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Theoretical and Applied Aspects of Developing a Methodology for Analyzing the State of Measurements and Forecasting Measurement Needs for the Sectors of the Economy of the Republic of Kazakhstan

Sattybaeva K.Z.
Kazakh National Technical University named after K.Satpayev, Kazakhstan, Almaty

Abstract

The article discusses theoretical and applied aspects that require solutions when developing a methodology for analyzing the state of measurements and forecasting measurement needs for the sectors of the economy of the Republic of Kazakhstan (hereinafter referred to as the methodology of analysis and forecasting). The international and foreign experience in analyzing the state of measurements and forecasting measurement needs across countries, regions, or individual organizations has been studied, which can be taken into account and used in developing a methodology applied to the economy of Kazakhstan. The analysis of the current state of the measurement uniformity system of the Republic of Kazakhstan has been carried out and problematic issues have been identified that make it difficult to analyze the state of measurements and predict measurement needs across the country's economy, which must be taken into account when developing an analysis and forecasting methodology, and solutions to some of these problems have been proposed.

Keywords: metrology, state of measurements, measurement infrastructure

Introduction

The development of a measurement uniformity system that supports the needs of the economy and society must be based on reliable knowledge of the measurement requirements of the state, business, and society. It is important to ensure the proactive development of measurement infrastructure that meets the needs of economic sectors and society for reliable measurements, considering technological progress and innovation. To do this, it is necessary to have accurate information on the state of metrological support across different sectors and types of measurements. Currently, the collection and analysis of such information presents a serious challenge for the authorized government body in the field of measurement uniformity and the State Scientific Metrology Center (SSMC) of the Republic of Kazakhstan.

Decision-making in any area of strategic national development always requires separate research, taking into account the unique features and individual influencing factors of each specific economy or industry. Existing developments on analyzing the state of measurements and forecasting the measurement needs of the economy generally consider the issue within the context of a specific country or regional association's metrological infrastructure. These approaches cannot be directly applied to Kazakhstan’s case. Therefore, there is a need to develop a methodology tailored to the conditions of Kazakhstan’s measurement system, existing information resources, data analysis capabilities, and specific influencing factors.

Analysis of International Experience

Foresight methodology, as a scientific approach to future development forecasting, forms the basis for investigating possible futures shaped by megatrends, sectoral or technological drivers. A wide range of methods is used in foresight studies, each aimed at solving particular tasks in strategic forecasting: scenario planning [1], the Delphi method [2], brainstorming, megatrend analysis, identification of critical technologies, backcasting, horizon scanning, cross-impact analysis, roadmapping, and hybrid methods [3].

A prominent example of successful foresight application in forecasting measurement needs is the

European project focused on scenario building and the future role of metrological institutes in the development of the European Research Area (ERA) [4], offering strategic recommendations to enhance their role in innovation and technological processes in Europe. The project utilized a five-step foresight model by Ian Miles [5], which includes a historical review, expert interviews and workshops, and joint formulation of strategic goals.

A valuable national-level example is the program document of the Ministry of Industry and Trade of the Russian Federation [6], which included large-scale surveys of enterprises, analysis of national and international strategies, and processing of data from the Federal Information Fund for Measurement Uniformity to forecast measurement needs.

In [7], [8] researches the development of a European metrology system to support advanced manufacturing (AdvManuNet) is described. This involved analysis of scientific publication trends, identification of gaps in metrological support, surveys of national metrology institutes, and SWOT analysis of existing European metrology projects.

The experience of the Turkish National Metrology Institute (TÜBİTAK UME), in addition to maintaining continuous dialogue with stakeholders (such as mid-level measurement laboratories, representatives of industry, and business sectors) through the organization of seminars, meetings, and other events, also includes conducting an annual analysis of rejected customer requests in accordance with the requirements of ISO/IEC 17025 [9], as well as analyzing the scope of accreditation of calibration laboratories listed on the website of the Turkish Accreditation Agency (TÜRKAK).

Availability and Accessibility of Information Resources for Measurement Analysis and Forecasting in the Republic of Kazakhstan

To apply international and foreign experiences in developing a methodology for analyzing the state of measurements and forecasting measurement needs in Kazakhstan, it is necessary to consider the current structure and development of the national measurement uniformity system. This includes its organizational model, the core elements of the system, and the availability of data and tools for analysis and forecasting.

Several key factors limit the effective analysis and forecasting of measurement needs at the national level:

First, the amendments made in 2018 to the Law of the Republic of Kazakhstan “On Measurement Uniformity” [10] removed the concepts of “Metrological Service” and “State Metrological Service”, as well as the provision allowing the creation of such services in government agencies and enterprises. As a result, the current organizational structure does not support systematic data collection from enterprises through sectoral ministries to the central authority or the SSMC. Creating metrology units in organizations remains voluntary.

A key challenge is the lack of qualified personnel responsible for metrological support in industrial enterprises and other organizations.

Second, the main source of metrology data is the State Measurement Uniformity Register (SMUR), which includes data on measuring instruments, measurement procedures, and related objects within the scope of legal metrology [11]. However, it lacks data on secondary and working standards used by accredited verification and calibration laboratories.

According to clause 16 [12], accredited entities must submit their list of measurement standards to the SSMC, but this requirement is often ignored. Meanwhile, this data is available to the National Accreditation Center (NAC) as part of the accreditation documentation. Integrating NAC's data into the SMUR system would help, bat NAC’s data confidentiality policies and international commitments pose a legal barrier.

To address this, the following solutions are proposed:

- Amend legislation to hold legal entities accountable for failing to provide data on their measurement standards;
- Ensure that NAC monitors compliance with this requirement as part of the accreditation criteria;
- Have the SSMC analyze publicly available accreditation scopes of verification and calibration labs as a temporary solution.

Third, the absence of a unified classification and coding system for metrological objects complicates centralized data collection and analysis. Coding involves assigning structured digital or symbolic identifiers to measuring instruments, standards, procedures, reference materials, and measurement types.

Information coding is not only a tool for classification but also a method for creating stable

logical connections between objects, as well as a mechanism that ensures the unambiguous identification of elements within the metrological system. In a context where thousands of measuring instruments, measurement procedures, and reference standards are registered and used throughout the country, the absence of a unified approach to their designation leads to data fragmentation, reduces the reliability of record-keeping, and complicates monitoring and forecasting.

Internationally, such systems are used in the BIPM's KCDB [13], and in Russia under national metrology recommendations [14], [15]. Kazakhstan currently applies a national standard ST RK 2.42-2002 [16], but it contains only single-level classification of measurement types and insufficient for structured data analysis.

Coding types and sizes of measuring instruments is resource-intensive and requires both financial and human resources. Experts suggest that a centralized, well-funded coding center - or even a distributed commercial network - would be ideal for implementation [17].

Fourth, a serious future challenge is the digital transformation of Kazakhstan's measurement system, including the adoption of big data, cloud computing, Internet of Things (IoT), and digital metrology services such as calibration e-certificates and digital twins for measuring instruments.

Countries with advanced metrological systems are already implementing "cloud metrology" — integrating measurement tools with cloud infrastructure for real-time data collection, analysis, and exchange, overcoming geographic and logistical barriers [18]. In the context of methodology development, cloud-based technologies offer enhanced analytics and reporting capabilities.

Based on the identified influencing factors, the following solutions are proposed to improve the information system in the field of ensuring the uniformity of measurements, as well as the tools for data analysis and forecasting:

- Reinstate in the legislation on ensuring the uniformity of measurements (EUM) the requirement to establish metrological services and expand the competencies of sectoral government authorities;

- Strengthen the accountability of EUM entities (legal and natural persons engaged in metrological activities) for failing to provide information on reference standards to the State Scientific Metrology Center (SSMC); introduce control mechanisms by the National Accreditation Center (NCA) to ensure compliance with this requirement by accredited entities;

- Until full access to the database of verification and calibration laboratories (VL/CL) is granted, the SSMC should analyze the scopes of accreditation of these laboratories;

- The SSMC should conduct an annual analysis of applications for metrological services;

- Develop a unified system for the classification and coding of measuring instruments (MI) based on BIPM classifiers, to be applied in the State Register of Measuring Instruments of the Republic of Kazakhstan, within the scopes of accreditation, in calibration/verification certificates, and in the creation of digital passports for measuring instruments;

- Implement the development of digital calibration certificates, digital passports for measuring instruments, and the creation of cloud-based data systems in metrology.

Conclusion

The study of international foresight practices and their application in forecasting the metrological needs of the economy and society demonstrates the necessity of a systematic approach to assessing and developing metrological infrastructure. A customized methodology must be developed that reflects the specific conditions of the Republic of Kazakhstan, including legal, institutional, informational, and personnel-related constraints.

Existing data resources such as the State Measurement Uniformity Register (SMUR), the BIPM KCDB, and international classifiers can serve as foundational sources for analysis. However, they require integration, standardization, and expansion to fully support measurement forecasting.

The development and implementation of an effective methodology necessitate systematic modernization of data collection, classification, and analysis processes, along with the digital transformation of metrological services and information systems.

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Саттыбаева К. З.
Қ. Сәтбаев атындағы Қазақ ұлттық техникалық университеті, Қазақстан, Алматы

Қазақстан Республикасы экономикасының салалары үшін өлшеу күйін талдау және өлшеу қажеттіліктерін болжау әдістемесін әзірлеудің теориялық және қолданбалы аспектілері

Аңдатпа

Мақалада Қазақстан Республикасы экономикасының салалары үшін өлшемдердің жай – күйін талдау және өлшемдерге қажеттіліктерді болжау әдістемесін (бұдан әрі-талдау және болжау әдістемесі) әзірлеу кезінде шешімдерді талап ететін теориялық және қолданбалы аспектілер қарастырылады. Қазақстан экономикасына қолдану әдістемесін әзірлеу кезінде ескерілуі және пайдаланылуы мүмкін елдер, өңірлер немесе жекелеген ұйымдар бөлінісінде өлшеулердің жай-күйіне талдау жүргізудегі және өлшеулерге қажеттіліктерді болжаудағы халықаралық және шетелдік тәжірибе зерделенді. Қазақстан Республикасының өлшем бірлігін қамтамасыз ету жүйесінің (ҚР ЕАА) қазіргі жай-күйіне талдау жүргізілді және талдау мен болжау әдістемесін әзірлеу кезінде назарға алынуы қажет өлшем жай-күйін талдау және ел экономикасы ауқымындағы өлшем қажеттіліктерін болжау жөніндегі жұмыстарды жүргізуді қиындататын проблемалық мәселелер анықталды, аталған проблемалардың кейбірін шешу жолдары ұсынылды.

Түйінді сөздер: метрология, өлшеу күйі, өлшеу инфрақұрылымы, болжау

Саттыбаева К.З.
Казахский национальный технический университет им. К.Сатпаева, Казахстан, Алматы

Теоретические и прикладные аспекты разработки методики анализа состояния измерений и прогнозирования потребностей в измерениях для отраслей экономики Республики Казахстан

Аннотация

В статье рассматриваются теоретические и прикладные аспекты, требующие решений при разработке методики анализа состояния измерений и прогнозирования потребностей в измерениях для отраслей экономики Республики Казахстан (далее – методика анализа и прогнозирования). Изучен международный и зарубежный опыт в проведении анализа состояния измерений и прогнозирования потребностей в измерениях в разрезе стран, регионов, или отдельных организаций, который может быть учтен и использован при разработке методики в применении к экономике Казахстана. Проведен анализ современного состояния системы обеспечения единства измерений Республики Казахстан (ОЕИ РК) и выявлены проблемные вопросы, затрудняющие проведение работ по анализу состояния измерений и прогнозированию измерительных потребностей в масштабах экономики страны, которые необходимо принимать во внимание при разработке методики анализа и прогнозирования, предложены пути решения некоторых из обозначенных проблем.

Ключевые слова: метрология, состояние измерений, измерительная инфраструктура, прогнозирование