Fixing a comfort cabin level in modern mining excavators

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Abstract. Foreign policy events of recent years, expressed in the adoption of sanctions, along with the global economic crisis, have identified the need for import substitution in Russian industry. The issue of import substitution in the mining industry is strategically important, because it determines the vector of development of the Russian economy. Therefore, in order to increase mineral extraction capacities, it is necessary to re-equip the parks with new-generation modern excavators and modernize existing models. In order to increase consumer value, and hence competitiveness, it is necessary to develop excavation equipment in several areas, an important role belongs to improving the materials of the mechanical component of the excavator, as well as improving the interaction of man and machine based on the principles of ergonomics and engineering psychology. The work presents an original software product created to solve the automation problem of the ergonomic reengineering process with the possibility of ranking models of mining excavators by the comfort level in the cab.

1. Introduction
Studies found that labor efficiency depends on ergonomics and the convenience of the workplace. Due to the complexity of accounting for a large number of constantly changing factors of operating conditions, the variety of mining machines, their small seriality and rapid change of samples, methods for assessing the quality of mining equipment require improvement and adaptation to modern mining conditions [1, 2].

An essential circumstance is an objective assessment of the threshold values of ergonomic quality indicators, going beyond which will require changes in design decisions to improve mining excavators.

The category “product quality” put on the agenda the problem of the role and place of the human factor in modern quality management, formulated as managing the ergonomic level of quality (ergonomics) of products (EQPL).

EQPL is a systemically structured process based on a set of interrelated scientific provisions, as well as methods for their implementation, aimed at achieving the required product ergonomics within the framework of quality management due to the convenience and safety of conditions, means and product of functional activities.

Manageability, serviceability and assimilation describe the properties of a system in which it is organically included in the structure and process of a person or group of people in management, maintenance and development. This happens in those cases when decisions are put into the system design that create the best conditions for convenient, efficient and safe implementation of the indicated types of activities [1, 2].
Habitat refers to the operating conditions of the system under which the health of people is maintained; the normal dynamics of their performance and well-being are maintained. One of the effective ways to create such conditions is to eliminate or weaken the adverse factors of the working environment (noise, vibration, radiation, gas contamination, etc.) at the very source of their formation in systems, machines and equipment.

Manageability defines the following group indicators:

- compliance of the design of the machine and its individual elements and the organization of the workplace with the optimal psychophysiological structure and the process of human activity in normal and emergency conditions;
- compliance of the content of the machine-defined activities for managing the optimal level of complexity and the diversity of human actions;
- correspondence of the intensity of activity set by the machine to the minimum tension at which control efficiency is achieved;
- conformity of the requirements set by the machine to the quality of activities for managing optimal accuracy, speed and reliability of a person.

Serviceability is determined by the correspondence of the design of the machine (or its individual elements) to the optimal psychophysiological structure and the process of its operation, maintenance and repair.

Masterability determines:

- the possibilities of its quickest development inherent in the machine and operational documentation on the basis of acquiring the necessary knowledge, management and maintenance skills;
- machine-specific requirements for the level of development of professionally significant psychophysiological and psychological functions of a person for activities in both normal and emergency conditions.

Habitability determines:

- compliance of the operating conditions of the machine with the biologically optimal parameters of the working environment, providing a person with normal development, good health and high efficiency.

Manufacturability determines the set of product properties, reflecting the adaptability of its design to achieve optimal resource costs in its production, repair and disposal. Manufacturability characterizes not only the functional properties of the product, but its properties as an object of production and operation.

Ergonomics defines an approach to a person as a special link included in the system of technical devices, machines, and the environment.

At the present stage of development of domestic excavator construction, one of the pressing issues is the creation of a comfortable working environment for a mining excavator driver. The issues of optimal organization of the workplace in the cabin are very complex and multifaceted, since various factors must be taken into account, such as natural lighting, vibration, noise, dust, etc. Comfort in the cabin is composed of ergonomics of the workplace, rational placement of controls and information display facilities, as well as the organization of the cabin space as a whole. The basis of the latter is the division into zones: a workplace and rest place so that any driver fulfills his functional duties as efficiently as possible. For a clear idea of improving overall performance when using ergonomic workstations, the following statistics are available (figure 1) [1-5].
Designing ergonomic workstations “from scratch” is already a fairly studied area. Experts in the field of human factor and ergonomics have a more difficult task - to formalize, model and mathematically evaluate and describe the process of ergonomic reengineering that is, redesigning existing jobs under established resources and certain conditions. Therefore, the establishment of the comfort level of the cabs of mining excavators at the redesign stage is undoubtedly in demand.

![Figure 1. The ergonomics effect on work efficiency: (1) increase in the overall performance; (2) increase in labor productivity; (3) increased performance; (4) improving the accuracy and error-free operation; (5) reducing the time to perform work functions; (6) reduction of labor costs for the development of human interaction means with the workplace; (7) reduction in the incidence rate; (8) reduction in the number of accidents and disasters.](image)

2. Methodology
One of the methods of decision theory is the hierarchy analysis method. The hierarchy analysis method was created by the American scientist T. Saati.

The uniqueness of the method lies in the fact that it is both qualitative and quantitative. Being based on quality, because information on pairwise qualitative comparisons is used according to linguistic criteria, MAI allows to quantify the priorities of alternatives or other elements of the hierarchy T. Saati found a mathematically sound way of operating with judgments. As a result, it became possible to reduce the study of even very complex systems to a sequence of pairwise comparisons of appropriately defined components. This allows you to raise the method of expert assessments to a higher logical level.

The general structure of the hierarchy analysis method may include several hierarchical levels with their own criteria. The method consists of a combination of the following steps: the first step is to structure the task in the form of a hierarchical structure with several levels; at the second stage, pairwise comparisons of elements of each level are performed; importance factors for elements of each level are calculated, and the consistency of judgments is checked; the combined weight is calculated and the best alternative is determined.

Currently, in connection with the increased capabilities of modern computers, software information systems have been developed that provide support for the decision-making process in all its phases [6, 7]. Created as the methods of using the MAI in the common office suite MS Excel, Access, Open Office, as well as specialized programs.

3. Implementation
In order to evaluate and analyze the cabs of mining excavators, a computer program has been developed that implements the procedure for the phased analysis and calculations.

The program is based on the hierarchy analysis method (figure 2). The functionality of the developed software allows:

- to create complex and branched hierarchies;
• provide complete information about pairwise comparisons with the possibility of eliminating possible inconsistencies in the matrices of pairwise comparisons;
• carry out the calculation of priorities of alternative solutions;
• to evaluate alternatives (excavators) for each of the ergonomic indicators with the conclusion of the final diagram.

The program features include support for both numerical values and subjective verbal preferences of the user. The advantages of the program are a flexible and developed user interface with the ability to receive intermediate and final information about the solution in a convenient form with its output to the printer.

![Diagram](image)

**Figure 2.** Decomposition of the task of establishing the most comfortable cabin.

At the initial stage, the required number of experts, qualified specialists with experience in the operation and maintenance of mining excavators is set. Further, according to the developed questionnaires, the significance of each of the factors is assessed from the point of view of the members of the expert group with the ability to edit and store the results of the survey of various groups of ergonomic indicators (figure 3).

![Image](image)

**Figure 3.** The dialog box of the paired comparison matrix for the expert.
The results of the first stage are displayed in the form of a diagram from the list of MS Excel (figure 4).

![Diagram](image)

**Figure 4.** Diagram of the questionnaire results in establishing significance: (1) location and accessibility of controls and information display facilities; (2) cockpit glazing and visibility of objects of primary observation; (3) air temperature in the cabin; (4) the presence of industrial dust; 5 - vibration effect on the driver; 6 - noise impact on the driver.

4. Conclusions
The introduction of promising modern mining excavators and robotic mining machines with the expansion of their application fields determines the comfort level of the driver’s workplace, revision and addition of forms to ensure safe and ergonomic working conditions for operators, combined with a high reliability level of human activities in the technological operation performance.

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