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Optimization of repair facilities based on the theory of reliability in a digital economy

Dolzhenkova E.V.
Ural Federal University
Ekaterinburg, Russia
lenag1981@mail.ru

Iurieva L.V.
Ural Federal University
Ekaterinburg, Russia
l.v.iuryeva@urfu.ru

***Abstract* — Reliability theory allows determining the economically feasible level of equipment operability at an industrial enterprise. the development on this basis of business planning and effective resource supply of the production unit contribute to the successful functioning of the industrial enterprise as a whole in the digital economy. The article analyzes the possibilities of using the theory of reliability to optimize the repair economy in a digital economy. Decisions made on the basis of reliability theory should increase the efficiency of the main production serviced by the repair service of the enterprise, as well as reduce the likelihood of investment risks. The article describes the conducted study of the reliability of technical objects, assuming reliability, durability, maintainability. The separation of reliability into these categories is made to more fully take into account time factors during the operation of equipment, maintenance, transportation, and storage. The organization of the repair facilities of the Mechanical Repair Shop of the Specialized Repair Enterprise OJSC «Vysokogorsky Ore Mining and Processing Plant» was used as an object. The article analyzes the methods for determining the costs of the repair unit for the purchase of spare parts. An author's model of the interaction of reliability theory with existing elements of business planning at an industrial enterprise is proposed. The model helps bring the costs of the repair unit of an industrial enterprise closer to the set limit and more efficiently and rationally plan the schedule of scheduled preventive repairs for this unit. Improving the process of planning repairs and maintenance of basic technological equipment based on the use of reliability theory will also reduce losses from unplanned downtime of this equipment, which is so important for ensuring the competitiveness of an industrial enterprise in a digital economy.**

Keywords — optimization, digital economy, industrial enterprise, reliability theory.

I. INTRODUCTION

As applied to industrial enterprises in the digital economy, the development of business planning and effective resource provision require a new approach based on the theory of reliability, which allows determining the economically feasible level of equipment operability. This fact has a significant impact on competitiveness indicators [3, 4].

All production processes are carried out through the use of technical objects that are different from each other in constructively manufactured products, operating conditions, technical level and age. Industrial enterprises also have a wide variety of technological processes, indicators of capital intensity, production volumes, structure and composition of equipment, dependence on climatic and other conditions.

Economic entities have to solve the problems of increasing capital and the successful functioning of an industrial enterprise in the digital economy in the near and distant future. The behavior of an economic entity in the market of goods, the choice of a business strategy, the need for savings, and the identification of internal production reserves depend on the successful solution of such problems. Obtaining economic profit - the main source of expanded reproduction as a result of solving these problems is evidence of increasing the efficiency of the industrial enterprise: competitiveness indicators are increasing, the financial situation is improving, it is possible to satisfy the interests of all business participants.

Since technical objects (their components) during operation are subject to physical wear and tear and gradually lose initial state and service parameters, their intended use within a certain service life is accompanied by two types of tasks: preventing pathological damage processes and restoring working properties by replacing worn one’s component parts.

The solution to these problems is carried out by services specialized in the types of work and equipment that form the maintenance and repair system. Analyzing the problems of the organization and economy of the repair economy, it can be concluded that the template approach is not acceptable for their solution. In the digital economy, the problems of the repair facilities of production associations are solved in one way for large enterprises, for small and medium-sized ones - in another. Decisions should provide an increase in the efficiency of the main production, which is serviced by the repair service of the enterprise, and also reduce the probability of investment risks [3, 8, 11].

When studying the process of monitoring power systems, it was proved that such monitoring will increase the reliability of such systems through strict security restrictions [1].

Many scientific papers have been devoted to the use of cyber-physical systems to increase reliability [6, 7, 9].

B. Kirubakaran and M. Ilangkumaran proposed four criteria to evaluate the optimal service strategy — safety, cost, value-added, and feasibility studies [5].

Issues of managing investment risks of industrial enterprises in the digital economy are presented in [10, 12].

The review of scientific works has allowed to generalize the experience, the particularities of using the theory of reliability in the work of industrial enterprises in the digital economy, and to note the incompleteness of research on such

issues at the moment, as well as the need to develop methodological approaches to managing investment risks and substantiating the life of equipment based on reliability theory.

II. The Research Method

The need for orientation on reliability lies in the fact that indicators allow estimating the duration of maintaining the operability of technical objects. Any reliability indicators are inextricably linked with such important factors as time or resource, expressing the production or processing of products in volume, linear or weight indicators.

The reliability of technical objects is a generalized property that includes the concepts of reliability, durability, maintainability, and storage. The separation of reliability into these categories is made to fully take into account time factors during the operation of equipment, maintenance, transportation or storage.

Reliability is the property of an object to continuously maintain operability for a certain period of time or some operating time. Reliability continuously decreases in this period. It is estimated by the magnitude of the probability of uptime or failure, the determination or purpose of which is a difficult technical task at any given time.

Durability is the property of an object to remain operational until the limit state occurs during the entire period of operation. The durability of the facility is characterized by the ability to maintain operating functions with minimal maintenance time. The lower these costs, the higher the durability.

Maintainability is a property of an object, which consists in adapting it to service. It determines the time spent on maintenance, being an integral part of longevity.

Preservation - this is the time during which the object retains the necessary properties during transportation and storage.

The essence of the time factor in the given reliability indicators is based on the one hand on the speed of the physical aging processes of machine parts, depending on the magnitude and nature of the operational impact, and the operational properties of the material of the parts that determine the resistance to these effects, and on the other hand, on the speed of the recovery processes, depending on the organization of their conduct.

The value of reliability from an economic point of view is determined by the influence that it has on reducing integrated downtime for scheduled repairs (by increasing the frequency and duration), on reducing unscheduled repairs, repair costs, and labor costs, on the durability of equipment components, on the consumption of spare parts and size stocks.

There are four main areas of organization and planning of repair and maintenance of fixed assets at industrial enterprises:

- organization and planning of repairs and operation of technological equipment - carried out by the services of the chief mechanic;
- organization and planning of repair and operation of power equipment and power supply (transformers, compressors, steam boilers, gas generators, electric motors, etc.) - carried out by the services of the chief power engineer;
- organization and planning of repairs and maintenance of industrial and other buildings and structures - carried out by services for the repair and maintenance of buildings;
- organization and planning of repair and operation of residential and public buildings - carried out by the housing and communal services..

The presence of a debugged mechanism for performing repair work is a necessary and sufficient condition for the effective organization of work of any industrial enterprise. If the proportion of repair costs, equipment maintenance is reduced in the cost of production, this indicates an increase in production efficiency and the repair facility itself. It is proposed to apply the theory of reliability to predict irrational losses in production and reduce repair costs. Theory can be used to manage spare parts inventory.

Using the theory of reliability, in addition, reduces the loss of working time as one of the reserves for increasing output. This circumstance does not always lead to a decrease in the volume of production, which is associated with a change in the intensity of labor of workers. Therefore, when analyzing the use of labor resources, it is also necessary to consider indicators of labor productivity. To improve such indicators on the basis of the theory of reliability, it is possible

- to reduce the complexity of products by introducing measures of scientific and technological progress, comprehensive mechanization and automation of production, equipment modernization;
- to improve such indicators on the basis of the theory of reliability, the concept of lean production can be introduced for the full use of the enterprise's production capacities: with increasing production volumes, only the variable part of the working time costs increases, and the constant remains unchanged, which leads to a reduction in the time spent on the production unit.

The volume of output as one of the indicators of the effectiveness of the enterprise is directly related to the value of production capacity, which is characterized by the maximum possible annual output of a certain assortment in constant conditions. Production capacity changes if new fixed assets are put into operation, the condition of existing assets is improved, or old and unnecessary equipment is eliminated. All this is easy to foresee when planning production. These points will be emphasized in the study of production efficiency problems.

Underutilization of existing production capacities is largely predetermined by the imbalance of individual parts of the enterprise, which are in a single technological chain. Therefore, the real production capacity of an enterprise is determined by the magnitude of the most "bottleneck" in production. Identification and elimination of such places is an important task of analysis.

As a result, a method based on information on the current state of the components of technical objects and on the management of this state helps to increase the frequency of

unit shutdowns for repairs and reduce their duration. This makes reliability the most important factor that should be taken as a basis when planning repairs and other equipment maintenance work.

Determining the need for spare parts involves several options for planned calculations:

- from the achieved level of the reporting year;
- from the frequency of repair (preventive) work;
- from the complexity of repair work;
- of the volume of products manufactured on this equipment;
- from the level of the minimum acceptable reliability of equipment.

According to the first method, the cost of spare parts is calculated by formula 1:

$$R = k * M_0 * P \quad (1)$$

where R is the cost of the purchase of spare parts, rubles .; k is the coefficient of change in the operating mode of the equipment in the planned year; M0 - consumption of spare parts in the reporting year, units; P - the price of spare parts, rub.

In the second method, the cost of acquiring spare parts are found in formula 2:

$$R = (T / t_0) * n * P \quad (2)$$

where R is the cost of the purchase of spare parts, rubles; T is the total operating time of the equipment in a year, h; t0 is the frequency of prevention, h; n is the number of replaced spare parts during one cycle of preventive maintenance; P - the price of spare parts, rubles.

Depending on the complexity of the repair work (method 3), the cost of purchasing spare parts are found by formula 3:

$$R = A * m * P \quad (3)$$

where R - the cost of the purchase of spare parts, rubles; A - the complexity of repair work, man-hours .; m - the number of replaced spare parts per 1 person-hour of repair work; P - the price of spare parts, rubles.

In the fourth method, the costs will be determined by formula 4:

$$R = S * m' * P \quad (4)$$

where R is the cost of the purchase of spare parts, rubles; S - the volume of products manufactured on this equipment per year, thousand rubles; m '- the number of spare parts per 1 rub. manufactured products; P - the price of spare parts, rub.

Finally, it is necessary to calculate the following indicators for determining costs using the theory of reliability [2]:

- failure rate characterizes the failure rate;
- probability of failure is the probability of failure before the end of the given interval;
- the probability of failure-free operation is the probability that the object will remain operational - there will be no failures for a given time interval.

III. Results And Discussion

Consider the organization of the repair facilities of the Mechanical repair shop of the Specialized repair enterprise OJSC «Vysokogorsky Ore Mining and Processing Plant» as an example.

The mining industry is one of the most important sectors of the economy of the Ural region. Here, up to 20% of the total production is mined.

The possibility of the normal functioning of a mining enterprise requires the proper organization of work in three main areas of activity: production, commercial, and financial. Only the joint, coordinated, and effective activity of the enterprise in all three areas can ensure the possibility and proper efficiency of the enterprise. The leading field of activity of such enterprises is production.

Specialized Repair Enterprise (SRE) is a subdivision of OJSC «Vysokogorsky Ore Mining and Processing Plant». The main objective of the PSA is to ensure the integrity of the technological equipment of the structural divisions of the LSP and VCP for the mechanical and electrical parts. The Vysokogorsky concentration plant (VCP) is engaged in the crushing of raw ore and its further enrichment, and the sinter is produced in the Lebyazhensky sinter plant (LSP). These and other workshops are serviced by the mechanical repair shop (MRS). According to the analysis, MRS is the most expensive among the repair divisions of the SRE. In our opinion, improving the production and business activities of the MRS SRE OJSC «Vysokogorsky Ore Mining and Processing Plant» will have a significant impact on the operation of the whole SRE.

Mechanical repair shop is the main base of OJSC «Vysokogorsky Ore Mining and Processing Plant» for the production of spare parts for ongoing and overhauls of sinter and mining equipment. Production facilities of the workshop are currently used to a limited extent. The mechanical equipment of the workshop is outdated both morally and physically. The wear rate is approaching 100%. The main machine park with a depreciation level of 100%. Production technology is outdated and lags far behind modern production methods.

We define the needs for the most expensive spare parts for the main technological maintenance of the enterprise. The cost of their acquisition is currently about 80% of the total cost of purchased spare parts of the enterprise (table 1).

Based on table 1, the following conclusion can be made. The costs of the enterprise will be the smallest when determining the number of spare parts in the unit based on the use of reliability theory. According to the calculations, they will amount to 523549.00 rubles. The need for spare parts at a specialized repair facility is currently being determined using the first method (depending on the achieved level of the reporting year). According to estimates, the enterprise's expenses for the purchase of spare parts amount to 663290.00

rubles, which is 139741.00 rubles higher than the same costs, determined on the basis of the use of reliability theory. Thus, costs are reduced by 21%.

TABLE I. METHODS FOR DETERMINING THE COSTS OF MRS SRE OJSC «VYSOKOGORSKY ORE MINING AND PROCESSING PLANT» FOR THE ACQUISITION OF SPARE PARTS, THOUSAND. RUB.

Method	Cone Crusher (UD-1)		Drum Mill MShR 36x40 №2		Total expenses
	Conical sleeve	Leakproof Armor	Armor	Lattice	
1	63,315	9,315	307,440	283,219	663,290
2	133,534	29,471	745,826	916,091	1824,924
3	70,350	10,350	341,600	314,688	736,988
4	140,700	20,701	683,200	629,376	1473,978
5	70,554	17,388	225,703	209,903	523,549

Currently, the need for spare parts is determined by the MRS repair service: the relevant requests are submitted to the SRE logistics department, which properly prepares them and submits them to the supply and sales organizations in the order form. Thus, the MRS performs procurement functions to the detriment of its obligations to ensure the reliable operation of the equipment through regular maintenance and preventive maintenance. MRS is not responsible for the submitted applications - all responsibility for providing the unit with spare parts rests with the SRE logistics department. Submitted requests for spare parts are often not sufficiently substantiated. This situation leads to an exacerbation of the problem of spare parts - to their shortage. Lack of spare parts leads to premature wear of equipment and premature wear increases the need for spare parts.

The cost limits for the operation of units established within the framework of the budgeting system of OJSC «Vysokogorsky Ore Mining and Processing Plant» involve the provision of repair services with spare parts at minimum cost. There is a conflict between the repair services and other units of the enterprise. Being responsible for providing the enterprise with spare parts, the logistics department is in a passive state, fulfilling the instructions of the MRS. These circumstances complicate the work of the department of material and technical supply of an industrial enterprise, create a false impression among some workers about the impossibility of planning the need for spare parts. As a result, spare parts supply activities are built on a purely operational basis. This means that the equipment operates until the orresponding spare part is completely worn out, i.e. until complete failure. Overspending of spare parts arising from inadequate maintenance and equipment prevention is charged to the repair service.

Thus, the calculations made using the theory of reliability show that the SRE repair service should carry out preventive maintenance:

- for a conical sleeve - with a frequency of 2 working shifts (16 hours);
- for leakproof armor -with a frequency of 5 working shifts (40 hours
- for armor - with a frequency of 1 shift (8 hours);
- for the lattice - with a frequency of 1 shift (8 hours).

IV. CONCLUSION

Thus, the application of the theory of reliability makes it possible to bring the costs of the repair unit of an industrial enterprise closer to the established limit and more effectively plan preventive maintenance for this unit. Improving the planning process for repairs and maintenance of the main technological equipment based on the use of reliability theory will also reduce losses from unplanned downtime of this equipment, which is so important for ensuring the competitiveness of an industrial enterprise.

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