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RESEARCH OF THE PROCESS OF COSTS AND SUPPLEMENT OF RESOURCES OF RAILWAY AUTOMATION OBJECTS

ИССЛЕДОВАНИЕ ПРОЦЕССА РАСХОДОВ И ПОПОЛНЕНИЯ РЕСУРСА ОБЪЕКТОВ ЖЕЛЕЗНОДОРОЖНОЙ АВТОМАТИКИ

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Summary *The article considers the issue of the research of the process of costs and replenishment of railway automation facilities. Unlike classical approaches, the process of cost and recovery is considered taking into account the functions performed by a particular object. Particular emphasis is placed on critical systems that provide functional safety.*

Keywords: *devices and objects of railway automation, service life, resource, process of expenses and replenishment of resource.*

Introduction

The problem of the resource of railway automation means is currently very important. This is due to the issue of accounting for wear and optimization of the process of modernization of railway automation and, in particular, train control systems. The problem is complicated by the very large volume of such work and the significant level of depreciation of fixed assets of the signaling and communications facilities. Given the existing financial constraints that can be directed to modernization, it is very important to optimize this process not only by financial criteria, but also to take into account the role of individual devices and systems in ensuring the continuity of the transportation process and safety of passengers and cargo. Therefore, theoretical research on these issues is not only relevant but also has a practical focus.

Analysis of research and publications

Scientific research on the problems of determining the resource of automation systems are focused mainly on the means of industrial automation, automation systems in energy, aviation, road transport and other industries. First and foremost, scientific works should be accounted for [1 - 6].

In railway transport, research on the issues traditionally considered is focused on rolling stock and engineering structures. The purpose of most of these works is to extend the service life primarily of traction rolling stock and man-made structures [7].

With regard to the technical means of railway automation, we can point out a relatively small number of scientific papers on resource issues. It is characteristic that the authors of the works specify the insufficient theoretical substantiation of the problems of the resource and the dominance of administrative approaches to the processes of planning modernization measures. [8 - 11].

In this respect, the monograph of the authors Boryak K.F., Brown V.O., Lenkova S.V., et al. dealing with the problems of cost process modeling and replenishment of complex renewable facilities and systems of electronic equipment appears to be of great interest. [12]. However, it is impossible to fully use these scientific achievements for devices and systems of railway automation. This is primarily due to the presence of a large number of differences related to safety requirements, design features and maintenance system in the repair. [13, 14].

The purpose of the work is research of the process of costs and replenishment of railway automation.

At the first stage we define a small concept of objects of railway automation. If we perceive this term in the plane of functions of realizations of system functions, then it can be applied to arrows, traffic lights, rail circuits, crossing alarm devices, slide retarders, etc.

Obviously, this list is far from complete, but only serves as an example. Usually all these facilities have a very high cost and significant service life which is normally at least 25 years for railway automation products [9], but in fact according to observations it can be up to 40-50 years. The level of functional safety requirements imposed on management and control facilities should be also taken into account. In accordance with the State Standard of Ukraine 4178 [14], 4 levels are specified depending on the requirements for technical means that perform safety functions. The latter requirement significantly affects not only the algorithm of the object, but also its design, selection of materials, structures, components, and so on. During operation, there is a loss of resource of the object, so it is expected to carry out repairs. A classic example of this is relays, which undergo the appropriate recovery processes in a timely manner. The frequency of these works varies from 1 to 10 years depending on the type of product [10]. However, most railway automation facilities are not subject to scheduled repairs, in most cases they are restored after damage.

It should be noted that the implementation of all repair works is aimed not only at restoring the facility, but also extending its service life. More often it can be observed at replacement of the damaged element, on new. For example, replacement of an auto switch or electric motor of an arrow, a signal head of a traffic light or other accessories.

It is also necessary to take into account the planned measures to prepare for the winter and summer periods of operation, during which some repair and restoration works are carried out. In any case, during all the above works, the initial resource of objects is restored.

The process is complicated by the heterogeneity of objects of even one type, for example, at the station there are 100 traffic lights in constant operation, of which 70 have been in operation for 25 years, 10 traffic lights - 12 years, and 5 were replaced with new ones this year. Obviously, a similar situation occurs in the analysis of the resource of a particular object in the process of operation of which is *i – Te* partial update of its initial resource Ro

$$R_{oi}=R_o \cdot K_i , \quad (1)$$

where: R_{oi} - the value of the resource of the object after the *i - that* repair;

K_i - recovery factor after the *i* repair.

In the classical approach to the recovery process [2], the timing of repairs is set according to some selected critical value of the recovery flow $\omega_k(\Delta t)$. That is, the criterion for the need for repair is inequality

$$\omega(\Delta t) > \omega_k(\Delta t)\ . \qquad (2)$$

It is obvious that while maintaining the same volume of repair work, the service life decreases after each repair. This approach is well illustrated by the graphs in Figure 1 of [12].

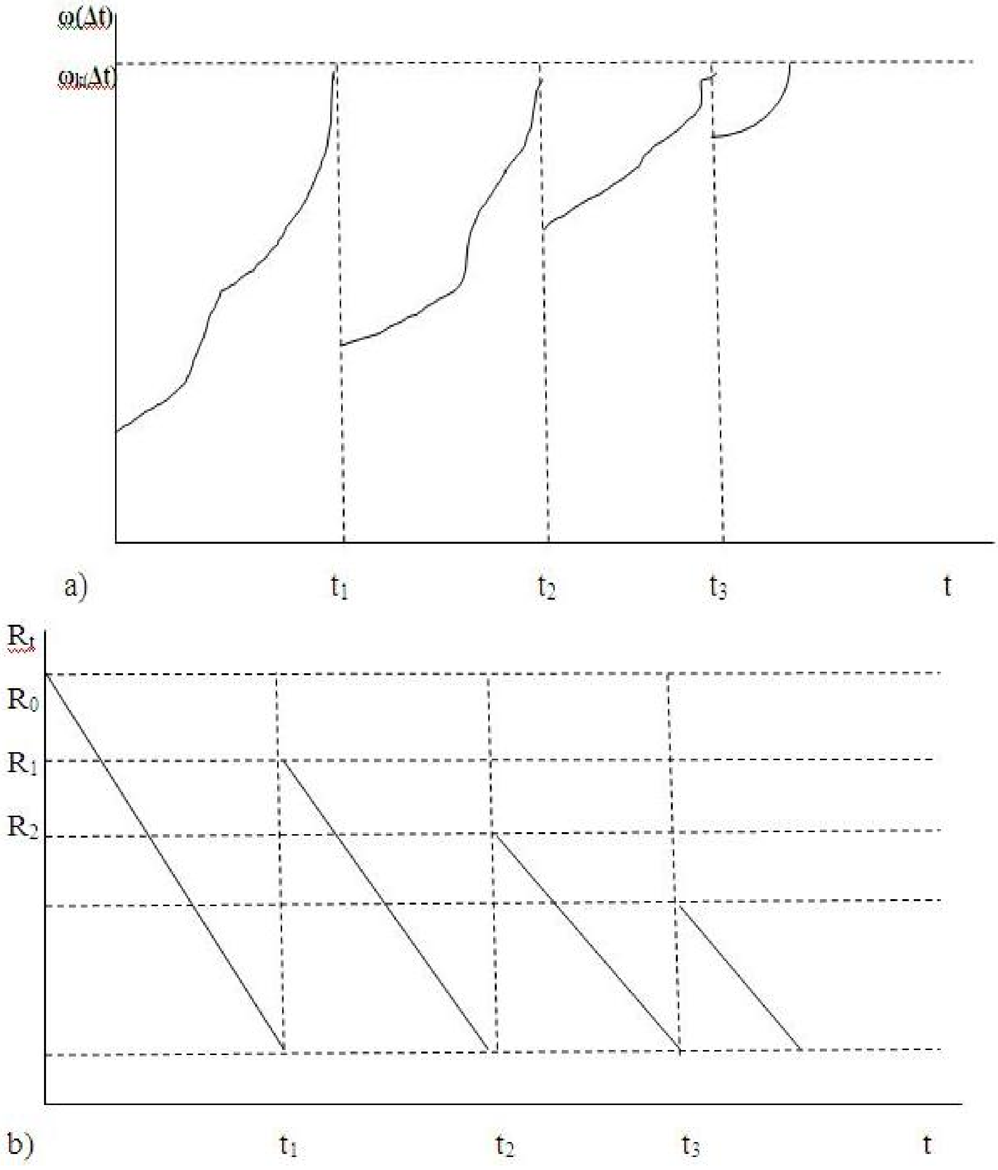

Fig.1 View of functions $\omega(\Delta t)$ ma R_t in case of partial renewal of the object

- **graph of the function to the stream of views $\omega(\Delta t)$;**
- **graphs of functions of the resource.**

The existing system of organization of maintenance of railway automation devices [13] provides for the implementation of mostly scheduled work. Unscheduled recovery usually occurs after damage to railway automation devices. That is, there is no reason to talk about a sustainable mode of repairs and, accordingly, the restoration of facilities.

Until now, the process of restoring the resource of objects has been considered under the assumption that repair work should not occur later than some limit value of the resource. However, as mentioned above, the vast majority of railway automation facilities are used for their intended purpose after depletion of the resource. With a planned system of repairs, it can occur when the object's resource is exhausted. This principle is applied to objects that perform functions critical to security, Fig. 2.

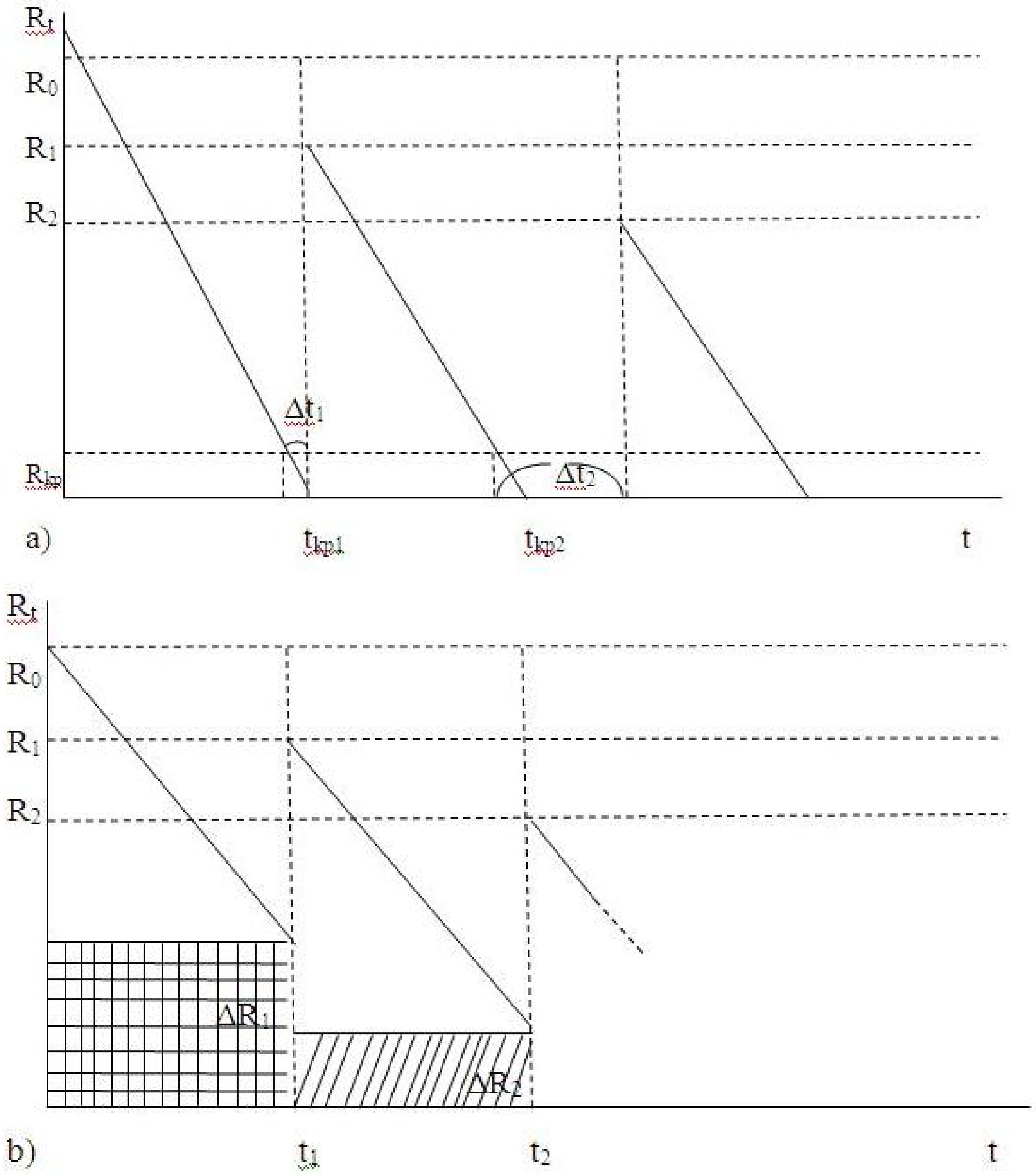

Fig.2 Functions of the resource of the object in the case of:

- **performing repairs after complete depletion of the resource;**
- **performing repairs until the resource is exhausted.**

Resource functions in fig. 2 illustrate situations when the object is used for its intended purpose after the complete exhaustion of its resource and repair when the resource is not fully exhausted. For objects, the operation of which is related to the safety of trains, the value of the intervals of operation Δt, та Δt_2 is critical (Fig. 2.a) after resource depletion.

Obviously, in these cases it makes no sense to consider this process according to the classical criterion of optimization of scheduled repairs. From the point of view of safety of use:

$$\Delta t_1 \to 0$$
$$\Delta t_2 \to 0$$
…………

In the case of unspent resources, early repair is economically impractical, although on the other hand it contributes to increased safety, which is extremely important for rail transport.

Unlike non-critical industrial automation systems, railway devices that perform safety-related functions have some differences in operating technology.

Responsible systems and their components cannot be operated to the field resource. A certain critical value $R_{kp.}$ is set at which the system or a separate element, such as a relay, meet the established requirements for functional safety [14]. This approach illustrates the graph in Figure 1, when repairs occur at some $R_{kp.}$. This approach is implemented in the system of technical use of class 1 relays, which undergoes a mandatory inspection every 10 years.

However, for many components, including floor equipment, inspection or repair times are not always available. In fact, very often the operation of devices is observed after the critical value $R_{kp.}$ of the resource during the time Δt_p (Fig. 2), and sometimes until its complete depletion, during the time Δt_2.. It should be noted that the countdown Δt starts from the moment when $R_i < R_{kp}$. It is obvious that the behavior of the control system at the time of Δti is critical for functional safety, and unfortunately this process has not been studied enough so far. In this regard, it is advisable to introduce some local optimization criteria, which, in contrast to [4], focuses on safety, rather than the economic component.

$$\left| t_{Pi-1} + R_i - t_{Ri}^{opt} \right| \to R_{min\,\acute{a}\mathring{a}\c{c}\ddot{i}}\,., \tag{3}$$

where t_{Pi} is the planned time of the *i - that* repair;

R_i - service life after the *i - th* repair;

t_{Pi}^{opt} - locally - the optimal value of time and *i- that* repair.

This does not take into account the restrictions on the timing of repairs, which significantly requires analysis of the problem. It is obvious that the parameter of the failure rate of the object of railway automation depends on its properties in terms of reliability and safety and on the characteristics of the process of costs and replenishment of the resource.

In general, this can be represented as a function of type

$$\omega(t) = \omega(t / \ddot{I}_1, \ddot{I}_2)\ , \tag{4}$$

where: Π_1 - a complex indicator that characterizes the functionality of the system (reliability, security….);

Π_2 - a comprehensive indicator that characterizes the technical use of the object (the process of repair and restoration).

The process of repairs and restorations will be determined in accordance with [12]

$$\ddot{I} = \{\ddot{I}_{\hat{e}}\} = \{\langle R_{pk,} V_{pk} \rangle ; \overline{k = 1, Np}\}\ , \tag{5}$$

where $\Pi_k = \langle R_{pk,} V_{pk} \rangle$ - parameters of *k - that* repair;

$R_{pk,}$ - maintenance resource *k - that* repair.

$$R_{pk} = \left(t_{pk} - t_{pk-1}\right), \text{ якщо } t_{po} = 0;$$

n_{pk} = set of elements that change during repair;

N_p - the number of scheduled repairs during the operation of the object [O, T_e];

K - serial number of the repair, $K = (1, N_p)$.

In the future, based on function (2) and the expression for the resource from [2], we define the resource function of the object of railway automation:

$$R(t / \ddot{I}_1, \ddot{I}_2) = \begin{cases} R_k - r_k(t), \text{ÿêù î } t \in \left(t_{pk,} t_{pk+1}\right) \\ 0, \text{ÿêù î } t \geq t_{pNp} \end{cases}$$

where R_k is the value of the resource that is restored after *k - that* repair;

R_k is a function of resource costs in the interval [t_{pk} ,t].

Define the function $r_k(t)$ as follows:

$$r_k(t) = R_k \left(1 - \frac{\omega(t / \ddot{I}_1, \ddot{I}_2)}{\omega_{kp}}\right); \tag{6}$$

$$t \in [t_{pk,} t_{pk+1}]; k = \overline{O, N_p}$$

The variable R_k determines the initial resource of the object at $k = 0$, which is denoted on the graphs as R_o.

$$\omega(t / \ddot{I}_1, \ddot{I}_2) \text{ та R } (t / \ddot{I}_1, \ddot{I}_2)$$

Thus, the functions together determine the actual process of costs and replenishment of the resource of the object in the time interval T_e of the process of technical use of the object. Also, analyzing the above functions, it is easy to determine that the resource function is uniquely determined by the failure parameter of the object $\omega(\Delta t)$ in the process of its use.

Conclusions

Research of the process of costs and replenishment of devices and systems of railway automation showed some very significant differences in approaches to the formation of estimates. This is primarily due to the requirements of functional safety and features of technical use of critical systems, which include systems of railway automation. In the future, it is necessary to take into account the above to synthesize cost models and replenishment of specific objects.

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Аннотация *В статье рассматривается вопрос исследования процесса расходов и пополнения ресурса объектов железнодорожной автоматики. В отличие от классических подходов, процесс расходов и восстановления рассматривается с учетом функций, которые выполняет конкретный объект. Особый акцент сделан на системах критического назначения, обеспечивающих функциональную безопасность.*

Ключевые слова: *устройства и объекты железнодорожной автоматики, срок службы, ресурс, процесс расходов и пополнения ресурса.*

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