Economic assessment when creating a comfortable operational environment for a mining excavator operator

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Abstract. Ergonomic studies aimed at ensuring competitiveness and compliance with the requirements of ergonomic standards of modern samples of traditional (mechanized) mining equipment will improve the reliability of the human operator. At the same time, it will allow creating the creation of comfortable and safe conditions for operators of remote-control devices for mining machines and dispatch centers for managing robotic mining equipment. The article presents economic assessment of measures when creating a comfortable working environment for a mining excavator operator.

1. Introduction
The need to implement plans for the strategic modernization of the Russian Federation (RF) economy involves solving the theoretical and applied problems of the domestic mining industry, and to a large extent determines not only the state of production resources of the country, but also its scientific and technical potential. The global mining development trend is mainly determined by open-pit mining of raw materials. This is due to the best economic performance of this method. Open-pit mining of mineral deposits is characterized by an increase in the volume of processed rock mass and overburden ratios, production processes are improved due to advanced technologies, which entail the use of mining equipment of large unit capacity. The efficiency and reliability of such equipment is ensured by its proper operation, minimizing the cost of maintaining and repairing machines, in particular mining excavators.

Mining excavators have reached a fairly high level of excellence. The equipment of excavators with modern control computer information and diagnostic systems, hardware and software for data transmission, processing and analysis provides an increase in the efficiency of open cast mining. At the same time, there remains a tendency to reduce the operational productivity of mining excavators due to an increase in the failure rate of the main components and mechanisms associated with the quality of managing a mining excavator due to operator fatigue and information overload. Mismatch of the interaction nature between the driver and the mining excavator, caused by the inadequacy of the system that allows minimizing the risks of failure of mining excavators during management, including due to insufficient ergonomic sophistication of the driver’s workplace.

The experience of leading foreign and domestic machine-building enterprises allowed establishing that improving the ergonomic and aesthetic parameters of products is increasingly becoming the main direction of growth in its competitiveness. Therefore, in order to increase the competitiveness of traditional and new types of excavation equipment, it is important to ensure a given level of consumer
properties based on the effective management of ergonomic quality indicators, increase the reliability of mining excavators, sanitary conditions and the comfort of the drivers.

In modern economic theory and practice, there are many approaches to assessing the economic efficiency of implemented measures. A variety of methods is due to the need to take into account when calculating the influence of various factors [1, 2].

However, the methodology for assessing effectiveness when using any of the methods is based on the calculation of the absolute and relative magnitude of the effects that arise when implementing measures.

The absolute value of the effects arising from the implementation of measures is estimated through the economic effect.

Economic effect is the final economic result obtained carrying out any event that causes the improvement of any indicators.

The experience in the development and operation of complex technical systems, which include a mining excavator, shows the need and importance of their ergonomic support. Ergonomic support means development and implementation of the requirements and conditions for the effective and high-quality functioning of a human operator.

The economic efficiency of ergonomic support is determined to justify the feasibility of its development, to determine its impact on the overall economic efficiency of the system, to compare competing system options for economic indicators, to evaluate the activities of development teams.

2. Methodology

Economic evaluation of ergonomic designs is carried out in the following sequence [3-6]:

- definition of the category of ergatic system - distinguish between systems with a rigid technological schedule, with an adjustable technological schedule and with a given amount of work;
- determination of possible sources of savings, which depend on the type of ergatic system (table 1 [1]);
- the choice of the basic version of the ergatic system, usually it is taken as its intended purpose option in which this ergonomic design has not yet been implemented;
- clarification of the list of initial data and calculation formulas for determining the economic effect depending on the type of system, its basic version and specific conditions for the implementation of ergonomic design;
- calculation of annual savings in operating costs from each source, as well as necessary for the implementation of the development of capital investments;
- determination of the magnitude of the economic effect and the effectiveness of ergonomic design;
- conclusions and recommendations for further similar developments.

Table 1. Possible sources of economic benefits.

| Source                        | Type of ergatic system |
|-------------------------------|------------------------|
|                               | With a tough          | with adjustable     | with a given |
|                               | technological         | technological       | amount of work |
| schedule                      | schedule              | schedule            |               |
| Decrease in losses of working hours | –                     | +                    | –             |
| Staff reduction               | +                      | +                    | +             |
| Increased reliability of ergatic system | +                    | +                    | +             |
| Increase of System Life       | +                      | +                    | +             |
Injury reduction and occupational diseases + + +
Decrease staff turnover + + +

3. Implementation
The study made an economic assessment of the measures effectiveness to create a comfortable working environment for a mining excavator operator (tables 2) [1,4].

Table 2. Characterization of the effect sources in the implementation of organizational and technical measures.

| Event | Sources of effect and their characteristics | At the macro level (country's economy) Social |
|-------|---------------------------------------------|---------------------------------------------|
| Improving the ergonomics of mining excavators | Increased labour productivity by reducing downtime | GDP growth (gross domestic product) |
| | GDP growth (in percent, in roubles per 1 excavator) | |
| | Savings on investments if you need to replace the excavator | Solving the problem of deterioration of equipment in the mining industry (the need to update the equipment fleet) (depreciation of 70%) |
| | 1.5 times longer ECC life | Creating ergonomic conditions for operators |
| Improving the efficiency of in-house training for drivers | Labor productivity growth due to higher operators’ qualifications | Solving the problem of labor shortages |
| | Cost saving (in roubles per year) | Continuing education, reducing staff turnover |
| | Savings on investments if you need to replace the excavator | |

Table 3. Indicators for assessing the economic effect of the measures implementation to create a comfortable working environment for a mining excavator operator.

| Economic Effect Source | An indicator characterizing the achieved effect quantitatively or qualitatively |
|------------------------|--------------------------------------------------------------------------------|
| Increased labour productivity by reducing downtime | The increase in the volume of work (in percent, in roubles per 1 excavator) |
| Labour productivity growth due to higher qualifications of drivers | The increase in the volume of work (in percent, in roubles per 1 excavator) |
| 1.5 times longer ECC life | Cost saving (in roubles per year) |
| 1.5-2 times increase in working capacity of hoisting ropes | Cost saving (in roubles per year) |
| Savings on investments if you need to replace the excavator | Savings on investments (in roubles per year) |

Social effect

3
Creating ergonomic working conditions for workers  Not quantified
Improving professionalism, qualifications of employees, reducing staff turnover  Not quantified

4. Conclusions
The implementation of the proposed organizational and technical measures will increase the amount of work performed on one mining excavator by 20%, or 12,528 thousand rubles per year; reduce annual operating costs by 417 thousand rubles per one mining excavator; reduce investment per year and one mining excavator by 1667 thousand rubles.

References
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