Mathematical model for selecting the best technology for restoring road construction machines

Aleksandr Belyaev[1,*], *Valeriy* Gordienko[1], *Petr* Druzhinin[1], and *Sergey* Evtukov[1]

[1]Saint Petersburg State University of Architecture and Civil Engineering, St. Petersburg, Russia

Abstract. The article considers the problem of effective and high-quality restoration of road construction machines and equipment. Operational features of reliable and high-precision equipment for road and construction works require high costs for maintaining the operability of machines. Since mainly foreign-made equipment is used, replacing worn-out, especially functionally important parts is very costly. To ensure the requirements of reliable and safe operation of road construction machines, a systematic approach to solving these problems is required, which is decided by the authors through developing an original model of the optimal choice of energy efficient technology for the restoration of parts of road construction machines, with the goal being the highest quality of the part after restoration.

1 Introduction

The modern development of the Russian Federation economy is inextricably connected with the development of construction, including road construction, construction of bridges and tunnels. In turn, modern construction technologies involve the provision of high automation and mechanization of construction operations through the use of special or specialized equipment. Such equipment or such road construction machines have high operational characteristics. The peculiarity of these machines is that they are often operated far from repair bases, therefore, they must have high reliability. Another difference of these machines is that they are designed in small-scale versions, are multifunctional and expensive to manufacture and operate.

Providing a high level of modern road, construction and hoisting-and-transport machines is ensured by their continuous improvement. The improvement of road construction machines is explained by the constant development in accordance with the increasing requirements of the operators.

In modern engineering production of road construction machines, much attention is paid to reliability and safety, and these issues are addressed at the design and manufacturing stages. High reliability and safety of these machines should be ensured during operation, including in the field. An important component of operational security is the restoration of

[*] Corresponding author: tm@spbgasu.ru

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parts of road construction machines. In modern production, the restoration of parts is considered from the point of view of the economy. There is no parts recovery system. When restoring parts, the basis is the availability of equipment and technologies. There is no systematic approach to the restoration of parts of road construction machines in terms of the quality of parts and the machine as a whole.

The equipment used for the construction of foundations has specific features, both in terms of design, and in terms of application and operating conditions. The main features of the operation of road construction equipment can be considered the high intensity of operation of these machines, high cost, long distances from service bases and, accordingly, the complication of the repair and restoration processes of machines.

Machines fail. In any machine there are functionally important parts that have a high cost, that are difficult to manufacture and are key in terms of machine reliability. The reuse of these parts is inherently an economic reserve of construction production. It is important to note that there are two important factors. The first is a large amount of repair work. The second is compliance with the technical documentation requirements. At the same time, there is the possibility of forming new qualitative characteristics of machines. Very important characteristics, such as productivity, machine safety and manufacturability in producing and restoration (economic performance) should be improved.

Particular attention is paid to the reliability and safety of road construction machines. The basis for managing these quality characteristics lies at all stages of the life cycle of machines. It is very important to preserve and, possibly, increase these quality criteria during the restoration and repair of the machine.

An analysis of the data sources showed that there is no uniform standard technique in the restoration of functionally important parts of road construction machines and equipment, the requirement for the implementation of quality has not been resolved as a decisive factor in the ultimate goal of restoration.

2 Methods

To solve the research problems, an analysis of methods for solving multicriteria problems was made by reducing them to single-criterion models, rhat are characteristic for the restoration of functionally important parts of road construction machines. It was revealed that most of these methods have many objective shortcomings. In such problems, the solution is carried out by simplifying the initial data and depends on the choice of using a number of methods or mathematical models for solving multicriteria problems, but can lead to incorrect decisions.

To develop a method for solving multicriteria problems, designed to select the optimal recovery route for functionally important parts of road construction machines in the conditions of multivariance and uncertainty of the restoration production conditions and the purpose of accurate restoration:

A general technique to study the recovery process of functionally important parts of road construction machines with a number of sequential operations in the form of a multi-level hierarchical system has been developed, for which it is important to conclude that if you go to a higher level, it becomes clear which criteria should be preferred and the coefficients should be correctly estimated relative importance in composite criteria. It is proposed to solve the problem by establishing a coefficient of relative importance in accordance with each solution, which reduces to determining the numerical values of these coefficients.

3 Results

Studies have been carried out to develop a theoretical model that allows the selection of a technology for the restoration of a road construction machine parts with an absolutely diverse content of both operations and sequences with an optimized technology choice with the aim of the best quality of restoration. The best options were accepted taking into account efficiency indicators.

In applied technical problems, it is often necessary to choose which process is more efficient, evaluating by a large number of efficiency values, and not by one. It is these tasks, in which it is necessary to optimize the solution according to several indicators, that are called multicriteria in the field of research under the general name "operation research". As a rule, finding numerical values in problems classified as multicriteria has difficulties due to the objective nature of mathematical calculations. In particular, there is a certain limit that cannot be crossed without clarifying the state of the environment under which a decision has to be made. Nevertheless, it is necessary to solve the problem under conditions of multicriteria. As a rule, a solution is artificially reduced to single-criterion situations from multi-criteria conditions, which means that in a significant number of methods for solving multi-criteria problems themselves there is already a fundamental option for turning these problems into single-criteria. Technically, this is done in a variety of ways.

The first way (the simplest) is to select the main efficiency criterion from all the criteria. Further calculation is carried out precisely according to the main efficiency criterion, but the remaining efficiency criteria are also used in the calculation, but only as limiters, upper and lower. As an example, consider maximizing *m* criteria:

$$k_i \to max, i = \overline{1,m}\,. \tag{1}$$

Having considered all the criteria *m*, we decide which of them is the main one (for example, k_i), while the remaining ones are limited from below to values $k_{0i}, i = \overline{1,m}, i \neq 1$. In this case, the decision takes the form:

$$kj \to max, k_j \geq k_{0i}, i = \overline{1,m}, i \neq j. \tag{2}$$

This method has its own characteristics. In particular, the concept of uncertainty appears, which manifests itself in two forms:

1) the uncertainty and the inability to distinguish the main criterion from the whole set of criteria;

2) the uncertainty of the limiting principle the remaining criteria by values k_{0i}.

Another widespread way of reducing multicriteria problems to single-criterion problems is called the "method of successive concessions". The essence of the method is as follows. The criteria are arranged in order of decreasing importance. The first criterion k_1 in this series is adopted (it is the main “important” one) and a solution is sought that turns this criterion to the maximum.

This method has the same difficulties as in the previous one:

1) it is not always possible to prioritize the criteria according to the degree of importance (this is even more difficult than choosing the most important among them);

2) it is not always clear for what reasons to assign “concessions” to the criteria.

Another of the most common methods for reducing multicriteria problems to single-criterion is the use of composite criteria. There are different approaches:

1) maximize the amount of criteria, that is,

2) maximize their product, that is,

3) if necessary, maximize some criteria, for example, the first criteria (q), but minimize the rest ($m - q$), in which case the solution is expressed as a fraction.

A composite criterion is formed in different ways, while the disadvantage of all methods is the ability to compensate for defects of one criterion due to another criterion.

Thus, practically all methods for solving multicriteria problems by reducing them to single-criterion are characterized by certain disadvantages. In some cases, these methods can be used for practical purposes, however, in most situations, their application can lead to the development of incorrect recommendations [1–11].

In our case, when it is necessary to study the process with a certain number of operations arranged in the form of technology, the process of managing them can be represented as a multi-level hierarchical system. At the same time, each level of the hierarchy includes the solution of problems according to their own criteria. The solution or process obtained at the k-th level is used at the (k+1)-th level, where it is used to solve other problems by other criteria. The transition from level to level in itself reduces the number of decisions, but at the same time their significance and complexity significantly increase. It is in this sequence that a hierarchical control system is formed. The basis of this hierarchy is the most common task of operational management. It is important to note that the criteria of tasks of the k-th level are agreed without fail with the interests of the (k+1)-th level of management. When solving problems in a multi-criteria environment, it is necessary to develop recommendations. It is this alignment that helps in making decisions. The main thing in solving our problem of choosing the best option for the technology of restoring the details of a road construction machine is an important conclusion: determining the criterion that should be preferred.

As a result, we conclude that the proposed method for solving multicriteria problems by moving to a higher level of management is, in our opinion, the most preferred solution to the multicriteria problem. It should be noted that the practical implementation of this solution can be associated with significant difficulties, and not always, having risen to a higher level, it is possible to formulate and solve the corresponding single-criterion optimization problem.

To ensure the structure and technology of restoration of road construction equipment and machines for road-building works, it is necessary to create the infrastructure of restoration production. At the same time, it will be important to evaluate some aspects of the effectiveness of investment projects.

The traditional indicators of evaluating the effectiveness of investment projects are: Net present value (NPV) of the project; Internal Rate of Return; Profitability Index; Payback Period; Payback period with discounting cash flows; The Average Accounting Return of the project and others.

4 Discussion

The indicators described in the scientific literature have a significant drawback: they are based only on the calculation of the value of cash flows, that is, they consider only the final part of the implementation of the investment project, giving priority to its financial component. In this connection, at the stage of development and evaluation of investment projects, the production process itself, which should act as the basis of the investment project and all its financial flows, is practically lost sight of the analysis. To eliminate this drawback, one of the components of a multicriteria approach to assessing the effectiveness of industrial investment projects, according to individual scientists, should be an assessment of the economic development of the production process itself. Studies confirm the need for such an assessment. This is due to the fact that traditional methods contain a detailed study of many practical and organizational aspects of future production, but they lack indicators of efficiency, profitability of the production itself, and the impact of investment costs on environmental protection procedures from the harmful effects of industrial enterprises.

Studies have confirmed that investment management should cover a wide variety of aspects of the project, since projects are usually complex. The process of creating an investment management system can be divided into the following stages.

The first stage is the selection and justification of the investment project in accordance with the goals and strategy of the enterprise.

The second stage is the selection of a criterion for achieving the project goal (the project goal may be, for example, the current value of future cash flows, market share, growth rate, degree of risk reduction of existing activities, etc.).

The third stage is the development of criteria for achieving goals and controlled indicators for each responsibility center, taking into account the capabilities and powers of managers of such centers.

The fourth stage is the study of the organizational aspects of investment management and, above all, the organizational aspects of monitoring and control.

5 Conclusion

Using the developed model for optimizing the construction of the technology for restoration of road construction machines, taking into account studies of growing economies, it will create a universal and highly efficient repair and restoration structure.

The analysis determined the main difficulties in restoring the functionally important parts of road construction machines, which is primarily due to the fact that indicators that are not related to the operational properties of the machine are displayed in the main criteria.

One of the main criteria for the quality operation of road construction machines was the reliability of the machine and its safety. In the work, these characteristics were theoretically and experimentally associated with the qualitative characteristics of a functionally important part.

A mathematical model of choosing the best option for the part recovery technology in terms of reliability, machine durability and its safety has been developed based on dynamic programming. The model allows to perform many technical and technological tasks associated with the best choice.

The development of unified methodological approaches to solving the problem of restoring parts would ensure comparability of data on investments in this area, which would contribute to a more efficient development of the construction industry.

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