# Prognostic Approach to Equipment Maintenance as a Leading Element of Digitalization of Production Processes

**Irina Reznikova***
Togliatti State University
Belorusskaya str. 14, 445020 Togliatti
Russian Federation
e-mail: IVReznikova@yandex.ru

**Irina Rashoyan**
Togliatti State University
Belorusskaya str. 14, 445020 Togliatti
Russian Federation
e-mail: rashoyan_i@mail.ru

**Abstract** This paper aims at analysing the advantages and disadvantages of various approaches to equipment maintenance. The advantages and disadvantages of the traditional approach to equipment maintenance and the reliability-oriented approach are considered.
The purpose of the study is to attempt to analyze the application of approaches inherent in predictive analytics to the methodology of reliability-oriented equipment maintenance. The analysis proved the feasibility of using predictive analytics methods in the overall digitization of processes.

***Keywords:*** *prognostic approach, equipment maintenance, leadership, digitalization, production process*

## 1 Introduction

Maintenance of equipment requires certain, often quite significant, costs. But without this kind of work, the service life of the equipment, i.e. the calendar duration from the start of operation of the facility or its renewal after major repairs until the limit state is reached, cannot be long (Rosstandart 2015; Yashura 2017). Nowadays, there are many state standards that regulate issues related to equipment reliability (Rosstandart 2011a; Rosstandart 2011b; Rosstandart 2011c; Rosstandart 2013; or Rosstandart 2015). These and other standards contain information on creating a reliability management system (IEC 2003; IEC 2004; IEC 2009; Atapin 2017).

According to (GOST 27.002-2015), reliability is the property of an object to retain in time the ability to perform the required functions in specified modes and the conditions of use, maintenance, storage and transportation. Another GOST by Rosstandart (2011a) provides the following reliability indicators: average availability, average failure rate, mean time to failure, and others (Shashurin 2009; Abdulina 2018).

Failures can be random and systematic. Systematic failures include multiple occurrences on most equipment. As a rule, systematic failures are subject to a normal distribution (Abiev 2017). Single failures, as a rule, obey the exponential law of the distribution of random variables. Issues of increasing reliability have been and remain relevant. Ways to increase reliability can be represented in the form of several groups: i) constructive; ii) technological, and iii) operational (see Zemlyanushnova 2017).

When designing any equipment, the choice of materials of parts made of the most durable materials should be provided. In addition, in the process of developing machine designs, normal working conditions of parts should be ensured with minimal friction losses (Alexandrovskaya 2008). Ensuring optimal temperature conditions for mating parts also contributes to increased durability. Ensuring the reliable operation of various machines and equipment is achieved by sufficient rigidity of the basic parts of the machines and resistance to vibration.

Technological measures to increase the reliability of equipment include ensuring the necessary accuracy and quality of manufacturing parts. Ensuring accuracy and quality is carried out using the accuracy and quality of equipment, the accuracy of the dimensions of the workpieces, as well as the qualifications of the employee. Increasing the wear resistance of various surfaces is possible with the help of such hardening technologies, such as galvanizing, nickel plating, oxidation, and others, and increasing the wear resistance ultimately leads to an increase in the reliability of the equipment. To the above technological methods for increasing the reliability of equipment, one can also add an increase in the technological discipline of manufacturing parts, laser processing and plasma spraying of powders (Zubrilina et al. 2010).

 

Operational methods for improving reliability are, first, conducting periodic technical inspections, diagnosing the condition of equipment. In addition, the creation of a normal mode of operation can also be attributed to operational methods for increasing reliability.

## 2. Literature review

The most effective way to increase the reliability of equipment is to organize and carry out scheduled preventive repairs. Rosstandart (2013) contains a description of the technique, called “Reliably Oriented Maintenance,” also called RCM. The specified methodology is focused on determining the need for any preventive maintenance actions. According to GOST R 27.606 (Rosstandart 2013), the process of reliability-oriented maintenance (RCM) includes several stages:

1. Initiation and planning
2. Functional failure analysis
3. Selection of maintenance tasks
4. Implementation of a reliable-oriented maintenance system
5. Continuous improvement.

Maintenance can be divided into preventive and corrective. Preventive maintenance is carried out before failure. Preventive maintenance is carried out at intervals determined in advance. Preventive maintenance is carried out by replacing or repairing components of equipment or entire components and assemblies. The so-called corrective maintenance is performed to restore the equipment to function after a failure.

## 3. Application of RCM analysis

Let us consider in more detail the components of the process of reliability-oriented maintenance. GOST R 27.606-2013 (Rosstandart 2013) gives the tasks that are not solved at the planning stage of RCM analysis:

1. Establishing the optimal scope of work for product maintenance
2. Identification of possible structural improvements to the product
3. Identification of unnecessary, inefficient maintenance work
4. Identification of possible reserves to improve the reliability of the product.

When carrying out activities at this stage of the RCM analysis, it is necessary to collect data arrays for the following indicators:

a) changes in operating conditions
b) insufficient levels of availability and uptime
c) incidents
d) labor costs for preventive or corrective maintenance
e) technological changes in the development and production of products.

When conducting an RCM analysis, failure information should also be used. The array of data on functional failures is, as a rule, quite voluminous. Functional failures may include:

- Completeness of functioning
- Loss of ability to meet the requirements for its characteristics
- Intermittent operation
- Turning on and functioning unnecessarily.

The methodology of reliability–oriented maintenance also involves the establishment of possible consequences for each type of functional failure (Rakhimova 2014; Rakhimova 2017). Obviously, the data array containing information about the consequences of functional failures will also be quite voluminous. When creating an array of data on the consequences of functional failures, it is recommended to carry out the following scheme (Fig. 1):

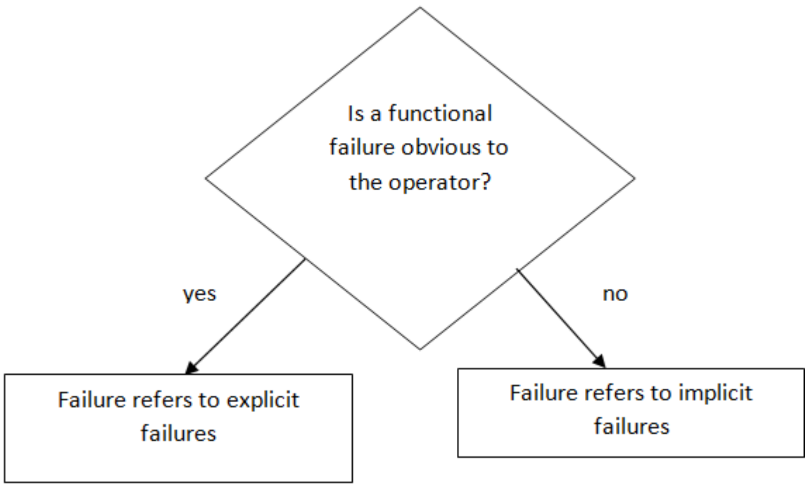


**Fig. 1.** Consequences of functional failures
Source: Own results

When classifying failures by their impact on safety, the environment, profitability, or operational efficiency, it should be determined whether the failure carries a safety risk (see Figure 2):

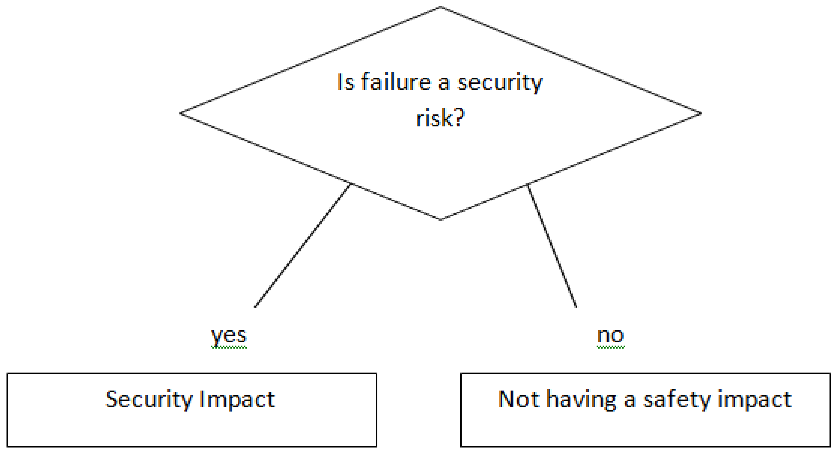


**Fig. 2.** Failure carrying safety risk
Source: Own results

Classification of the consequences of failures and their severity is a very urgent task when carrying out work within the framework of a reliable-oriented approach to equipment maintenance. The most common characteristics of failure consequences are those that describe financial and safety damage. However, in the realities of the modern world, it seems appropriate to conduct a deeper analysis of the consequences for the environment.

The methods of the risk-based approach make it possible to analyze the situation with possible failures and their consequences in more detail to assess the possible consequences. As a rule, when determining the severity of the consequences, ranking is required on several levels. It is possible to distribute the severity of the consequences of equipment failures at four levels:

1. Disastrous consequences
2. Serious consequences
3. Minor consequences
4. Minimum consequences

The assignment of the consequences of any refusal to one of the above categories is a task that requires personnel conducting such actions to have a sufficiently high level of qualification. It is assumed that the employees conducting such a ranking have information on the possible consequences of equipment failures and the severity of each of them. At this stage, to increase the reliability and efficiency of work, various team analysis methods are excellent, allowing the most efficient use of the knowledge of each of the employees involved.

Distributing the severity of the consequences of failures, it is necessary to establish a clear gradation associated, for example, with the equipment shutdown time. Criteria of this kind are the most revealing and informative; they simplify the process of subsequent analysis of the severity of the consequences of failures. An attempt should also be made to determine the criteria for the severity of the consequences of equipment failures in terms of possible environmental damage. In determining this criterion, the severity of the consequences can be determined both from a financial point of view and from the point of view of the duration of the elimination of environmental damage.

The work on the analysis of the consequences of possible equipment failures can bring some difficulties also because, within the framework of applying the risk-based approach, it becomes necessary to determine the probability of equipment failures. As a rule, when creating such a classification, analysts make attempts to take into account all possible categories of failures–often arising, rare, and unlikely. It should be borne in mind that for equipment of various levels of complexity, the expert group has the right to create a different classification, including almost any number of categories.

Carrying out analytical studies related to the causes and consequences of failures, it is impossible not to pay attention to such an indicator of the reliability of the equipment as reliability. According to GOST 27.002-2015 (Rosstandart 2015), reliability should be understood as "the property of an object to continuously maintain the ability to perform the required functions for some time or operating time in predetermined modes and conditions of use". As a rule, equipment failure-free prediction is carried out at the development stage. GOST 27.002-2015 (see Rosstandart 2015) defines the goals of failure-free prediction as follows:

1. Checking the ability to meet specified requirements or assessing the possibility of the required level of reliability.
2. Analysis of the reliability of options for various design decisions.

In addition, the goals of predicting equipment uptime include assessing the effectiveness of measures taken by designers and technologists at the stage of development of equipment and its elements. Moreover, the prediction of reliability must occur at all stages of the design of equipment, from the technical proposal to the manufacture of the prototype.

The reliability prediction procedure at the equipment development stage includes, as a rule, nine stages of equal importance. GOST 27.002-2015 (Rosstandart 2015) also classifies the stages of equipment reliability analysis as follows:

1. Product identification
2. Determination of the required values of the predicted indicators
3. The definition of the method for predicting reliability
4. The definition of forecasting models for each of the established reliability indicators
5. Analysis and evaluation of the source data for the forecast of equipment uptime
6. Performing equipment failure prediction. If necessary, it is possible to develop a methodology for predicting equipment uptime
7. A comparative analysis of the results of predictive studies of equipment uptime and required equipment uptime
8. Reporting forecasting results

Preventive maintenance solves one of the following tasks (Rosstandart 2013):

1. Monitoring the technical condition of the product
2. Scheduled repairs
3. Scheduled replacements
4. Failure detection.

One of the basic advantages of implementing RCM analysis is the elimination of unnecessary work that increases the cost of maintenance without increasing the level of reliability of the product.

All modern management systems require continuous improvement. Continuous process improvement involves working within the framework of the Deming cycle: "Planning"- "Implementation"- "Verification"- "Actions". In the case of RCM analysis, a continuous improvement cycle can be represented (according to GOST) as follows (Figure 3).

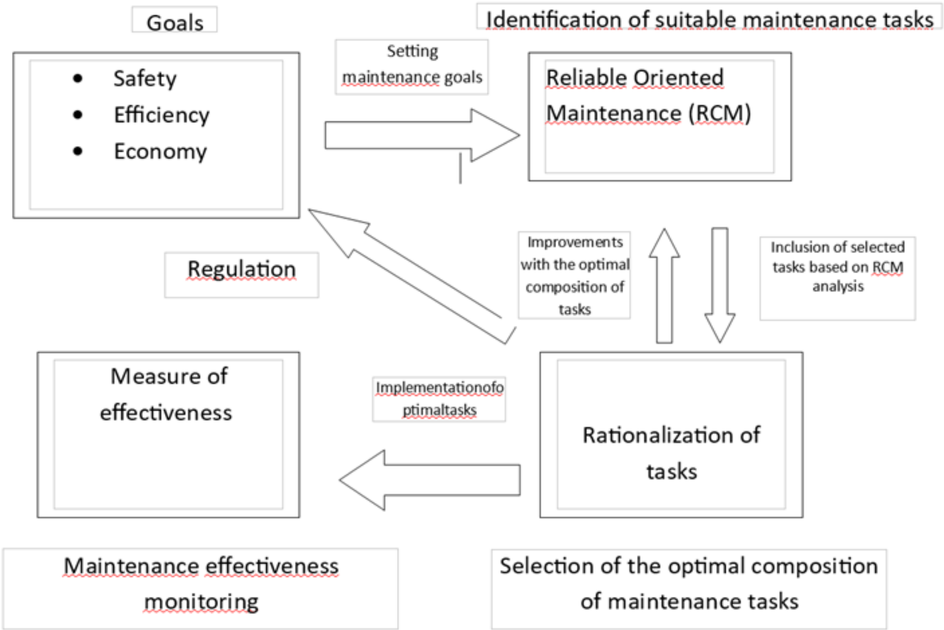


**Fig. 3.** Continuous improvement cycle
Source: Own results

Thus, the introduction and application of reliable-oriented technical maintenance of equipment in production activities involves the processing of large amounts of data. The best way to ensure fast and complete data processing is to use predictive analytics. Predictive analytics is a forecasting method using a large amount of data. Predictive analytics is based on forecasting using the available information, which allows us to imagine what result can be expected with the existing process dynamics. In general, the forecasting process consists of several stages:

1. Data collection
2. The choice of determining parameters
3. The formation of the predicative model
4. Verification of the forecast

The purpose of data collection is constructive improvement, technology improvement, as well as the development of measures aimed at improving the efficiency of maintenance. Obviously, the "Data Acquisition" stage is "aimed" at creating a database and in case of using the methodology of reliable-oriented maintenance, at this stage, a database should be created related to the operation of the equipment. At the stage of selecting the determining parameters, a list of potential failure equipment characteristics is formed. Special attention should be paid to functional failures that threaten the safety of the environment and personnel.

The stages "Formation of the predicative model" and "Verification of the forecast", as well as the previous stages, involve working with a large amount of data. The transitions to predictive maintenance allow quickly and accurately assess the condition of the equipment and accurately determine the date of maintenance. This approach, in contrast to traditional preventive maintenance, including functional checks, maintenance, repair and replacement of various components and assemblies, allows considering the actual condition of the equipment. Using the traditional approach to maintenance, equipment repair is usually planned based on various indicators of equipment reliability, for example, average life. In general, the predictive approach using Smart Prediction Maintenance consists of the following steps:

1. Collection of data on the condition of equipment, its various components and assemblies
2. Processing
3. Troubleshooting
4. Equipment maintenance planning

## 4. Conclusions

Overeall, predictive maintenance of equipment allows you to assess the condition of equipment by monitoring its condition. Such monitoring can be carried out both periodically and continuously. Using a predictive approach to equipment maintenance allows optimizing maintenance costs, since equipment maintenance occurs at a time when the equipment is just starting to lose performance indicators. A predictive approach eliminates situations in which maintenance is performed according to a plan based on averaged performance indicators of equipment.

The predictive approach makes extensive use of statistical process control and makes it possible to predict trends in equipment status.

Processing arrays of data on the operation of the equipment allows simulating the most diverse situations of the equipment. In addition, the use of predictive maintenance of equipment involves the use of modern software based on the so-called "artificial intelligence", which to the maximum extent allows excluding people from the process of servicing equipment maintenance. Erroneous actions of personnel made for various reasons are excluded in the case of the use of artificialintelligence.

The use of artificial intelligence in the predictive maintenance of equipment allows accurately establish which parameters have influenced the occurrence of a failure. Artificial intelligence is also great for evaluating situations with non-obvious failures

With the introduction and development of predictive maintenance, fast processing of other data sets is also possible. Related to equipment such as catalogs, repair cards, etc. The use of artificial intelligence for their processing, which is part of the ongoing digitalization of the economy, makes it possible to manage information effectively and continuously.

## References

Abdulina E, Reliability of technical systems and technogenic risk: practicum, 1st edn. (North Caucasus Federal University Press: Stavropol, 2018), 106 p.

Abiev RSH, Reliability of mechanical equipment and complexes, 1st edn. (Prospect Nauki: Saint Petersburg, 2017), 224 p.

Alexandrovskaya LN, Safety and reliability of technical systems,1st edn. (Logos: Moscow, 2008), 376 p.

Atapin VG, Fundamentals of reliability theory, 1st edn. (Novosibirsk state technical University: Novosibirsk, 2017), 94 p.

IEC (2003) Analysis techniques for reliability. General principles IEC 60300-3-1:2003. https://webstore.iec.ch/publication/1294 Accessed 21 April 2020

IEC (2004) Maintenance and maintenance support IEC 60300-3-14:2004 (NEQ). https://webstore.iec.ch/publication/1298 Accessed 20 Apr 2020

IEC (2009) Reliability centred maintenance IEC 60300-3-11:2009. https://webstore.iec.ch/publication/1296. Accessed 20 Apr 2020

Rakhimova NN, Quantitative characteristics of safety and reliability of technical systems, 1st edn. (Orenburg state University: Orenburg, 2014), 39p

Rakhimova NN, Reliability of technical systems and technogenic risk, 1st edn. (Orenburg state University: Orenburg, 2017), 277p

Rosstandart (2011a) GOST R 27.003-2011 GOST. Dependability in technics. Dependability management. Guide to the assignment of dependability technical requirements IEC 60300-3-4:2007Dependability management, Part 3-4: Application Guide: Guide to the specification of dependability requirements (NEQ). https://www.gost.ru/portal/gost Accessed 22 Apr 2020

Rosstandart (2011b) GOST R 27.301-2011. Dependability in technics. Dependability management. https://www.gost.ru/portal/gost Accessed 22 Apr 2020

Rosstandart (2011c) GOST R 27.601-2011. Dependability in technics. Dependability management. https://www.gost.ru/portal/gost Accessed 22 Apr 2020

Rosstandart (2013) GOST R 27.606-2013. Dependability in technics. Dependability management. https://www.gost.ru/portal/gost Accessed 22 Apr 2020

Rosstandart (2015) GOST 27.002-2015. Dependability in technics. Terms and definitions. https://www.gost.ru/portal/gost Accessed 22 Apr 2020

Shashurin VD, Reliability of technical systems. Reservation, restoration, 1st edn. (Bauman Moscow State technical University: Moscow, 2009), 60 p.

Yashura AI, System of maintenance and repair of general industrial equipment, 1st edn. (ENAS: Moscow, 2017), 356 p.

Zemlyanushnova NY, Fundamentals of reliability theory, 1st edn. (North Caucasus Federal University Press: Stavropol, 2016), 152 p

Zubrilina E, Zhevora Yu, Lebedev A, Kulinich A, Zemyanushina N, Zakharin A (2010) Fundamentals of machine reliability, 1st edn. (Stavropol State Agrarian University: Stavropol, 2010), 120 p,