Reliability theory for repair service organization simulation and increase of innovative attraction of industrial enterprises

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Abstract. The study presents the author's algorithm for the industrial enterprise repair service organization simulation based on the reliability theory, as well as the results of its application. The monitoring of the industrial enterprise repair service organization is proposed to perform on the basis of the enterprise's state indexes for the main resources (equipment, labour, finances, repair areas), which allows quantitative evaluation of the reliability level as a resulting summary rating of the said parameters and the ensuring of an appropriate level of the operation reliability of the serviced technical objects. Under the conditions of the tough competition, the following approach is advisable: the higher efficiency of production and a repair service itself, the higher the innovative attractiveness of an industrial enterprise. The results of the calculations show that in order to prevent inefficient losses of production and to reduce the repair costs, it is advisable to apply the reliability theory. The overall reliability rating calculated on the basis of the author's algorithm has low values. The processing of the statistical data forms the reliability characteristics for the different workshops and services of an industrial enterprise, which allows one to define the failure rates of the various units of equipment and to establish the reliability indexes necessary for the subsequent mathematical simulation. The proposed simulating algorithm contributes to an increase of the efficiency of the repair service organization and improvement of the innovative attraction of an industrial enterprise.

1. Introduction

The urgency of the issue of simulating the industrial enterprises work organization under the condition of reliability increasing is determined by the current geopolitical situation in the world, once again proving the inconsistency of the export and raw materials orientation of the Russian Federation economy and the need for its transition to the path of the innovative development, which is associated with the acceleration of the equipment upgrades and the need for an economic justification for its reliability.

Consequently, an entrepreneur operating under conditions of competition at his own risk, whose future in a market economy is unpredictable or poorly predictable, first of all, is interested in the possibility to prevent the damage due to a risk situation onset. In this connection, the methods for the investment risks managing are, within the framework of which it is provided for carrying out various measures aimed at the reducing or preventing the risk events onset. One of the directions for reducing the likelihood of losses due to the investment risks onset is the implementation of measures to simulate the repair service organization on the basis of reliability theory.

The power systems monitoring process is described in the work [1], the authors of which believe that the power electronic systems monitoring will increase the reliability of the said systems using the strict security restrictions. The use of the cyber-physical systems to increase reliability is described in the works [2-4]. Kirubakaran B and Ilangkumaran M proposed a study on the selection of the service strategies depending on the reliability level of the equipment [5], in which four main criteria were used to evaluate the optimal service strategy - safety, cost, value added, and technical and economic grounds. The study of the theoretical aspects for the institutional factors analysis in the innovation development is considered in the works [6-8]. The issues of managing investment risks to increase the innovative attraction of enterprises are considered in the works [7, 9].

Despite a large number of works devoted individually to the problems of the technical systems reliability, investment risks and justification of their service life; the study of these issues in the interconnection and in the context of science has not received due attention. All this, as well as the existence of a number of disputable and unresolved aspects of the said problems that are not adequately reflected in the scientific literature, determined the choice of the research subject.

2. Research Methods

The repair service is interpreted as the totality of a factory and workshops units that carry out a complex of measures for repair, maintenance and supervision of the equipment state, as a result of which the following issues are solved:

- maintenance of constant operating readiness of all equipment, its updating;
- equipment interrepair time elongation
- improving the organization and quality of repairs;
- increase of the repair workers' productivity and a reduction of the repair costs.

It should be noted that one of the conditions for the effective organization of the work of any industrial enterprise is the availability of a well-functioning mechanism for the repair work performing. The lower the share of the expenses for the repair and maintenance of the equipment in the production costs, the higher the efficiency of the production and the repair service itself, the higher the innovation attraction of an industrial enterprise. Despite the outlined growth of the innovative activity of the Russian industrial enterprises, the investments in innovations are still insignificant [10]. However one can note the following trend: with the positive dynamics of expenses for technological, organizational and marketing innovations, the innovative activity of Russian enterprises is growing. Thus, in the period from 2009 to 2014, according to the Federal Service of State Statistics of Russia, the innovation activity of the enterprises grew by 4% with an almost double increase in innovation costs. The low activity of the business sector in R&D financing is largely defined by the lack of interest in the introduction of innovations in the production process, including due to the high costs of managing the repair business.

To prevent the unnecessary losses in production and reduction of the repairs cost, it is proposed to use the reliability theory.

The authors' algorithm includes the following stages:

– evaluation of the repair service state by the main resources on the basis of reliability level determination;

– designing of a new model of an industrial enterprise repair service organization;

– the repair service organization effectiveness evaluation on the basis of the reliability theory, feedback.

Stage 1: Evaluation of the repair service state by the main resources. The main parameters of the repair service include: equipment, labour, finances, and repair areas. The authors suggest evaluating each of the parameters using the following indexes (Table 1).

After assigning a rating value to each of the parameters, it is necessary to find the resulting rating of the state of the repair facility. To do this, one needs to find the sum of the ratings for all the parameters. If the resulting rating is negative or equal to zero, this indicates a low level of reliability; if the value is equal to 1 or 2, this indicates an average level of reliability, hence if the value of the indicator is 3 or 4, this indicates a high level of reliability. The repair services of such enterprises are not considered in the framework of the proposed algorithm.

Stage 2: Design of a new model for an industrial enterprise repair service organization. This stage begins with an evaluation of the amount of the current costs for the repair service organization. To do this, it is proposed to analyze the data of an industrial enterprise accounting records, as well as of the internal reporting to analyze the enterprise divisions activities.

Table 1. Repair service state indexes

Parameter	Evaluation Index	Index Calculation Formula	Change	Rating Value
Equipment	Yield of capital investments (Yci)	Revenue / Average value of basic assets	Increase (Decrease)	+1 (–1)
Labour	Productivity (Pr)	The amount of the products / labour time spent on production of these products	Increase (Decrease)	+1 (–1)
Finances	The share of the actual expenses for repairs in the budget of the service (Se)	Subdivision's costs of repairing / Subdivision's budget	Decrease (Increase)	+1 (–1)
Repair Areas	Equipment standstill intervals due to the inappropriate location of the repair area (Tst)	Standstill period	Decrease (Increase)	+1 (–1)

Further, the parameters of the new model of the repair service organization are determined, for which the factor analysis data, the chain substitutions method, etc. may be used. Other methods and the necessary combinations thereof may be used also. Since any method is limited in its capabilities, in practice it is advisable to combine different methods with the aim to level their shortcomings and to strengthen their merits. Therefore, in order to obtain a more complete and justified picture, it is inevitably necessary to use various methods.

At the moment there are many formalized and non-formalized methods used for the analysis. Some methods require highly qualified training; other methods are simple, but they require good knowledge of the production specifics; others are very simple, mostly meant for intuition, etc. It should also be noted that any forecast is effective only in the process of the constant monitoring of the particular factor dynamics.

The second stage ends with the preparation of a plan for the transition to a new model of the repair service organization, as well as its implementation in an industrial enterprise.

Stage 3: The repair service organization effectiveness evaluation on the basis of the reliability theory, feedback. At this stage, the evaluation of the repair service organization effectiveness is made on the basis of reliability theory, which is based on the calculation of three main indicators:

1) The failure rate characterizes the frequency of the failures occurrence and is determined by formula 1:

$$\lambda = \frac{n}{N_0 * \Delta t} \tag{1}$$

where λ is a failure rate, 1/hour; n is a number of failures, registered during the test period; N_0 is a number of the tested objects; Δt is a test period, hour.

2) The probability of failure is the probability of a failure before the end of the specified interval. The probability of failure is determined by formula 2:

$$Q = \lambda * e^{-\lambda t} \tag{2}$$

where Q is a probability of failure; λ is an failure rate, 1/hour; t is a test period, hour.

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3) The probability of a failure-free operation is the probability that the object will remain operational, that is, there will be no failures during a given time interval. The probability of failure-free operation is determined by formula 3:

$$P = 1 - \frac{n}{N_0} \tag{3}$$

where P is a failure-free operation probability; n is a number of failures, registered during the test period; N_0 is a number of tested objects.

If the dynamics of the indicated indicators seems to be positive, then one should return to the first stage of the algorithm and outline new goals for improvement of an industrial enterprise repair service organization to increase its investment attraction. In case of the negative dynamics of these indicators, which testifies to a decrease in the efficiency of the material, labour and financial resources use at the repair service and, as a consequence, a drop in the level of the equipment operability and reliability, one should go to the design stage and to adjust the measures aimed at optimizing an enterprise repair service and increasing its investment attraction.

Under conditions of the modern management, the reasonable planning of the timing of the technical maintenance and repair of the equipment is of great importance. The duration of the equipment failure-free operation, the period of its standstill under repair, the cost of the repairs and, as a consequence, the efficiency of the enterprise as a whole, its investment attraction depend on the establishment of a reasonable duration of the interrepair periods and, accordingly, the timing of the repair work. The results of the analysis and forecasting of the equipment failures by groups and types can serve as the basis for the repair work planning system and measures to ensure the required reliability of the equipment.

To solve the problem of predicting the timing of the machines and equipment failures the mathematical models may be used with the application of the parts resource allocation laws classified according to the nature of the initial information: repairs statistics, diagnostics statistics, data on loads, expert estimates of the resource. The result of the mathematical models use is the finding of the parameters needed to determine the predictive estimate of the residual life of a part (unit, machine). To develop the repair standards, establish the regulated terms and volumes of work on diagnostics and maintenance, forecasting, planning and the repair system management, it is necessary to establish the regularities of aging of the parts, units and machines in general.

3. Results and Discussion

The approbation of the proposed algorithm was performed at JSC "NPK "UVZ". The work of the various workshops and divisions of the enterprise was analyzed, the summary reliability rating of which is calculated in Table 2.

Table 2. The summary reliability rating of the workshops and divisions of JSC "NPK "UVZ"

№№	Workshop	Evaluation Index				Summary Rating
		Yci	Pr	Se	Tst	
1	640	-1	-1	-1	-1	-4
2	900	1	1	-1	1	2
…	…	…	…	…	…	…
18	Department 450	1	1	0	0	2

According to table 2, the smallest summary rating among the workshops and divisions of the machine-building enterprise is –4 for workshop № 640. This indicates the need to increase the efficiency of this unit in order to improve the financial component of the investment attraction of an industrial enterprise as a whole.

Workshop №640 of the JSC "NPK "Uralvagonavod" has a schedule of maintenance and repair of the equipment, according to which the divisions should carry out preventive works on equipment adjustment. The maintenance schedule is shown in Table 3.

Table 3. The schedule of maintenance and repair of the equipment of workshop № 40 of the JSC "NPK "UVZ"

№ №	Equipment Unit	Repair type by months											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Welding Equipment	PR	PR	PR	PR	PR	PR	PR	PR	PR	Ov	PR	PR
2	Overhead Cranes			PR			PR			PR			Ov
3	Crane Beams		PR			PR			PR			Ov	
4	Welding Stands		PR		PR		PR		Ov		PR		PR
5	Intermediate Trolley	PR		PR		Ov		PR		PR		PR	
TOTAL man-hours			12	22	20	16	34	32	12	134	20	218	162

According to Table 3, the following indexes can be defined. Man-hours:

1. Welding equipment: Permanent repairs (PR) - 8 hours; Overhaul (Ov) - 210 hours.
2. Overhead Cranes: PR - 8 hours; Ov - 190 hours.
3. Crane Beams: PR - 6 hours; Ov - 150 hours.
4. Welding stands: PR - 8 hours; Ov - 120 hours.
5. Intermediate trolley: PR - 4 hours; Ov - 20 hours.

Table 4. Actual performance of maintenance and repair of equipment

№ №	Equipment Unit	Repair type by months											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Welding Equipment	-	PR	PR	-	-	PR	-	-	PR	Ov	-	-
2	Overhead Cranes	/	/	-	/	/	PR	/	/	PR	/		Ov
3	Crane Beams	/	-	/	/	PR	/	/	PR	/	/	Ov	/
4	Welding Stands	/	PR	/	PR	/	-	/	Ov	/	-	/	PR
5	Intermediate Trolley	PR	/	-	/	-	/	PR	/	-	/	PR	/
TOTAL man-hours			4	16	8	8	8	16	4	126	16	210	154

The actual performance of maintenance and repair of the equipment in workshop № 640 is given in Table 4.

When comparing the data from Tables 3 and 4, it is easy to determine that there is a violation of the maintenance and repair schedule in the workshop. This circumstance indicates a problem in the repairs planning and carrying out. For scheduling repairs, it is proposed to use the technique of predicting equipment failures based on the equipment aging.

Basing on the statistical material, the authors conducted a study of the equipment failure rates in the workshop. The processing of the statistical data made it possible to establish the following characteristics of the equipment reliability: the mean failure time m, the dispersion of the failure time D, the rate parameter $\lambda=1/m$.

According to the empirical observation results, the failure rates of the various pieces of equipment in the workshop were determined. The processing of statistical data made it possible to establish the reliability indicators necessary for subsequent mathematical simulation (see Table 5).

On the basis of the statistical data from Table 5, the authors, using the STATGRAPHICS Centurion software, approximated the dependencies of the changes in the failure parameters of each equipment group from its lifetime, and an equipment unit lifetime was also determined. Thus, for the welding equipment it was 130.4 h; for the overhead cranes it was 436.5 h; for the crane beams it was 186.7 h; for the welding stands it was 134.2 and for the intermediate trolleys it was 206.8 h.

Table 5. Reliability characteristics of the manufacturing equipment of workshop № 640 of the JSC "NPK "UVZ"

Equipment Name	Number of Failures	Operating Time, h	m	D	λ
Welding Equipment					
1	7	210	30.00	1.2522	0.0333
…	…	…	…	…	…
Overhead Cranes					
1	24	480	20.00	0.75593	0.0500
…	…	…	…	…	…
Crane Beams					
1	18	240	13.33	2.3255	0.0750
…	…	…	…	…	…
Welding Stands					
1	3	650	216.67	0.7071	0.0046
…	…	…	…	…	…
Intermediate Trolley					
1	32	250	7.81	0.7471	0.1280
…	…	…	…	…	…

Based on the data obtained, a schedule for the equipment maintenance and repair was proposed taking into account the revision of the equipment aging standards. Besides, it was revealed that the standstills due to the equipment breakdown amounted to 257.92 hours. During this time the shop could produce 7020 units of production, which in value terms is equal to 90250453.8 rubles.

4. Conclusion

Thus, the developed methodological tool allows increasing the effectiveness of an industrial enterprises repair service organization on the basis of the reliability theory and improving the innovative attraction of enterprises.

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References

[1] Choi U-M, Blaabjerg F, Jorgensen S, Munk-Nielsen S and Rannestad B 2017 *IEEE Transactions on Power Electronics* **32 (10)** 7990-7997
[2] Lazarova-Molnar S, Shaker H R and Mohamed N (2017) 2016 *IEEE 35th International Performance Computing and Communications Conference (IPCCC 2016)* 7820666
[3] Lee E A 2007 *University of California, Berkeley, Tech. Rep.* 72
[4] Pasqualetti F, Dorfler F and Bullo F 2013 *IEEE Transactions on Automatic Control* **58 (11)** 2715-2729
[5] Kirubakaran B and Ilangkumaran M 2016 *Annals of Operations Research* **245 (1-2)** 285-313
[6] Wu W, Chen Q, Yu B and He H 2008 *WSEAS Transactions on Systems* **7 (5)** 455-465
[7] Zdrazil P, Kraftova I and Mateja Z 2016 *Inzinerine Ekonomika-Engineering Economics* **27(3)** 304-315
[8] Zieba M and Zieba K 2014 *Inzinerine Ekonomika-Engineering Economics* **25(4)** 458-465
[9] Rodriguez M 2014 *Inzinerine Ekonomika-Engineering Economics* **25(1)** 31-39
[10] Smelova O V 2012 *Problems of modern economy* **3(43)** 16-19