The European Proceedings of
Social and Behavioural Sciences
EpSBS

www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2020.10.03.153

ICEST 2020

International Conference on Economic and Social Trends for Sustainability of Modern Society

ESTIMATION OF COSTS FOR METROLOGICAL SUPPORT OF PRODUCTION

E. A. Zhirnova (a)*, Yu. G. Malakhova (b), N. S. Kulakova (c), R. I. Kuzmich (d)
*Corresponding author

(a) Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Ave., Krasnoyarsk, Russia, kasy2424@yandex.ru
(b) Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Ave., Krasnoyarsk, Russia
(c) Krasnoyarsk State Agrarian University, 90, Mir Ave., Krasnoyarsk, Russia
(d) Siberian Federal University, 82A Svobodny Ave., Krasnoyarsk, Russia

Abstract

The article describes the metrological support of a machine-building enterprise on the basis of a process approach. This procedure providing the main production is traditionally financed on a residual basis. The economic efficiency of metrological support is considered in three basic concepts: quality management system, standardization and quality economics. A comprehensive approach to metrological support based on the management of technical and managerial factors is proposed in interconnection and interaction with reliable measurement information. The advantages of the process for the "Metrological support of production" are listed, in particular, monitoring as the main function for increasing the reliability and accuracy of measurements. The models of classification of expenses for quality and the theory of functional-cost analysis in relation to the process metrological support of production are analyzed. The versatility of the model for the process and the functional-cost analysis as a tool for identifying excess functions are noted. The requirements for the functional model are examined. The methodology procedure for assessing expenses of the quality of the process is proposed, which includes determining the significance of functions, based on the principle of correspondence main functions and costs of their implementation. The classification of expenses in the model of costs for the process is taken into account. The expert method for assessing the significance of functions is mentioned. The advantage of the method allows to adjust the expenses of implementing functions to impact on ensuring the quality of measurement information.

Keywords: Metrological support, process approach, quality management, economics of metrology, quality expenses, functional-cost analysis.

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

In order to control production processes and create high-quality and reliable products, it is necessary to make scientifically based decisions, which are impossible without ensuring the unity, accuracy, reliability and reproducibility of measurements that reflect the objective characteristics of products and technological parameters of production processes. Reliability of measurement information on production processes and product quality are essential conditions for the successful operation of any enterprise. The growth of requirements to the quality of measurement information is caused by the needs of both innovative economic development and scientific and technical progress. The necessity for metrological support of digital communications was mentioned by the head of digitalization coordination working group of the Federal Physical-Technical Institute of Germany (Eichstedt, 2018), and Russian scientists (Okrepilov, 2020).

According to GOST R 8.820-2013 "Metrological support - the creation and maintenance of conditions for obtaining measurement information that meets established requirements". Quality assurance of measurement information for enterprises of science-intensive and machine-building production includes multidimensional and multipurpose processes aimed at meeting the needs of the customer and mandatory requirements of legislation. Metrological support contains the organization of measurement processes and quality assurance of measurement information with a minimum probability of obtaining inaccurate measurement results.

In the 21st century, more attention is paid to the economic aspects of metrology and the effectiveness of metrological support in foreign and Russian literature. The connection of metrology with quality management and quality economics is mentioned by (Okrepilov, 2017). Methods and approaches to calculating the expenses of measuring processes are considered.

Understanding the relationship between the expenses of measuring processes and the cost of production is the basis of scientific works of many Russian (Litvinov et al., 2017; Matveev & Okrepilov, 2016) and foreign scientists (Swann, 2009). Thus, various theoretical models for the development and implementation of quality management systems based on a process approach are proposed in accordance with the concept of ISO 9000 series standards of 2015 (Adler, 2019). The study of metrological support in the concept of the process approach shows that this process is traditionally funded residually.

A number of international and Russian standards on economic issues of product quality were developed. The analysis of expenses is used in quality economics, both for products and business processes.

The economic efficiency of metrological support is divided into three basic concepts: quality management system, standardization and quality economics.

2. Problem Statement

The quality of measurement information depends on both technical and managerial factors. Technical factors include the accuracy of the applied measuring instruments and standards, the competence of the personnel, ensuring the measurement conditions, the correctness and precision of measurement and verification methods, and the availability of relevant standard and technical documentation.

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Management factors primarily include the issues of measuring information based on the quality management system GOST R ISO 9001-2015, including the process approach and decision-making based on certificates.

The authors believe that the maintenance of the integration of measurements, accuracy and reliability of measurement information is possible only by applying an integrated approach to metrological support, based on the management of both technical and managerial factors in interconnection and interaction in order to ensure reliable measurement information.

The economic efficiency of metrological support is based on determining and optimizing the cost structure for technical and managerial factors to guarantee the quality of measurement information. However, the complex application of the process approach and functional-cost analysis for metrological support of production is not sufficiently disclosed.

3. Research Questions

To solve the issues, authors suggest the following steps:

- consider metrological support of production based on a process approach for the machine-building industry.
- analyze the quality cost models and the theory of functional cost analysis in relation to the process of metrological support of production.
- define a model for estimating costs and functional model requirements for the process.
- develop a methodology for estimating costs for the process of metrological support of production on the basis of a functional-cost analysis, which allows to identify excessive functions and prevent costs due to failures and inconsistencies.

4. Purpose of the Study

The main purpose of the study is to develop recommendations for the implementation of an integrated approach to ensure the quality of measuring information based on the cost estimation methodology for the process of metrological support of production.

5. Research Methods

The theoretical and empirical basis of the study is the regulatory legal and technical Russian and international documentation in the field of metrology, technical regulation and standardization, the theoretical foundations of quality management and the economics of metrology.

The empirical basis of the study is materials published in monographs, periodicals that study the problems of the economics of metrology, the organization of metrological support, the efficiency and effectiveness of the quality management system, as well as a number of data provided by a large Russian machine-building enterprise.

To achieve the goal, the authors used general scientific research methods: analysis and synthesis, classification and schematization of the results. When conducting a scientific study, comparative and causal

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

analysis, statistical methods of data analysis, expert assessment methods, functional-cost analysis were used.

6. Findings

The process of "Metrological support of production" is aimed at ensuring the specified accuracy and reliability of measurements in the enterprise units, performing verification, calibration of measuring instruments, equipment certification in order to determine and confirm their compliance with established technical requirements.

The implementation of the process approach for the “Metrological support” process means establishing requirements for input data, process results, evaluation criteria and methods, resources and information necessary to maintain and monitor the process (Zhirnova, 2018). A systematic documented set of monitoring procedure is aimed at monitoring the implementation of the planned results. Thus, it is the platform for evaluating the effectiveness and development of measures for continuous improvement of the process.

The analysis of metrological support of production based on the process approach provides a number of advantages. First, the process approach allows to manage technical factors for ensuring the quality of measurement information by setting process criteria and monitor the implementation of planned requirements for metrological support. To improve the reference base and measurement process conditions, new quality of measurement capabilities were created. The importance of the reference and measurement, its impact on the reliability and competitiveness of products is mentioned in the works of foreign and Russian scientists (Granovsky, 2014; Taimanov & Sapozhnikova, 2018; Okrepilov, 2018).

Second, the process approach is in providing the interconnection and consistency of all processes associated with the metrological support of production. Moreover, this process is used to distribute management functions, eliminate loss of interfaces, excessive duplication of functions and other problems.

Third, the transparency of the process approach is in rationally accounting for the expenses of supporting the quality of measurement information.

A number of approaches of classifying and accounting for quality expenses have been developed in the economy of quality (Rachlin & Skripko, 2017; Skripko, 2016). The authors used a "process cost model" that classifies into two groups: compliance and non-compliance. The advantage of this model is in its versatility: compliance with the process approach to management and the ability to describe costs for any process based on its model. Compliance costs include the expenses necessary for the process to function in accordance with the specified demands, non-compliance costs due to disruption of the required operation of the process, failures, breakdowns are considered as excessive and must be reduced.

However, the "process cost model" does not provide a tool for a comprehensive analysis of the functions of the object. The generally accepted method of integrated system research of the object is the functional-cost analysis. This method of systematic research includes functions of objects, specific products, business processes and management structure.

It is assumed that functional-cost method aimed at minimizing costs when providing a high level of functionality and quality of the object. The use of this method allows to build a functional model containing an exact specification of all functions that determines the distribution of resources between the operations

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

of the business processes is in evaluating their effectiveness (Adler & Shchepetova, 2018; Tebenkov et al., 2017).

The functional-cost method of process improvement is based on the principle of correspondence of the functions value and the costs of implementation (Efimov, 2011). Functions differ in significance and necessity for the operation of the investigated object. Therefore, it is important to allocate the cost of implementing functions in proportion to their significance. Based on the comparison of the functions significance and the cost of its implementation, it is possible to develop economically reasonable solutions for improving the object of analysis.

A process model of quality costs based on factor and functional analysis is proposed in (Leonova & Babarin, 2014), but the priorities and significance of the functions performed were not taken into account.

The authors believe that the combined use of the process model of quality costs and functional-cost method give the opportunity to analyze the costs of ensuring the quality of the process, identify redundant functions, reduce expenses for imbalanced functions and develop measures to prevent costs due to inconsistencies.

The method for estimating the costs of the “Metrological support of production” process is proposed in the following procedure:

1. The creation and definition of a functional model.
2. The use of an expert method to assess the significance of functions.
3. The identification of cost elements and the assignment of each element to the expenses of compliance or non-compliance according to the process model.
4. The determination of the calculation method and estimation of expenses, registration of information sources.
5. The calculation of the coefficient of functional costs for analyzing the main characteristics of functions
6. Search for solutions aimed at reducing costs for inconsistent functions and develop measures to prevent costs due to non-compliance.

The authors determine the list of functions for the process “Metrological support of production”:

- planning and preparation for metrological support of production F1;
- verification and certification of equipment F2;
- maintenance of equipment F3;
- creation of a fund of standards and normative documents on metrological support of production F4;
- develop metrological supervision of the state and the use of measuring instruments F5.

The functional model for the process "Metrological support of production" should be built as a business process model from the point of view of management of the organization's quality system and meet the regulatory and technical requirements of standardization and legal metrology.

At the second stage, an expert method is used to determine the relative significance of functions. The expert assessment is carried out after the established periods, due to the fact that the significance of

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

individual functions is related to the importance of the goals implemented without a definite value. Consequently, it is possible to rank and set priorities of the main functions highlighting more important ones. The specific structure of goals for any level and control unit can be represented in the form of a hierarchical tree. The significance of functions is determined by an expert method discussed with of chief specialists from various departments of the organization. The total sum of the initiate coefficients of functions of one level should be equal to one. The reliability of the expert method is estimated as a degree of consistency based on the concordance coefficient (Fedyukin, 2017).

$$W = \frac{12S}{n^2(m^3 - m)}, \quad (1)$$

where S – the sum of the squares of the deviations of the sum of the ranks of each examination object from the arithmetic value ranks; n – the number of experts; m – the number of functions. The verification of the significance of the values of the coefficient of concordance W is carried out on the basis of the criterion χ_w^2 (Fedyukin, 2017).

The results of the significance of functions evaluation: F_1 =0.37; F_2 =0.36; F_3 =0.13; F_4 =0.04; F_5=0.10

At the third stage, the function expenses are identified according to the classification of both compliance and non-compliance costs.

For instance, "Maintenance and equipment support" function, compliance costs are the expenses of planned repairs of measuring instruments, maintenance, and equipment support. Non-compliance costs include the cost of repairing measuring instruments and equipment in the event of a malfunction, and re-maintenance in case of malfunctions.

It is obvious that after the calculation methods of expenses is defined all sources of information should be registered. The calculation of expenses of functions includes: salary expenses that depend on the complexity of the work and the salary of employees; training expenses, business trips and official travel; material costs (consumables and electricity); depreciation and expenses for support and operation of computer equipment, etc. For example, the costs of plan development to eliminate violations of metrological rules and regulations are calculated according to the formula (Zdanovich, 1988).

$$E=(S+ME+ST+DC+M), \quad (2)$$

where E is expenses of functions; S – the employees` salary involved in the development of the plan taking into account the time spent; ME – material expenses, which include the cost of consumables and electricity; ST – social tax; DC – depreciation charges; M – miscellaneous expenses (2% of total expenses).

The data presented in the Table 01 show the analysis of expense characteristics of functions where the coefficient of functional expenses is used.

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Table 01. The results of functions and expenses analysis

Function	Function significance, %	The proportion of expenses in the total cost, %	The coefficient of functional expenses $C_{f.e}$
F_1	37	30	0.81
F_2	36	29	0.81
F_3	13	26	2.00
F_4	4	7	1.75
F_5	10	8	0.80

On the basis of the giving data, it is considered that the degree of significance of individual functions is expressed as a percentage and compared with the specific weights of costs for a specific function in the total cost. The coefficient of expenses $C_{f.e}$. allows to judge the balance of functions and the costs required for their operation in accordance with the specified requirements in the most efficient way. The optimal value of this coefficient is considered to be approximately equal to one. If the coefficient is $C_{f.e} > 1$, then the cost of the function exceeds its significance, therefore, it is necessary to reduce it.

In this regard, functions F_3 (equipment maintenance) and F_4 (creation and updating of the fund of standards and normative documents for metrological support of production) are not balanced with their significance ($C_{f.e}$ is 2.00 and 1.75, respectively). Therefore, it is necessary to search for solutions aimed at reducing them. In order to reduce the cost of the F_3 function, a set of measures to prevent improper handling of measuring instruments should be developed. The costs of the F_4 function can be lowered by reducing the time for updating the fund of normative documentation and standards and the use of information technology and electronic document management.

7. Conclusion

The implementation of a comprehensive approach ensuring the quality of measurement information at a machine – building enterprise is a complex problem that can be solved by the systematic application of advanced quality management methods in conjunction with generally recognized methods of cost management, in particular, functional - cost analysis.

Thus, the authors came to the conclusion, that the process approach to the study of metrological support allows monitoring both technical and managerial factors that ensure the quality of measurement information, serves as the basis for improving the reliability and accuracy of measurements. The process expenses model is versatile in accounting the costs due to failures and inconsistency, however, it is not sufficient to assess economic efficiency. Functional-cost analysis can be a tool for system research of the process based on the correspondence between the significance of the function and the implementation cost identifying redundant functions to reduce expenses.

It is assumed that the methodology based on the functional-cost analysis is an effective tool for assessing the expenses of quality. According to the principle of correspondence of the significance of functions and the expenses of their implementation, it should be taken into account that the classification of expenses for quality and the functional model meets the substantive normative and technical requirements of standardization, legal metrology, international standards ISO 9000 series.

The advantage of the method is in using the expert assessment method, the results which may adjust the cost of implementing the functions with regard to their impact on software quality measurement

https://doi.org/10.15405/epsbs.2020.10.03.153
Corresponding Author: E. A. Zhirnova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

information, serve as the basis of improving the economic efficiency of metrological support of production. The methodology promotes the adoption of economically sound decisions on the optimal distribution of labor, cost and time costs for metrological support of production, aimed at improving the quality of products and the quality of measuring information.

References

Adler, Yu. P. (2019). *Management in the changing world standards and quality, 8,* 105-109. [in Rus]

Adler, Yu. P., & Shchepetova, S. E. (2018). *From quality costs to cost management quality management, 8,* 68-77. [in Rus]

Efimov, V. V. (2011). *Collection of methods for searching for new ideas and solutions for quality management.* UlSTU. [in Rus]

Eichstedt, S. (2018). Digital economy can't do without metrology. *Chief metrologist, 3*(102), 16-19. [in Rus]

Fedyukin, V. K. (2017). Qualimetry. Measuring the quality of industrial products. http://biblioclub.ru [in Rus].

Granovsky, V. A. (2014). Metrological support at an industrial enterprise: problems and solutions. *Chief metrologist, 4,* 27. [in Rus]

Leonova, T. I., & Babarin, M. S. (2014). The process model of quality costs of the organization. *Management quality, 2,* 14-19. [in Rus]

Leonova, T. I., & Mammadov, E. E. (2017). Directions of development of standardization in the field of quality. *Economics, information and economic aspects of standardization and technical regulation, 4*(38), 8. [in Rus]

Litvinov, B. Ya., Okrepilov, M. V., & Pavlov, R. V. (2017). *Management of measuring equipment competence, 4*(145), 21-25. [in Rus]

Matveev, V. V., & Okrepilov, V. V. (2016). Economic problems of metrology. *Measurement technology, 2,* 67-71. [in Rus]

Okrepilov, V. V. (2017). *Economics of Metrology monograph of the Ministry of education and science of Russia. Federation, Federal state auth. educat. establishment of the company. education of St. Petersburg state University.* GUAP. [in Rus]

Okrepilov, V. V. (2020). Metrology as a driving force of economic growth. *Metrological support of innovative technologies international forum*, 4-5. [in Rus]

Okrepilov, V. V. (2018). *Quality and Metrology Standards and quality, 5*, 47-51. [in Rus]

Rakhlin, K. M., & Skripko, L. E. (2017). *Methodology of classification of costs for quality standards and quality, 3*, 18. [in Rus]

Skripko, L. E. (2016). Economics of quality: you can't refuse to implement it! Where do I put a comma? *Quality management methods, 12,* 10-15. [in Rus]

Swann, P. (2009). The Economics of Metrology and Measurement. https://www.gov.uk/government/publications/national-measurement-system-economics-of-metrology

Taimanov, R., & Sapozhnikova, K. (2018). Metrological problems of industry 4.0. *IMEKO 2018-Measurement Science*, 22.

Tebenkov, Y. S., Leonova, T. I., & Mamedov, E. E. (2017). *The Management of quality costs in the organization Science and business: ways of development, 6*(72), 120-123. [in Rus]

Zdanovich, I. A. (1988). *Economic efficiency and optimization of metrological support of industrial enterprises.* Publishing house of standards. [in Rus]

Zhirnova, E. A. (2018). Process approach for improving the organization's activities in the collection: Problems of certification, quality management and documentation management. *Collection of materials of the all-Russian scientific and practical conference*, 37-39. [in Rus]