certified reference materials (CRMs). However, a reference for data traceability can be a standardized procedure, an acknowledged data processing computer program, or an expert-elicited data verification model. By defining a common reference within a shared data traceability chain, the comparability of each datum quality in the same big data set is ensured, and it is possible to combine multiple similar big data collections from different sources. In this sense, the definition and standardization of a reference for a data production system become essential prerequisites for reliable and consistent big data analytics.

In big data quality assurance, uncertainty evaluation aims to examine the reliability of the data production system. In other words, verifying a data production system can also be viewed as designing a data traceability chain in which the known and suspected uncertainty components that are related to the major elements of the system are defined, calculated, and managed in an appropriate manner for the intended purpose. In this vein, the concept of measurement uncertainty needs to be understood as a comprehensive uncertainty statement regarding the data production system. The data confidence can be ensured by defining and managing uncertainties in each stage of the data production system.

According to the GUM (2008) method and its underlying philosophy, uncertainty is a quantifiable attribute and can be reported by combining the known and suspected components of uncertainty [24]. In practice, uncertainty equations can vary according to the various characteristics and application purposes of the data. In addition, an acceptable level of uncertainty is appropriately determined by comparing the various levels and requirements of data accuracy in the subject field and the intended use of data. However, from the perspective of big data application, the numerical expression of an uncertainty statement should include additional comprehensive information about data uncertainty. Whereas it is an important task to proclaim the level of data quality, the sharing of information regarding data quality should be emphasized for data quality management in all phases of data application. Overall data quality is assured through a comprehensive data uncertainty statement that is a quantitative and qualitative summary of the 'states of data quality' with all the necessary information regarding how the uncertainty components of data are verified and managed. Using this statement, one can adequately and accurately consider the expected influence of uncertainty components at each stage of data application such as data collection, data pre-processing, and data analytics.

[10]In this study, a data production system is a logical structure of a data supervising system that includes a data production process and a data uncertainty evaluation method.

## IV. MATRIX OF DATA QUALITY EVALUATION

In terms of big data quality assurance in various social and industrial fields, the 10 aforementioned SRD evaluation criteria should be redefined in a systematic and concise manner. Recent studies [2], [5], [21] on data quality enumerate various terms to define data quality dimensions, but these terms are often confusing due to semantic similarities and difficulties in terms of data quality evaluation practices. Table 1 shows the three dimensions of data quality according to the elements of a data production system and related evaluation criteria.

**TABLE 1. Matrix of data quality evaluation.**

| Elements of a Data Production System | Dimensions of Data Quality | Evaluation Criteria |
|---|---|---|
| Data properties | Specification (Completeness) | ▪ Reliability<br>▪ Comparability<br>▪ Reproducibility |
| Method and procedure | Accuracy | |
| Data value and information | Consistency | |

In Table 1, the first dimension is the specification of data properties or attributes, which provide necessary information for data evaluation and analytics. The second dimension involves ensuring data accuracy from the perspective of data traceability and uncertainty. It involves demonstrating a validated and specified data production system that is traceable to defined references, and is accompanied by an uncertainty statement. The final dimension, consistency, is the degree to which two sets of data obtained through different techniques or methods are consistent and logically connected in a system of statistics. These three dimensions of data quality should be evaluated in terms of data reliability, compatibility, and reproducibility. The aim of big data quality evaluation is to define and manage uncertainties in big data to fit the intended use at a stated level of data confidence. In this sense, each dimension of data quality should be specified through collaborative translation between the data producers and the data evaluators within the shared domain knowledge and through practical experience from performing the test methods.

## V. CONCLUSION

The national SRD program in Korea is a testament of a significant feature of the big data era that promotes knowledge distribution through the disclosure and sharing of data with certain required levels of confidence. The presented SRD mechanism shows an expanded metrological approach to design a reliable data traceability chain for data quality comparability. In addition, uncertainty evaluation for the verification of the traceability chain is performed by defining suspected uncertainty components and managing them through multiple collective translation works among the actors who are involved in the process of data production, evaluation, distribution, and application.

In this vein, the case of the Korean SRD program provides important social and policy implications for the future direction of metrology in the big data era. The goal of data quality evaluation is to ascertain a required level of data quality within a shared data network to be 'fit for the particular purpose'. For this goal, the significant role of metrology is to provide scientific approaches and interpretations that allow for the development of reasonable and practical reference methods to ensure accuracy and reliability in big data generation processes.

For this purpose, the current SRD mechanism should actively and openly communicate with various kinds of experts by involving a broader perspective of data standards. In addition to domain knowledge, other technical and social elements that affect data quality and the final usage of data should be considered. By developing a commonly shared metrological frame for defining and managing uncertainties in big data, verified and reliable sources of big data can result in actionable decision-making in various scientific and social sectors.

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