Targeted Management of Performance Indicators of the Park of Control and Measuring Equipment Used in the Construction and Housing and Public Utilities Sectors

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Abstract. The mathematical model is presented for the purpose of management the performance indicators of the park of control and measuring equipment used in construction and the housing and public utilities sectors. The model is based on performance management algorithms that ensure a smooth monotonous transition of indicators from current values to the required values for a fixed period of time. The smoothness of the transition is ensured by using the pieces of monotonic degree functions as a reference plan. The developed algorithms make it possible to effectively build preliminary target plans, as well as to make refined plans in the event of underfunding (refinancing) at individual planning stages. The main directions of development of the technical base of park of control and measuring equipment are the modernization of existing samples and types of control and measuring equipment as a result of scientific research and development work, as well as the purchase of new advanced control and measuring equipment to replace obsolete samples of control and measuring equipment. The article presents the results of mathematical modeling of the specified directions of development of the technical base of park of control and measuring equipment.

1. Introduction

The task of managing the indicators of modernity and availability of park of control and measuring equipment (CME) is relevant in the field of construction [1-3], housing and communal services [4] and other areas of activity [5-7]. Due to the presence of financial, production and other risks (for example, underfunding, delays in financing, postponement of work commencement and completion of work associated with insufficient funding or environmental conditions), the implementation of planned indicators at the required planned targeted level should be able to be regulated and to be periodically refined [4]. Therefore, the development of a mathematical model of target management of the efficiency indicators of the park of CME, allowing to calculate various options for the transition to the required value of the indicator of efficiency at the end of the planned period with an estimate of the proportion of modern and available samples is an actual practical task.

2. Performance indicators of the park of CME

Consider the following indicators:

- Indicator of sufficiency: $P_i^o = N_i^o / N_i^s$;
- The share of modern samples of CME (indicator of modernity): $P_i^{oco} = N_i^{oco} / N_i$;
- Indicator of sufficiency of modern samples of CME: $P_i^{oco} = N_i^{oco} / N_i^s$;
The share of available samples of CME (indicator of availability): \( P_{\text{av}}^i = \frac{N_{\text{ucn}}^i}{N_{\text{st}}^i} \);

- Sufficiency with available samples of CME: \( P_{\text{avo}}^i = \frac{N_{\text{ucn}}^i}{N_{\text{st}}^i} \);

where \( N^i \) is the number of samples available in the \( i \)-year, \( N_{\text{st}}^i \) is the number of samples per state in the \( i \)-year, \( N_{\text{con}}^i \) - the number of modern samples in the \( i \) year, \( N_{\text{ucn}}^i \) - the number of available samples in the \( i \) year [1-2];

\[
N_{\text{ucn}}^i = k_{\text{con}}^\text{ucn} \cdot N_{\text{con}}^i + k_{\text{ucm}}^\text{ucn} \cdot (N^i - N_{\text{con}}^i)
\]

where \( k_{\text{con}}^\text{ucn} \) - the coefficients of availability for modern samples of CME, \( k_{\text{ucm}}^\text{ucn} \) - the coefficients of availability outdated samples of CME, \( 0 < k_{\text{con}}^\text{ucn} < 1, 0 < k_{\text{ucm}}^\text{ucn} < 1 \).

3. Performance indicators of the park of CME

For definiteness, we describe the procedure for planning the improvement of performance indicators using the indicator of the share of modern samples \( P_{\text{dco}}^u \) as an example.

Let at the time \( T = T' \) of the start of planning with the indicator of modernity was equal to \( P_{\text{dco}}^u \).

The task is to improve this indicator to the value of \( P_{\text{dco}}^< \), and \( P_{\text{dco}}^< > P_{\text{dco}}^u \), for the planning period \( T = T' - T'' \).

In the paper we additionally require that the transition from the initial to the final value occurs fairly smoothly without abrupt jumps. This requirement is satisfied, for example, by a use of pieces of a linear increasing function and pieces of degrees increasing functions.

The planned value of the indicator for the \( i \)-year can be calculated by the formula:

\[
P_{\text{dco}}^\text{pl} (T^i) = P_{\text{dco}}^u + \frac{P_{\text{dco}}^< - P_{\text{dco}}^u}{(T' - T'')^\alpha} \cdot (T^i - T'')^\alpha, \quad T^i = \frac{T' - T''}{N} \cdot i. \quad (1)
\]

Note that if \( \alpha = 1 \), the formula (1), it defines a linear function, and if \( \alpha > 1 \) the formula (1) it defines, a degrees function that provides an exit to the planned value of the “delayed” indicator. To ensure that the indicator reaches the planned value by ahead, the following formula can be used:

\[
P_{\text{dco}}^\text{pl} (T^i) = P_{\text{dco}}^< + \frac{P_{\text{dco}}^U - P_{\text{dco}}^<}{(T' - T'')^\beta} \cdot (T^i - T'')^\beta, \quad \beta > 1. \quad (2)
\]

With parameter \( \beta > 1 \). Note that with \( \alpha = \beta = 1 \) formulas (1) and (2), they gives the same straight line, although they have different analytical expressions.

In the figure 1, as an example, smooth changes of the indicator \( P_{\text{dco}}^\text{pl} (T^i) \) are shown in the range of values 0.5-0.7 (50% - 70%) for different values of the parameters of the degrees function (1) - (2).
For the remaining performance indicators $P^i_o$, $P^i_{oco}$, $P^i_{oco}$, $P^i_{oco}$ the target planning for improving of these indicators are done similarly.

4. Management of the indicator of modernity when planning scientific research and development work

The indicator

$$P^i_{oco} = F_{oco} (N^i_{coa}) = F_{oco} (N^i_{coa} + N^i_{SRDW})$$

is a function of the number of completed scientific research and development work (SRDW), where $N^i_{coa}$ - is the number of modern samples in accordance with the base plan. We will build such a plan for SRDW (in order to clarify the initial plan) so that at each planning step $i = 1,2,...,n$, the values of the present indicator should be as low as possible if planned $P^i_{oco} \geq P^i_{oco} (T^i)$. The number of completed SRDW in the $i$ - year should be as low as possible:

$$\min_{N_{SRDW}} \{ P^i_{oco} \geq P^i_{oco} (T^i) \} \quad (3)$$

The calculations were carried out with the following values of the initial data: $N^n = 53$, $N^n_{coa} = 29$, $P^n_{oco} = 0.5472$, $k^{n}_{coa} = 0.97$, $k^{n}_{xco} = 0.9$, $N^k_{coa} = 0.7$. The planning period equal 1 years, the number of planning periods $n = 10$, the time from the start of SRDW to the commissioning of a modern sample of CME equal 3 years.

The dependence of the number of modern samples of CME on the planning year with complete lack of funding for SRDE is presented in the second line of Table 1. The third and fourth lines show data on the number of modern CME that should be put into operation as a result of SRDW in accordance with the based plan and a with revised plan, calculated by the formulas (1) - (3), respectively.
Table 1. Management of planning of SRDW

| Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 |
|------|------|------|------|------|------|------|------|------|------|------|
| Number of CME in the absence of funding | 28 | 26 | 23 | 20 | 12 | 12 | 6 | 0 | 0 | 0 |
| Number of completed SRDW (based plan) | 1 | 2 | 1 | 5 | 4 | 2 | 3 | 5 | 5 | 5 |
| Number of completed SRDW (revised plan) | 1 | 2 | 3 | 7 | 9 | 8 | 7 | 7 | 2 | 1 |

Calculations showed that only by carrying out the SRDW planned in accordance with the based plan, it is impossible to ensure the fulfillment of the target indicator of modernity in 2022 (figure 2). To ensure the target value of the indicator in 2022, it is necessary to have three out of nine SRDW projects with a planned completion date in 2022, complete ahead of schedule in 2021, with the subsequent commissioning of three modern CME in 2022.

If it is impossible to complete these three SRDW projects in 2021, the current indicator will be broken in 2022 by 5.66%. Starting from 2023, the target value of the indicator of modernity will be a smooth increase in the indicator of modernity to the desired value.

![Figure 2. Indicator of modernity](image-url)

The results of assessments of modernity and availability at the time of completion of planning are:

\[ N^x = 53, \quad N^x_{con} = 38, \quad N^x_{jcm} = 15, \quad N^{ucm}_{con} = 37, \quad N^{ucm}_{jcm} = 14. \]

5. Management of performance indicators in the planning of procurement of new samples of instrumentation

Performance indicators are the functions of purchases and write-offs:

\[ P_{io} (T') = F_{io} (z_i, s_i), \quad P_{seo} (T') = F_{seo} (z_i, s_i), \quad P_{seo} (T') = F_{seo} (z_i, s_i). \]
We will build such a plan for purchases and write-offs \( \{(z_i, s_i), i = 1, 2, \ldots, n\} \), that at each planning step \( i = 1, 2, \ldots, n \) the value of indicator of modernity was not lower \( z_i \) than those calculated by formulas (1) - (2). The volume of purchases \( z_i \) in the \( i \)-year should be the minimum possible:

\[
\min_{z_i} \left\{ P_i(T^i) \geq P^u_i(T^i), \; P_{soc}(T^i) \geq P^u_{soc}(T^i), \; P_{dso}(T^i) \geq P^u_{dso}(T^i) \right\}
\]

(4)

The calculations were carried out with the following values of initial data: \( N_{st}^{u} = 7500 \), \( N^{u} = 6000 \), \( N_{corp}^{u} = 2228 \), \( P^{u} = 80.0\% \), \( P_{soc}^{u} = 37.13\% \), \( P_{dso}^{u} = 29.71\% \), \( k_{soc}^{u} = 0.97 \), \( k_{dso}^{u} = 0.9 \), \( P_{st}^{k} = 95\% \), \( P_{soc}^{k} = 70\% \), \( P_{dso}^{k} = 65\% \).

The dependence of the number of modern samples of CME in case of absence of funding is presented in the second line of Table 2.

### Table 2. Management of planning of purchases and write-offs

| Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 |
|------|------|------|------|------|------|------|------|------|------|------|
| Number | 2228 | 1828 | 1498 | 1208 | 928  | 688  | 478  | 298  | 148  | 48   |
| Purchases | 276  | 677  | 606  | 565  | 555  | 516  | 487  | 456  | 426  | 376  |
| Write-offs | 164  | 563  | 493  | 452  | 443  | 403  | 374  | 343  | 312  | 263  |

Number of purchases and write-offs according the plan (1), (2), (4) are presented in third and fourth lines of the table. The results of estimates of the number of modern and available samples of CME at the time of completion of planning: \( N^{k} = 7130 \), \( N^{k}_{soc} = 4988 \), \( N^{k}_{ycm} = 2142 \), \( N^{k}_{dso} = 4838 \), \( N^{u}_{soc} = 1928 \), \( N^{u}_{ycm} = 6766 \).

The number of planned purchases and write-offs is presented in figure 3.

![Figure 3. Number of planned purchases and write-offs](image)
6. Discussions and conclusions
The algorithms described in the article for a smooth transition to the required values of the indicators of modernity park of CME are used in the State Scientific Research Metrological Center of Russia.

The algorithms described in the article for the purpose-oriented control of performance indicators of the park of CME are used:
- when planning the purchase of samples of CME and planning the conduct SRDW aimed at upgrading existing samples of CME used in the field of construction and housing utilities.
- when planning the purchases of metrological tools and planning SRDW, aimed at upgrading high-precision Standards of the first and second category [8].

The presented algorithms can be applied for planning the development of the park of road - building machines, park of machines and equipment used in construction; parks of excavators, mechanisms and equipment used in mining and so on.

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