Toolkit for determining the costs of developing new measuring tools and optimizing their production plan

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Abstract. The tools for determining the forecast value of the costs associated with creating new measuring tools that have standardized metrological characteristics are proposed. It is adapted to the cost estimation procedures carried out to develop a plan for their production in both monopolistic and competitive markets. Existing models for optimizing these procedures cannot always be applied since, due to the considerable complexity of the simulated process, they are often illustrative in nature. Some procedures are not formalized and do not consider the required extent of their application's specifics on a competitive basis. Therefore, when predicting costs in creating new measuring tools, it is sometimes necessary to use analogies and expert evaluations. This circumstance reduces the validity of forecast estimates. In contrast to existing methods of solving the problem under consideration, the proposed toolkit allows solving it systematically and based on formalized procedures. The article presents a model statement of this problem's solution using a system of criteria and indicators for the quantitative assessment of the processes under consideration. The proposed toolkit is based on the methodology of structural synthesis of cost forecasting procedures. The use of the proposed toolkit will increase the validity of the forecast values of the costs associated with the creation of measuring tools. This will ensure the optimality growth of production plans for new measuring tools used in metrology. One of the possible solutions to this problem is presented in the article.

1. Introduction
Metrological support refers to establishing and applying scientific and organizational bases, technical means, rules, and regulations necessary to achieve the unity and required accuracy of measurements. The main tendency in the development of metrological assurance is the transition from the earlier narrow task of assuring the uniformity and required accuracy of measurements to the fundamentally new task of assuring the quality of measurements. When developing metrological support, it is necessary to use a systematic approach, the essence of which is to consider this support as a set of interrelated processes united by one objective — to achieve the required quality of measurements [1].

Currently, the role of various factors with a negative impact on the costs associated with the development of new measuring tools, which generate an increase in prices for these products, has increased. It is necessary to increase the validity of determining the forecast prices for new product
samples being created and optimizing their production plans to neutralize the influence of these factors [2-4].

2. Determination of the forecast value of the costs associated with the creation of new measuring tools

Option 1
To solve this problem, let us assume that new measuring tools are carried out by only one enterprise, which produces these products without a tender [5]. Denote by \( z_n^p \) — the costs of the enterprise-developer of this product at the \( n \)th stage of their creation. In this case, the total costs associated with the creation of new measuring tools can be determined using the following relationship:

\[
Z^p = \sum_n z_n^p
\]

where \( Z^p \) is the enterprise’s cost to create new measuring tools at all stages of this process.

Let us assume that the average annual additional profit that a manufacturer of new measuring tools can get is \( V_G \), the payback period for the costs associated with the creation of products is \( U_Z \), and the profit of the enterprise developing this product is \( V_W \). The following dependency is used to determine the value of \( V_W \):

\[
V_W = V_G \cdot U_Z - Z^p
\]

Taking into account the dependence (2), the profitability ratio of creating new measuring tools \( K^S \) will be equal to:

\[
K^S = \frac{V_W}{Z^p} = \frac{V_G \cdot U_Z}{Z^p} - 1
\]

Option 2
In market conditions, the creation of new measuring tools is usually carried out with several manufacturing enterprises producing the same type of products and being competitors. In this case, the composition of manufacturers of new measuring tools is determined on a competitive basis [6]. In relation to different compositions of producers, different versions of the draft plan for the creation of these funds are formed, taking into account the objectives and resource constraints. If \( k \) enterprises that develop new measuring tools participate in the competition, then the total costs associated with their creation on a competitive basis, taking into account all stages of production, can be determined using the dependence:

\[
Z^p = z_n^p \sum_n z_n^p
\]

In the conditions of competitive creation of new measuring tools, the share of costs at a particular stage of project implementation in the total cost can be determined as follows:

\[
Q_n^p = \frac{z_n^p}{Z^p},
\]

where \( Q_n^p \) — the share of costs \( z_n^p \) at the project implementation stage \( n_i \) in the volume of costs \( Z^p \).

The total \( Z^\text{ALL} \) costs of creating new measurement tools on a competitive basis based on the use of the indicator \( Q_n^p \) for all enterprises included in the draft plan for creating these tools are equal:
\[ Z^{\text{ALL}} = k \cdot Q_{n_i}^P \cdot Z^P + (1 - Q_{n_i}^P) \cdot Z^P = Z^P \cdot (1 + (k - 1) \cdot Q_{n_i}^P) \] (6)

Then the total profit of all enterprises producing new \( P^{\text{ALL}} \) measuring tools is determined using the following formula:

\[ P^{\text{ALL}} = (V^G + \Delta V^G) \cdot U^Z - Z^P \cdot (1 + (k - 1) \cdot Q_{n_i}^P), \] (7)

where \( \Delta V^G \) — the increase in profit for consumers of all enterprises developing new measuring tools; \( n_i \) — the stage of project implementation; \( k \) – the number of manufacturing enterprises; \( U^Z \) — the payback period.

In this case, the profitability ratio for developers of new measuring tools in the conditions of market competition and the application of competitive procedures can be determined using the following formula:

\[ K^{\text{ALL}}_N = \frac{P^{\text{ALL}}}{Z^P} = \frac{(V^G + \Delta V^G) \cdot U^Z}{Z^P} \cdot (1 + Q_{n_i}^P \cdot (k - 1)), \] (8)

where \( K^{\text{ALL}}_N \) — the ratio of profitability for developers of new measurement tools; \( P^{\text{ALL}} \) — the total profit of developers of these tools.

3. Toolkit for optimizing the project plan for the production of new measuring tools

The objective of optimizing the draft plan for the production of new measuring tools is to choose from possible options the one that will maximize the economic efficiency of the production process:

\[ E^C(W^B) = \sum_i \sum_j C_{ij} \cdot V_{j}^{\text{ALL}} \Rightarrow \max, \] (9)

where \( E^C \) — the integrated criterion of economic efficiency; \( W^B \) — optimal production plan of new measuring tools; \( W^B \in W^{\text{ALL}} \), where \( W^{\text{ALL}} \) — set of production plan options of new measuring tools; \( V_{j}^{\text{ALL}} \) — the total volume of production of new measuring tools of the \( j \)-th kind (\( j = 1,...,J \)) at realization of \( i \)-th (\( i = 1,...,I \) option of the project production plan; \( C_{ij} \) — the cost of \( j \)-th kind of new measuring tools, produced at the realization of the \( i \)-th option of the project plan;

At all stages of the plan implementation for the production of new measuring tools, the following conditions must be met:

\[ \sum_{t=1}^T E_{t}^c \rightarrow \max, \quad \frac{1}{T} \sum_{t=1}^T E_{t}^c \geq E_{t_0}^c, \] (10)

where \( E_{t}^c, E_{t_0}^c \) — the integrated criteria of economic efficiency of the production plan of new measuring tools in the \( t \)-th year and the previous year \( t_0 ); T — implementation period of the production plan for new measuring tools (years).

Optimization of the production plan for new measuring tools must be carried out by reallocating various resources between its activities. If the number of options for changing \( x \) for all \( y \) resources is equal \( D_{x}, \) where \( x = 1...X, \) \( y = 1...Y, \) then the total number of options for allocating all resources when optimizing the production plan for new measuring tools does not exceed \( x'. \) Let us assume that a variable characterizes the attraction of the \( y \)-th resource to the \( i \)-th version of the production plan for new measuring tools \( P_{i}^{\text{PL}}: \)

\[ P_{i}^{\text{PL}} \in \{0,1\} \quad y = 1,...,Y; \quad i = 1,...,n \] (11)

Then the demand for different resources for the implementation of different production plan options for new measuring tools is in the interval:
\[ 0 \leq \sum_{i=1}^{n} P L_i \leq n \]  

(12)

An essential condition for optimizing the production plan for new measuring tools is the risk assessment of its implementation [7; 8]. A quantitative assessment of the risk of implementing the \( n \)th option of this plan can be obtained using the following dependence:

\[ R_n^{GNR} = \sum_{j=1}^{A} C_j \cdot H_j \]

where \( C_j = \frac{1}{\alpha} \sum_{i=1}^{\Phi_j} L_i^{j} \cdot H_i^{j} \)  

(13)

where \( R_n^{GNR} \) — the generalized indicator of the production plan implementation risk for new measuring tools; \( C_j \) — quantitative risk assessment of \( j \) kind; \( H_j \) — specific risk weight of \( j \) kind; \( \alpha \) — risk assessment chart; \( \Phi_j \) — risk factors for the \( j \)-th kind; \( L_i^{j} \) — estimation of factor \( i \) influencing the risk of \( j \) kind; \( H_i^{j} \) — the weight of factor \( i \) in the risk \( j \), \( A \) — risk types.

4. Conclusion

Currently, much attention is paid to the indicators used in the economic analysis of the enterprise activities, and therefore the tools for their calculation are developed quite fully. Despite this, there is no uniform point of view on system coordination of the given indicators at different stages of development and production of measuring tools used in solving metrological support issues [9]. Therefore, the article offers a conceptual model for solving this issue, which includes a toolkit for determining the forecast value of costs associated with creating new measuring tools and optimizing the production project plan for these tools. A distinctive feature of this toolkit is that it is systematic in nature and considers the risks of the process for creating new measuring tools. The developed tools meet the specific conditions of enterprises’ economic activity at present and the production specifics for measuring tools. It can be used to perform multivariate calculations in the development of management decisions that regulate the development and production of measuring tools.

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