Integral estimation of the activity of the maintenance department of the mining company

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Abstract. This paper demonstrates the results of study in relation to increasing the efficiency of the maintenance department of the mining company. We consider the systematic and complex approach to estimating the activities of the maintenance department, which is based on analyzing the efficiency of the arrangement for repairing and maintaining the mining machinery, evaluating the practicability of its operation according to the ratio ‘result/expenses’, studying the structure of the maintenance personnel and also evaluating the influence of operating modes and conditions on the productivity of machinery. This approach allows to find out the hidden reserves in the organizational, technical, technological and economic systems of the company. In addition, we demonstrate the results of evaluating the system ‘excavator-cut face’, which characterize the condition of an excavator and conditions (cut face, working area) of its operation, perform the analysis of the downtime of the equipment during the maintenance and when it breaks down. We consider the systematic approach to estimating the economic practicability of operating and repairing the mining machinery, which allows to make managerial decisions in relation to every unit of machinery. Also the recommendations for increasing the efficiency of the maintenance department of the company are given.

The material for the article is the study of authors in relation to increasing the efficiency of the maintenance department of the mining company. The accumulated experience allows to say that the increase of the production efficiency with the focus not only on the technical re-equipment but also on the increase of the single output of a machine, which is carried out without proper changes in the arrangement of the maintenance department, leads to the ineffective usage of resources, including the working time of the operating and maintaining personnel, which in its turn influences the output of the final product.

The applicability of the issue of maintaining the mining machinery is explained by significant and constantly growing expenditures of labour, material and financial resources. The non-core assets (maintenance and repair of the mining machinery) occupy about 30...40% in the production cost of the product. The amount of financial charges during the whole period of operating the machinery, as a rule, exceeds the initial cost by many times. [1]

The abovementioned situation puts a task of performing a quality analysis of problems of the maintenance department to owners and heads of mining companies in order to develop exact solutions which will provide the growth of its efficiency.
Scientific notions and practical recommendations related to the maintenance and repair of the mining machinery, which have been described in papers of G.A. Boyarskikh, A.S. Dovzhenka, L.I. Kantovich, A.A. Kuleshov, V.I. Morozov and other scientists, have been the basis for further studies of the maintenance department of the mining company.

In connection with this fact, the application of expert methods (audits) for analyzing the activities of the maintenance department becomes more important because it allows to study the activities of the maintenance department in more details and in a quality manner and to make the appropriate managerial decisions on the basis of received results.

Using the systematic and complex approach to estimating the efficiency of the maintenance department, it seems possible to find out the ‘bottlenecks’ and hidden reserves in the organizational, technical, technological and economic systems. [2,3]

Taking into account all the abovementioned information, many mining companies, which are interested in the growth of their efficiency, initiate the performance of the industrial and technical audit in relation to problematic issues with the involvement of outsourcing specialists.

The Institute of Efficiency and Safety of Mining Operations (NIIOGR) has quite large experience in fulfilling these works at the mining enterprises of Yakutia, Kuzbass, Kazakhstan and North-West of Russia in the following fields of activity:

- Evaluating the organizational and technical system of the maintenance department (maintaining facilities);
- Evaluating the practicability of operating the mining and transporting equipment according to the ratio ‘results/expenses’;
- Determining the sequence of withdrawing the machines from operation;
- Studying the structure and the efficiency of employing the maintaining personnel;
- Evaluating the interaction of structural units of the enterprise;
- Evaluating the influence of operating modes and conditions on the productivity of the mining machinery.

The structure of performing the industrial and technical audit at the mining enterprise is demonstrated in figure1.

![Figure 1. Structure of the industrial and technical audit of the mining enterprise](image)
The basic principles of performing the complex study of the activities of the maintenance department are [4]:

- Applicability of received results for a Customer and readiness of the personnel to go through all stages: from setting tasks to their resolution;
- Purposefulness of work;
- Efficiency of communication when performing the works.

In this paper we have demonstrated the results of the systematic and complex study (audit) of the maintenance department of one of mining enterprises in the Republic of Kazakhstan.

The fulfilled studies allow to determine that the efficiency of maintaining and repairing activities is influenced by the factors both in the sphere of operation and in the sphere of maintenance of the mining machinery (figure 2)

![Figure 2. Factors which influence the efficiency of maintaining and repairing activities](image)

The analysis of distribution of time for planning, preparing and fulfilling the maintenance works in workshops of the enterprise has shown the following results: for planning the maintenance and repair one should use 1.3-3.8 times more time, for preparing - 1.5-2.0 times less, for fulfilling the maintaining and repairing activities - 1.5-3.0 times more in comparison with the values, which are recommended in the Regulations on Preventive Maintenance. Nevertheless, the specialists of the maintenance department think it necessary to increase the period of time for fulfilling the maintenance and repair due to reallocation of time, which is planned for their preparation. As practice shows, this approach will lead to the reduction of the time between repairs and, as a consequence, to the reduction of amounts of extracted minerals.

The analysis of the downtime of the mining equipment has demonstrated that out of 8760 hours of the calendar labour time fund (CLTF) the planned outage and the downtime related to the breakdown of the machines are 37% and 24%, respectively. According to calculations, 1 hour of the planned outage takes 0.2-3.0 hours of downtime related to the breakdown (figure 3).

![Figure 3. Downtime of the equipment due to planned outage and related to the breakdown of the machines](image)
The revision of the technical condition of excavators, which has been carried out with due regard to the intensity of the operational load and the applied system of preventive maintenance and repair has shown that it significantly depends on the conditions, which this or that machine operated in, and operating modes (qualification of operators, degree of drive adjustment), which have significant influence on the appearance and development of defects in parts and units of a machine (Table 1).

Table 1. Number of defects, which have been detected when examining the excavators.

| Subdivision      | Number of examined excavators, pcs | Number of defects, pcs | Total number of defects, pcs | Number of defects for one machine on the average, pcs |
|------------------|------------------------------------|------------------------|------------------------------|-----------------------------------------------|
| Open cut 1       | 5                                  | 11                     | 5                            | 11                                            | 27 | 5.4 |
| Open cut 2       | 11                                 | 15                     | 15                           | 12                                            | 42 | 3.8 |
| Open cut 3       | 9                                  | 17                     | 27                           | 19                                            | 63 | 7.9 |
| **Total**        | **25**                             | **43**                 | **47**                       | **42**                                        | **132** | **5.5** |

According to preliminary calculations, about 55% of the loading capacity (total volume of bucket capacity of excavators) is operated either in unsatisfactory modes or in unsatisfactory conditions. Moreover, the consumption of spare parts for provision of 1 machine-hour of an excavator increases by 2.0-2.5 times in such conditions.

When studying the activities of the maintenance department, we used the parameters, which characterize the duration, the labour input and the cost of the maintenance, on the basis of which and using the matrix approach it is possible to identify the system «excavator/cut face», to determine its actual condition (figure 4) and to define the directions of changes in the arrangement of processes of technical and industrial operation.

**Figure 4. Matrix of conditions of the system «excavator-cut face»**

\( t_{пр} \) – time of productive work of the equipment, machine-hours; 
\( t_{yp} \) – specific duration of maintenance and repair, h/machine-h; 
\( t_{т} \) – labour input of maintenance and repair, man-h/machine-h; 
\( C_{тр} \) – specific cost of the current maintenance and repair, rub/machine-h
As a basis for evaluating the condition of the cut face and of the excavator we took the information from the Manual on capital repair of the excavator ЭКГ-10 and results of measuring the granulometric composition of the rock mass in the cut face (Table 2).

**Table 2. Condition categories for excavators and cut faces.**

| Excavator condition | Cut face/area condition |
|---------------------|-------------------------|
| **Good**            | **Good**                |
| Light wear and deformation of components (tracks, body sheets); Light loosening of component fastenings; Welded cracks, which do not go beyond the border, are permitted; Uniform wear of the working equipment and swing bearing. | Absence of «non-standard» pieces, Lumpiness of rock 150-300 mm, Time of Ps and Pn = 0%; Longitudinal and lateral tilt of the working platform is < 3°; Width of the working platform is 60-70 m, 2 drives. |
| **Satisfactory**    | **Satisfactory**        |
| Acceptable wear and deformation of components; Insufficient leakage of reduction gear oil; Loosening of component fastenings; Small cracks in metal structures, which do not go beyond the border; Traces of wire strands on drums, flattening of wires, broom of wire strands; Permissible wear of joints. | Existence of «non-standard» pieces, Lumpiness of rock 300-400 mm, Time of Ps and Pn = 10%; Longitudinal and lateral tilt of the working platform is ~ 3°; Width of the working platform is 40-60 m. |
| **Unsatisfactory**  | **Unsatisfactory**      |
| Unacceptable wear and deformation of components; Sufficient leakage of reduction gear oil; No component fastenings; Cracks in metal structures, which go beyond the border (boom, bucket); Multiple cracks in the upperstructure, track frame, deformation of swing bearing elements); Unacceptable heating of mechanisms; Unacceptable wear of joint. | Existence of «non-standard» pieces, Lumpiness of rock > 400 mm, Time of Ps and Pn > 20%; Longitudinal and lateral tilt of the working platform is > 3°; Width of the working platform is < 40 m (less than recommended); Existence of the «shield» in the cut face and holes in the working area; Soil subsidence in the working area. |

P\(_s\), P\(_n\) – time for clearing the cut face and demolishing the ‘non-standard’ pieces, in % of the shift duration

The important part of study is the analysis of the calendar labour time fund (CLTF) of operating the mining machinery, which allows to determine the structure of the productive and unproductive work. The calculations have demonstrated that the reserve of time for increasing the level of operating the technological excavators is 60-68% (figure 5).

**Figure 5. Structure of the calendar labour time fund of operating the excavator**
The specificity of the maintenance department is that it is closely connected with the operating department because the mining machinery must be in good operating condition in order to reach the planned amounts of extracted minerals. Taking this fact into account, according to the methodology which has been developed by the institute, when analyzing the efficiency of the maintenance department we have applied the criteria which describe:

- **Intensity** of operation – productive (estimated) time, during which the normative productivity is provided;
- **Reliability** of equipment (downtime due to the equipment failures);
- **Economy** – expenses on operation and maintenance.

On the basis of calculating the efficiency of operation of excavators according to the suggested criteria and applying the visualization according to the system ‘traffic lights’, it becomes possible to distribute the excavators into the spheres of efficiency in accordance with the calculated indices (figure 6).

| Excavator index, utility number | Intensity of operation | Throughput capacity, thou.m³/m³ | Throughput time, machine-h. | Reliability of machines | Downtime (emergency failure), h. | Economy of maintenance, s.u./machine-h. |
|--------------------------------|------------------------|---------------------------------|---------------------------|-------------------------|---------------------------------|----------------------------------|
| ЭКГ-8И, №2                    | 270 to 350             | More than 5000                  | Up to 170                 | #38                     | From 20 to 50                   | #2, 7, 9, 13, 37, 39, 40, 43 |
| ЭКГ-8И, №3                    |                        |                                |                           |                         |                                 |                                  |
| ЭКГ-10, №5                    | 190 to 250             | Up to 4000                      | #2, 3, 5, 13, 35, 43      | From 55 to 115          | #2, 7, 9, 13, 37, 39, 40, 43    |                                  |
| ЭКГ-10, №7                    |                        |                                |                           |                         |                                 |                                  |
| ЭКГ-10, №8                    |                        |                                |                           |                         |                                 |                                  |
| ЭКГ-10, №9                    |                        |                                |                           |                         |                                 |                                  |
| ЭКГ-8И, №13                   |                        |                                |                           |                         |                                 |                                  |
| Hitachi6000, №38              |                        |                                |                           |                         |                                 |                                  |
| Cat 385, №32, 38              |                        |                                |                           |                         |                                 |                                  |
| Cat 385, №33, 35              |                        |                                |                           |                         |                                 |                                  |
| Cat 385, №36, 37              |                        |                                |                           |                         |                                 |                                  |
| Bucyrus, №39, 43              |                        |                                |                           |                         |                                 |                                  |
| Bucyrus, №40                  |                        |                                |                           |                         |                                 |                                  |
| Bucyrus, №41                  |                        |                                |                           |                         |                                 |                                  |
| Bucyrus, №42                  |                        |                                |                           |                         |                                 |                                  |
| Bucyrus, №43                  |                        |                                |                           |                         |                                 |                                  |

From 270 to 350
More than 5000
Up to 170
#38
From 20 to 50
#2, 7, 9, 13, 37, 39, 40, 43

**Figure 6.** Distribution of excavators according to efficiency indices.

An inefficient sphere of operation is characterized with low productivity, high frequency of emergency downtime and also unacceptable expenses on repair. As a result, it has been found out that 67 of 112 excavators operate in the low-efficient and cost-intensive zone.

On the basis of achieved results of the study, the enterprise has been recommended the following critical measures:

1. To make a schedule of inspecting the technical condition of units and parts and to personify the responsibilities for its fulfillment with the framework of fulfilling the preventive maintenance of excavators.
2. To develop an instruction for inspecting the quality of repairing works which are carried out by maintenance teams.
3. To hold a revision (availability and quality) of technical documents (regulations on maintenance and current repair) for every excavator. To complete, if necessary.
4. To arrange the inspection of the condition of cut faces, modes and conditions of operation. To assign the responsibility to the crew and the mechanic.

5. To arrange the conditioning for every machinery unit (characteristics, technical condition, consumption of materials and spare parts, statistics of failures, maintenance and repair plan, its cost, etc.).

Heads of mining enterprises often face a choice: which machines they should buy and which machines should be withdrawn. The methodical approach, which is based on calculating the expenses on operation (technical and industrial) and also the income, which is received from selling the amounts of minerals, allows to make managerial decisions in relation to every machinery unit (figure 7).

![Figure 7. Distribution of excavators according to the ratio «expenses - income»](image)

The performance of the industrial and technical audit of the maintenance department at the following enterprises: «UK «Kuzbassrazrezugol», JSC «ALROSA» (CJSC), JSC «Sokolovsko-Sarbaiskoe gorno-obogatitelnoe proizvodstvennoe obedinienie» and JSC «Euroasian Resources Group» (Republic of Kazakhstan), JSC «Kovdorskiy GOK» using the systematic and complex approach has allowed to for these enterprises to demonstrate the following results, which are represented in the Table 3.

On completing the works related to the analysis of the activities of the maintenance department, the enterprise has been given the methodical materials, Regulations on preventive maintenance, repairing and technological and regulatory documents, methodics and methodical recommendations, which contain the analytical calculations and which allow to reach another level of efficiency of the maintenance department on condition of the proper arrangement and interest of the key personnel of the enterprise by way of optimizing the resource consumption and increasing the reliability of the mining machinery.[5]

As a brief summary of the results of the fulfilled study, it is important to pay attention to the necessity of constant improvement of the methods of calculation and evaluation of activities of the maintenance department of the mining company, which allows to react to negative changes and to make appropriate managerial decisions in due time.
Table 3. Recommendations for enterprises.

| Excavation                                           | Ore preparation                                                                 | Enrichment                                                                                   |
|------------------------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| • Decision to withdraw a part of mining machines from operation according to the following criteria: - reliability; - intensity; - economy. | • Evaluation of the technical condition and productivity of the crushing and grinding equipment (CGE); | • Calculation of the possible productivity of the enriching equipment |
| • Development of five projects of efficient arrangement of works of maintenance departments | • Development of recommendations for replacing the CGE with due regard to its technical condition and productivity | • Evaluation of skills of the operating and maintaining personnel in relation to its functions |
| • Development of technological regulations on excavator repair (standards) | • Development of technological regulations on repairing the CGE                  | • Arrangement of analytical and modelling seminars in relation to issues of motivation and interaction of the personnel |
| • Attestation of excavator operators                  | • Arrangement of training workshops for studying the technological regulations by the personnel | • Development of technological regulations on repairing the enriching equipment |
| • Attestation of maintaining and repairing personnel   | • Arrangement of the knowledge control of the maintaining and operating personnel in relation to the knowledge of safety rules and regulations | • Fulfilment of the metering of the working time by heads and supervisors of the department. Determination of losses of the working time as 35% |
| • Development of road maps of inspection for mining machinery and equipment (checklists) | • Development of «Regulations on the interaction of departments »               | • Fulfilment of the metering of the working time of the maintaining and repairing personnel. Determination of losses of the working time as 30% |
| • Development of Regulations on motivating the operating and maintaining personnel | • Development of «Regulations on motivating the personnel »                    |                                                                                               |

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