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System of Indicators for Evaluating the Efficiency of Municipal Machines

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ABSTRACT: The article is devoted to the development of technical performance indicators based on a structural analysis of economic integral indices such as reduced unit costs. Based on the structural analysis of the components of the reduced costs (operating costs and capital investments), the structural components of the indicators and the weight of each component indicator were identified. The developed system of coefficients allows for choosing municipal machines with effective systems of indicators.

I. INTRODUCTION

In market conditions, the basis for an objective assessment of the effectiveness of the machine is the profit from the use of technology. The best machine or set of machines is determined by the amount of costs. The efficiency of the use of technology is recommended to be set according to the value of unit costs. Cost minimization determines the high capacity of the technology used [2].

A comprehensive analysis of the effectiveness of technology requires the presence of various indicators that determine the capacity obtained, depending on the goals facing the managers of the work, who use various types of equipment in their activities in different operating conditions. The system of target indicators linked into a single hierarchical structure can be obtained based on the analysis of such an integral indicator as the reduced unit costs [1]:

$$Z_{sp} = \frac{Z_r}{P} \text{ soum/production units,} \qquad (1)$$

where $\boldsymbol{Z_r}$ are the reduced costs per hour of operation, soum/h;

P – is the hourly operational productivity, production units/h.

The latter is determined through the hourly technical productivity $\boldsymbol{\Pi_m}$

$$\mathrm{P} = \mathrm{k_t} \cdot \mathrm{P_t} \qquad (2)$$

where $\mathrm{k_t}$ is the machine utilization factor over time. The value of the reduced costs Z_r is found by the following formula

$$\boldsymbol{Z_r} = \mathrm{C} + \boldsymbol{kE_n} \qquad (3)$$

where C are the operating costs, reduced to the hour of machine operation, soum;

k are the capital investments;

E_n is the standard efficiency coefficient, determined by the value of the credit interest in fractions of a unit

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(E_n = 0.20-0.8).

The resulting systems of criteria are based on the analysis of the machine as a complex system [1] and the allocation of costs for each of the subsystems. The machine is divided into a number of subsystems, taking into account the connections between them and the characteristics of the input, output and restrictions. The system includes the following subsystems:

- power (energy) subsystem (engine, environmental equipment of the engine and other elements);
- technological subsystem (working equipment, machine frame, mover);
- subsystem of life support and control (cabin, life support equipment, computer and hydraulic equipment);
- operating staff (operators and employees of auxiliary services).

The reduced costs are determined by expense items separately for each of the main subsystems of the machine: for the power supply subsystem, the costs are proportional to the installed engine power N in kW; for the technological subsystem, the costs are proportional to the mass of the machine m in kg; for the life support subsystem, the costs do not directly depend on N and m; the costs for the operator and maintenance staff can be taken proportional to the mass of the machine and the number of workers servicing the machine, n_w.

Capital investments for new equipment k consist of the costs of acquiring equipment (wholesale price, leasing, dealer costs, transportation and installation costs), as well as the costs of capital investments associated with the operation of equipment (new buildings, equipment, insurance, etc.).

Referred to the hour of work, these cost items can be determined by the cost of the main subsystems that make up the machine:

$$\boldsymbol{k} = a'_0 + a'_1 \cdot \boldsymbol{N} + a'_2 \cdot \boldsymbol{m} \qquad \textbf{(4)}$$

where a'_0 is the dimensional coefficient characterizing capital investments in the operator's life support subsystem, which do not directly depend on the power and mass of the machine, soum/h;

a'_1 is the coefficient that considers capital investments in the power subsystem, proportional to the engine power, soum/(kWh);

a'_2 is the coefficient that considers capital investments in the technological subsystem, proportional to the mass of the machine, soum/(kg·h).

Current operating costs (for raw materials, management, wages, and deductions for renovation, maintenance and repair, and relocation costs) are proportional to the mass of the machine m. The cost of energy (fuel) and lubricants consumed is proportional to the power of the machine N. Current costs reduced to the hour of work and calculated for each subsystem, can be established by the following formula

$$C = a''_0 + a''_1 \cdot N + a''_2 \cdot m + a''_3 \cdot n_w \cdot m \qquad (5)$$

where a''_0 is the dimensional coefficient characterizing the operating costs for the life support and control subsystem, soum/h;

a''_1 is the dimensional coefficient characterizing the operating costs of the power subsystem, soum/(kWh);

a''_2 is the dimensional coefficient characterizing the operating costs of the technological subsystem, soum/(kg·h);

a''_3 is the dimensional coefficient that characterizes the operating costs for wages, depending on the number of service

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staff and the mass of the machine, soum/(person/kg·h);

π_p is the number of operators and workers servicing the equipment, persons.

The efficiency of production mechanization within the framework of the national economy is usually assessed by the indicator of reduced unit costs Z_{sp} based on dependencies (1) and (3).

For engineering and other organizations with operating equipment, the efficiency of using machines is evaluated according to criterion C_{sp} - the unit operating costs or the cost of work, measured in soum/production units:

$$C_{sp} = C/\boldsymbol{P} \qquad (6)$$

or, after substituting expression (5) into (6) and transformations:

$$C_{sp} = \boldsymbol{m}/\pi_{\boldsymbol{p}} + a_1'' \cdot \boldsymbol{N_{sp}} + a_2'' \cdot \boldsymbol{m_{sp}} + a_3'' \cdot \boldsymbol{m}/\pi_{\boldsymbol{p}} \qquad \mathbf{(7)}$$

Where N_{sp} is the specific energy consumption of the working process of the machine, kW/productivity units, $N_{sp} = N/P$; $m_{y\partial}$ is the specific material consumption of the working process of the machine, kg/productivity units, $m_{sp} = m/P$; $n_p$is the output per worker, showing productivity units per worker, productivity units/persons, $n_p = P/k$. Other designations were given above.

The coefficients characterizing the operating costs, $a_0'', a_1'', a_2'', a_3''$ in equations (5) and (7) can be established based on the analysis of statistical information on operating costs for each of the machine subsystems per unit time, referred to the characteristics of the subsystem:

$$a_0'' = \frac{\sum Z_0''}{\sum T}, \textbf{ soum/h,}$$

$$a_1'' = \frac{\sum Z_1''}{N \cdot \sum T}, \textbf{ soum/kWh)}$$

$$a_2'' = \frac{\sum 3_2''}{m \cdot \sum T}, \textbf{ soum/(kg· h)}$$

$$a_2'' = \frac{\sum Z_3''}{\sum \pi_p \cdot m \cdot \sum T}, \textbf{ soum/(persons· kg · h).}$$

The following notation was applied above:

$\sum Z_0''$ are the operating costs for life safety, computers, management for the period of operation, soum; $\sum Z_1''$ are the operating costs for the power subsystem of the machine (fuel, lubricant, etc.) for the period of operation, soum; $\sum Z_2''$ are the operating costs for the technological subsystem of the machine (raw materials, technical service, repair, relocation, etc.), soum; $\sum Z_3''$ are the operating costs for the wages of service staff, soum; $\sum \boldsymbol{T}$ is the machine operation life, h.

Productivity $\boldsymbol{P}$ is an important component of most performance indicators. Performance is determined either experimentally or theoretically. Experimental determination of productivity is performed in accordance with the requirements of state standards GOST and ISO [3, 4]. At that, the compared machines must operate under the same

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operating conditions.

The theoretical calculation of productivity is based on the definition of each of the time terms of the cycle through the main technical and operational parameters. This makes it necessary to obtain and analyze data about the nature of the working cycle of the machine and the elements of its components.

II. CONCLUSION

1. Expression C_{sp} in formula (7) is an integral indicator of evaluation under operating conditions. The indicator can be used as a target function for the analysis and evaluation of the technical and economic efficiency of the use of machines.

2. To determine the reduced unit costs, considering the acquisition and subsequent operation of machines, it is necessary to have statistical data that must be obtained in organizations that operate these types of machines. The costs of capital investments and operating costs are formed based on these data.

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