DOI: 10.32703 / 2617- 9040- 2021- 38-229-22

UDC 658.2: 656.11: 625

Ivan Kulbovskyi[1], Halyna Holub[2], Snezhina Andonova[3], Inna Saiapina[4], Mykola Tkachuk[5]

[1]Department of Automation and Computer-Integrated Transport Technologies, State University of Infrastructure and Technologies, vul. Kyrylivska, 9, Kyiv, 04071, Ukraine. ORCID: http://orcid.org/0000-0002-5329-3842

[2]Department of Automation and Computer-Integrated Transport Technologies, State University of Infrastructure and Technologies, vul. Kyrylivska, 9, Kyiv, 04071, Ukraine. ORCID: https://orcid.org/0000-0002-4028-1025

[3] Faculty of Engineering, South-West University "Neofit Rilski", Blagoevgrad, 2700, Bulgaria. ORCID: https://orcid.org/0000-0003-0818-9947

[4]Department of Artificial Intelligence and Telecommunication Technologies, State University of Infrastructure and Technologies, vul. Kyrylivska, 9, Kyiv, 04071, Ukraine. ORCID: https://orcid.org/0000-0003-1541-1681

[5]Service of signaling and communication of the Russian Federation "South-Western Railway" JSC "Ukrzaliznytsia", st. Lysenko, 6, Kyiv, 01054, Ukraine. ORCID: https://orcid.org/0000-0002-9683-4303

*** Corresponding author:** golub_gm@gsuite.duit.edu.ua

MODEL AND METHODS OF MANAGEMENT OF EFFICIENCY OF USE OF PRODUCTION AND TECHNOLOGICAL POTENTIAL OF ROLLING STOCK OF RAIL TRANSPORT

The article considers the problems management of efficiency of use of production and technological potential of rolling stock of rail transport. It is investigated that to improve the efficiency of functioning requires a comprehensive solution of many problems, with the rational use of labor, material and labor resources.

A set of many tasks aimed at improving and ensuring the level of efficiency of rail transport facilities and systems is considered.

It is investigated that in order to achieve the required level of efficiency of rolling stock operation it is necessary to improve the management process by system model of the set of problems of efficiency of use of production and technological potential of work of rail transport.As a result of solving the problema mathematical model of the set of problems was proposed, which became the basis for building a system model of the set of problems. The decomposition method and AllFusion Process Modeler software were used to build the system model.

The paper considers the task of ensuring the required level of efficiency in the use of production and technological potential of rolling stock and the proposed ways to solve it. There is also a comprehensive review of objects, systems and processes, which involves their identification, providing a formalized description. On the basis of which a model and method of diagnosis were proposed, which inopen the possibility of interaction between the management of the subsystem of diagnostics and planning of work of objects and systems of rolling stock on the basis of the actual technical condition. The solution in this way will increase the indicators of the main aspects of production and technological potential, which is the purpose of this work.

Keywords: *diagnostic method, model, decomposition, system analysis, system, production and technological potential.*

Introduction. The main laws of construction, operation, development and adaptation of production and technological potential of rolling stock should be based on the principle of functional unity of their

objects and systems, which are described in the following sequence, taking into account the system patterns and sequence:

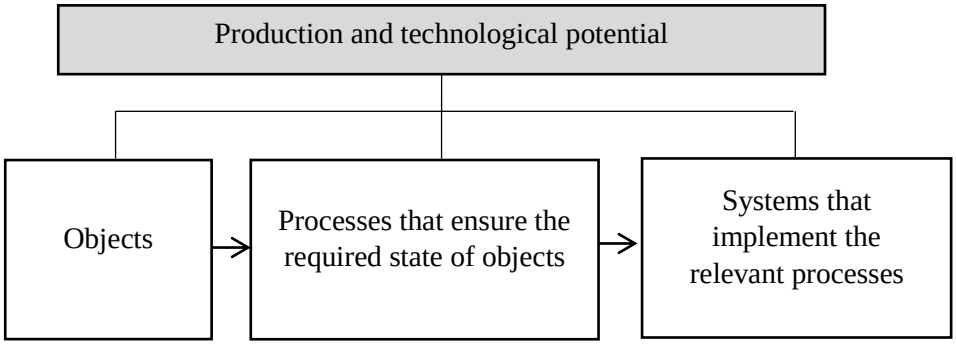

Fig. 1. **Components of production and technological potential**

The efficiency of production and technological potential largely depends on the complex solution of many Q_{ik} problems, which are focused on achieving high end results of rail transport with the rational use of labor, material and financial resources [1, 5].

The set of Q_{ik} tasks is a necessary condition for the functioning and ensuring the required level of efficiency and quality of work of rolling stock. Many Q_{ik} tasks are formed taking into account the organizational, technological, technical, economic and social aspects of rail transport.

Organizational aspects of work include the level of organization of labor and production.

Technological aspects necessitate the search for new technological solutions for production processes in order to intensify the use of production and technological potential of rolling stock.

Technical aspects characterize the technical equipment of production processes, as well as technical performance of facilities and systems of rail transport.

Economic aspects characterize the efficiency of use in the work and production of all types of resources and the ultimate effectiveness of the functioning of systems and facilities of rail transport.

The set of Q_{ik} tasks that is necessary to ensure the required level of efficiency of the rolling stock rolling stock must comprehensively take into account all aspects of its work.

The purpose and objectives of the study. The purpose of the study is to study the methods and models of management of the efficiency of use of production and technological potential of rolling stock for rail transport for improving the indicators of the main aspects of production and technological potential.

Objectives of the study: 1. Analyze problems management of efficiency of use of production and technological potential of rolling stock of rail transport. 2. Investigatemany tasks aimed at improving and ensuring the level of efficiency of facilities and systems of rail transport. 3. Analyzecomprehensive consideration of objects, systems and processes, which provides for their identification and provides a formalized description. 4. Develop a modeltasks of efficiency of use of production and technological potential of work of rail transport. 5. Suggest methods thatinopen the possibility of interaction between the management of the subsystem of diagnostics and planning of facilities and systems of rolling stock.

Materials and methods of research. To study the effectiveness of the use of production and technological potential the work of rail transport needs to streamline many tasks Q_{ik} in accordance with the tasks and objectives set before the operation of rail rolling stock. For this purpose it is necessary to divide by the method of decomposition of the system analysis into two subsets and to present system model of set of problems of efficiency of use of production and technological potential of work of rail transport [2-5]:

$$Q_{ik} = Q_{ik}\left\{Q_{ik}^{\,1}, Q_{ik}^{\,2}\right\} \rightarrow Q_{ik}^{\,1} \cup Q_{ik}^{\,2} = Q_{ik}, \quad (1)$$

where Q_{ik}^{1} – a subset of tasks, the solution of which ensures the achievement of the required level of quality of production processes due to the efficiency of the rolling stock of rail transport;

Q_{ik}^{2} – a subset of tasks, the solution of which ensures the rational use of resources;

I – types of resources i = 1,2,…, I used to solve new optimization problems;

k – stages of the life cycle of rail rolling stock k = 1,2, ……, K.

Also, the main aspects that affect the efficiency of the use of production and technological potential were investigated and analyzed, as a result of which many tasks were identified [4, 7]. On the basis of which the system model of problems of efficiency of use of production and technological potential of work of rail transport by a method of decomposition by means of the AllFusion Process Modeler software is presented. The model is modeled withfunctional diagrams, which are based on the IDEF0 standard and presented in the form of a context diagram (Fig. 2) and in the form of a decomposition diagram and descriptions (Fig. 3).

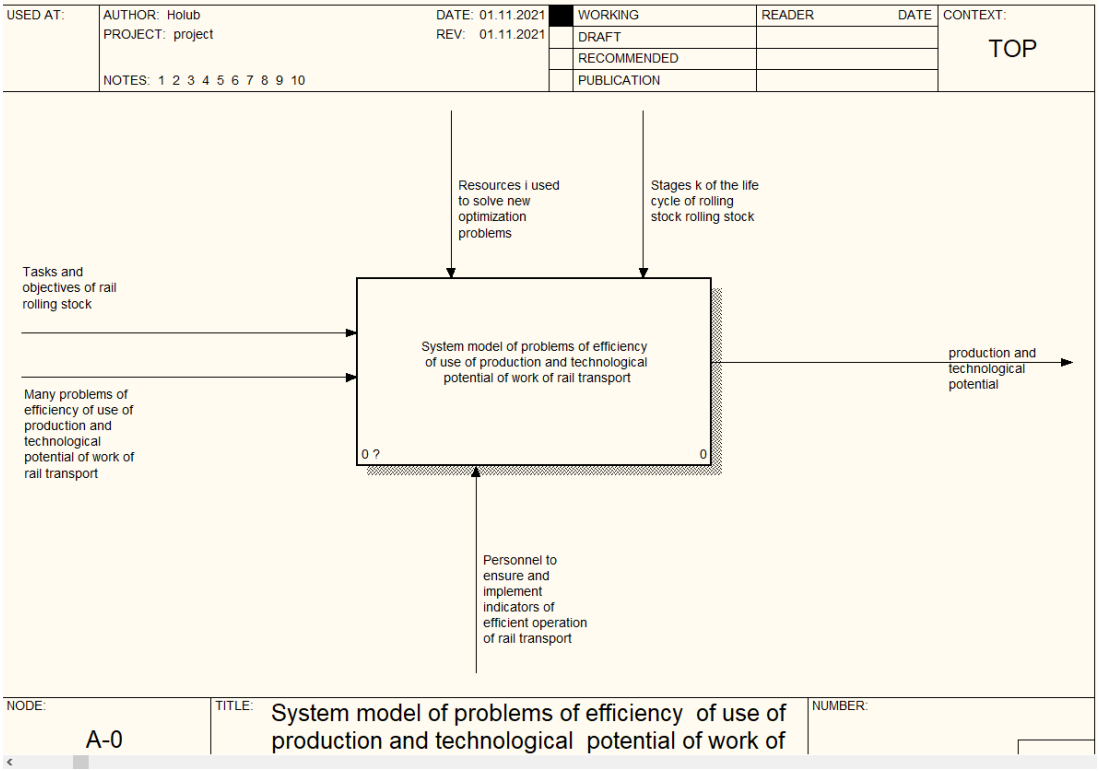

Fig. 2. **System model of problems of efficiency of use of production and technological potential of work of rail transport by means of the context diagram**

The main criteria for the systematic solution of many problems Qikthe quality and efficiency of the operation of the rolling stock of rail transport, taking into account all aspects of its activities. Criteria are formed on the basis of the formula of system analysis:<quality>↔<efficiency>.

Many tasks are formed on the basis of system criteria Qik, which provide optimization of the relevant processes [6] and the final results of the operation of facilities and systems of rail transport.

The problem of ensuring the required level of efficiency in the use of production and technological potential of rolling stock was considered.

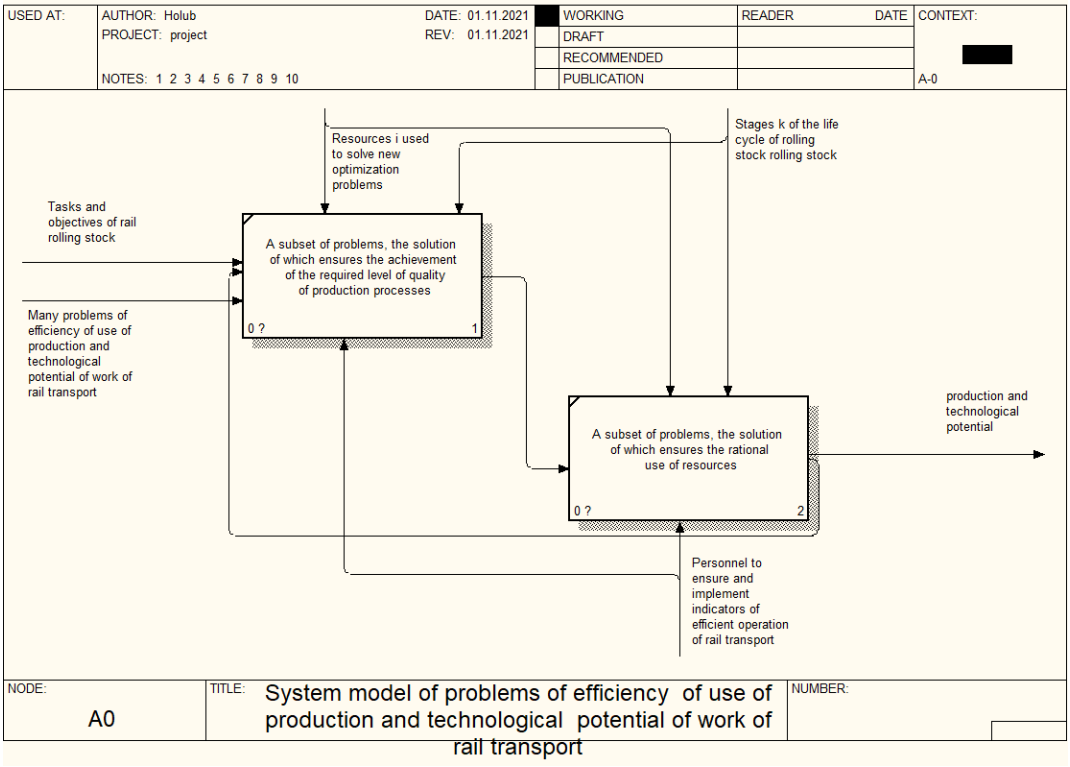

Fig. 3. **System model of problems of efficiency of use of production and technological potential of work of rail transport by means of the diagram of decomposition and the description**

The main purpose of operation is presented in the form of a mathematical model:

$$\max_{U_i \in U} \Pi = \max_{U_i \in U} \left[IC_i - \left(\sum_{j=1}^{J} A_i + A_{Hi} + A_{Ai} \right) \right], \qquad (2)$$

where $\max_{U_i \in U} \Pi$ – maximum profit for the i-th period of time with the rational use of labor, material and financial resources;

IC_i– income from efficient operation of rail transport in the i-th period of time;

Ai – labor and material resources spent on the operation of production processes of rail transport in the i-th period of time;

A_{Hi} – overhead for the i-th period of time;

A_{Ai} – depreciation accruals for the full restoration of fixed assets.

Depreciation accruals are mostly used to form the investment fund required for the modernization and technical re-equipment of rail transport facilities and systems.

Given the complexity of production processes of efficient operation of rail transport, a mathematical model for managing the efficiency of use of production and technological potential of rolling stock in the form of:

$$T_{ppi} = T_{ppi}(T_{1i}, T_{2i}, T_{3i}, ..., T_{qi}), i = 1, 2, 3, ..., I; q = 1, 2, 3, ..., Q, \qquad (3)$$

where T_{ppi} – model of functioning of production processes of rail transport on the i-th period of time;

T_{qi} – model of functioning of separate production processes of rail mobile transport on the *i*-th period of time.

Models of functioning of separate production processes can be set on a set of tasks Qik, the solution of which in the system unity [6] on the basis of wide application of modern methods and information technology ensures the achievement of high results of efficient operation of rail transport.

The paper considers the issue of solving at different levels of the hierarchy of production and technological potential of many problems Q_{ik} that providesformation relevant system requirements, which are based on a comprehensive consideration of all facilities and processes of production and technological potential of rail transport. Comprehensive consideration of objects, systems and processes involves their identification [7-10], which provides a formalized description. Identificationincludes a study of structural and functional features of facilities and systems of production and technological potential of rail transport .. Required list of key parameters that are diagnostic features of subsystems and components of rolling stock, a set of inspection methods and a list of defective conditions for each type of technical means [6, 7]. Diagnostic assessment is determined by the task of classification:

$$X = (x_1, x_2, \dots, x_n) \to Y = (y_1, y_2, \dots., y_n), \tag{4}$$

where are the diagnostic parameters of objects and systems, which are presented in the form of a hierarchy; Y - many state classes of objects and systems.$X = (x_1, x_2, \dots, x_n)$.

The obtained fuzzy model is used to assess the actual technical condition Y * depending on the monitoring of data on the parameters X* [5] of the rolling stock of rail transport. At kcomplex consideration of objects, systems and processes the one of problem is the imperfection of methods of diagnostics of objects and systems of rolling stock in terms of accessibility of data processing and decision-making on quality assurance and repair planning [11], including in conditions of uncertainty [13, 15]. In this situation, it is advisable to use intelligent technology to solve diagnostic problems that are complex and difficult to formalize. In contrast to classical approaches [15], they allow to analyze not only preliminary data on the operation of systems and objects, but also the knowledge and experience of specialists [16, 17].

Mechanisms of the intelligent decision support system [12, 14] can be implemented using fuzzy inference systems, in combination with optimization and clustering methods. This approach allows the use of statistical data and expert opinions in the development of diagnostic models and increase the reliability of assessing the condition of objects and systems of rolling stock [5, 6, 16].

Fuzzy rules are generated by an expert. They mimic the logic of experts in assessing the state of objects and systems of rolling stock and form a knowledge base built on a hierarchical principle [16, 17]. Thus, a comprehensive assessment of the general condition of rolling stock can be obtained, as well as an assessment of its condition of the elements, which is the basis of the technical aspect of production and technological potential of rail transport management efficiency.

The rules of the intermediate and resulting databases, hierarchically linked, are written in the format:

$$\begin{gathered} if\ \left(x_1^i = \tilde{g}_{1f}^i\ and\ x_2^i = \tilde{g}_{2f}^i\ and\ \dots..and\ x_{n1}^i = \tilde{g}_{nif}^i\ with\ the\ weight\ \omega_f\right), \\ then\ y_1 = \tilde{d}_{1f}^i, f = \overline{1,q}, \\ if\ \left(y_1 = \tilde{d}_{1j}\ and\ y_2 = \tilde{d}_{2j}\ and\ \dots..and\ y_l = \tilde{d}_{lj}\ with\ the\ weight\ \omega_j\right), \\ then\ Y = h_j, j = \overline{1,z}, \end{gathered}$$

where $g^{\sim ij}$ – is a fuzzy term that is an attribute of the estimate x_1^i, $\tilde{d}_{if}, \tilde{d}_{ij}$ are fuzzy sets that estimate the state i_{th} of an element or system of rolling stock, h_j – is the value derived from jth rules of classes $S\ \epsilon\{s_1, \dots. s_l\}$ for real assessment of the state of rolling stock.

As a result of the actual assessment of the technical condition of rolling stock is defined as the class with the maximum degree of membership [14]:

$$Y = \arg_{.\{s1,s2,\dots,sl\}} \max\left(\mu_{s1}(Y), \mu_{s2}(Y), \dots, \mu_{sl}(Y)\right), \tag{5}$$

where де $\mu_{s_t}(Y) = agg_{\forall j:h_j=s_t}\left(\mu_j(X)\right)$ is the degree of number of system members and objects of key diagnostic parameters of values to classes $s_t, t = \overline{1,l}$;

$\mu_j(X) = \omega_j * (min_{i=1}^{n}\left(agg_{\forall f:d_f=e_t}((\mu_f(X_i)))\right)$ - the degree of implementation of the jth rules characterizing the state of rolling stock;

$\mu_f(X_i) = \omega_f * (\min\left(\mu_f(x_1^i), \ldots, \mu_f(x_{n_i}^i)\right))$ - the degree of compliance fth rules characterizing the qualitative state ith the element.

Thus, the proposed method of diagnosis opens the possibility of interaction between the management of the diagnostic subsystem and the planning of rolling stock facilities and systems based on the actual technical condition, which will improve the main aspects of production and technological potential.

Creating a system model for managing the efficiency of use of production and technological potential of rolling stock [6] of rail transport is a key element of the approach. The efficiency of its management allows to collect data on the operation of facilities and systems of rolling stock and use it to improve the performance of components of many tasks of production and technological potential and efficiency of decision-making aimed at operational costs of optimization.

Conclusions. Analyzed the problem of efficiency of management of production and technological potential of rail rolling stock.Based on the system criteria, a set of Qik tasks has been formed, which provide optimization of production processes and final results of operation of facilities and systems of rail transport. The system model of problems of efficiency of use of production and technological potential of work of rail transport by a method of decomposition is developed. The method of diagnostics of objects and systems of a rolling stock is offered,which will increase the indicators of the main aspects of production and technological potential.

REFERENCES

1. Kulayev, Y.U. (2001). Metody ekonomicheskoy otsenki investitsionnykh proyektov na transporte. Ucheb.-metod. Posobiye. Kiev:Transport Ukrainy, 128 p. [in Ukrainian].
2. Blokhin, L.M., & Burichenko, M.Yu. (2003). Statychna dynamiky system upravlinnya [Static dynamics of control systems]. Kyiv: National Aviation University [in Ukrainian].
3. Levkovets, P.R., Gedz, Y.M., & Kanarchuk, O.V. (2002). Systemna efektyvnist′ na transporti. Metody, modeli i statehiyi [Static dynamics of control systems]. Kyiv: National transport University [in Ukrainian].
4. Gorbachev, P.F., & Dmitriev, I.A. (2002). Osnovy teorii transportnykh sistem [undamentals of the theory of transport systems]. Kharkiv: KhNADU [in Russian].
5. Kulbovskyi, I., Holub, H., Melenchuk, V., & Chmyr, V. (2021). Development of a system model of technical operation management intransport infrastructure projects. *Transport systems and technologies*, (37), 196-203. https://doi.org/10.32703/2617-9040-2021-37-19.
6. Shchabelska, I. (2012). Otsinka stalosti y efektyvnosti investytsiynoho proektu, Upravlinnya rozvytkom 2: 23-26 [in Ukrainian].
7. Bushuyev, S.D., Bushuyeva, N.S., Babayev, I.A., Yakovenko V.B., et al. (2010). Kreativnyye tekhnologii upravleniya proyektami i programmami [Creative technologies for project and program management]. Kiev: Summit-Book [in Russian].
8. Holub, H., Kulbovskyi, I., Skliarenko, I., Bambura, O., & Tkachuk, M. (2019). Research of methods for identification of emergency modes of power supply system in transport infrastructure projects. *Technology Audit and Production Reserves*, *5*(2(49), 34–36. https://doi.org/10.15587/2312-8372.2019.182830
9. Kulbovskyi I., Sapronova, S., Holub, H., Tkachenko, V., & Musorina, M. (2019). Modeling of Management Strategies for Manufacturing Technological Processes in Metro Power Supply Projects. *TRANSBALTICA 2021: TRANSBALTICA XI: Transportation Science and Technology*, 211-219.
10. Babayev, V.M. Upravlinnya proektamy: Navchal′nyy posibnyk dlya studentiv spetsial′nosti «Upravlinnya proektamy» [Project Management: Textbook for students majoring in «Project Management»]. Kharkiv: KNAMG [in Ukrainian].
11. F. Gustafsson. 2010. Particle filter theory and practice with positioning applications. IEEE. Aerospace and Electronic Systems Magazine 25 (7): 53–82.
12. Vasylevs′ka, A. (2012). Upravlinnya proektamy pidpryyemstva iz vykorystannyam informatsiynykh tekhnolohiy [Project management of the enterprise with the use of information technologies]. *Visnyk KNTEU - Bulletin KNTEU, 1*, 99-105 [in Ukrainian].

13. Khoroshev N.I., Kazantsev V.P. (2015) Management Support of Electroengineering Equipment Servicing Based on the Actual Technical Condition. *Automation and Remote Control*, 76 (6):1058 – 1069.

14. Shtovba S.D., Pankevich O.D., Nagorna A.V. (2015). Analyzing the Criteria for Fuzzy Classifier Learning. *Automatic Control and Computer Sciences*, 49 (3):123 – 132

15. Petrochenkov A.B. (2012). Regarding Life-Cycle Management of Electrotechnical Complexes in Oil Production. *Russian Electrical Engineering*, 83 (11): 621 – 627

16. Eltyshev D.K. (2015). Intellectualization of Diagnostics of Electric Machinery. *Informatika i sistemy upravleniia*, 43 (1): 72 – 82.

17. Eltyshev D.K. (2015). Expert statistical method for estimating the lectrical equipment operability. *Sistemy. Metody. Tekhnology.* 28 (4): 79 – 85.

***Іван Кульбовський*[1], *Галина Голуб*[2*], *Snezhina Andonova*[3], *Інна Саяпіна*[4], *Микола Ткачук*[5]**

[1]Кафедра автоматизації та комп'ютерно-інтегрованих технологій транспорту, Державний університет інфраструктури та технологій, вул. Кирилівська, 9, м. Київ, 04071, Україна

[2] Кафедра автоматизації та комп'ютерно-інтегрованих технологій транспорту, Державний університет інфраструктури та технологій, вул. Кирилівська, 9, м. Київ, 04071, Україна

[3] Faculty of Engineering, South-West University «Neofit Rilski», Blagoevgrad, 2700, Bulgaria

[4]Кафедра штучного інтелекту та телекомунікаційних технологій, Державний університет інфраструктури та технологій, вул. Кирилівська, 9, м. Київ, 04071, Україна

[5]Служба сигналізації та зв'язку РФ «Південно-Західна залізниця» АТ «Укрзалізниця», вул. Лисенко, 6, м. Київ, 01054, Україна

***Corresponding author:** golub_gm@gsuite.duit.edu.ua

МОДЕЛЬ ТА МЕТОДИ УПРАВЛІННЯ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ВИРОБНИЧО-ТЕХНОЛОГІЧНОГО ПОТЕНЦІАЛУ РУХОМОГО СКЛАДУ РЕЙКОВОГО ТРАНСПОРТУ

У статті розглянуто проблеми управління ефективності використання виробничо-технологічного потенціалу рухомого складу рейкового транспорту. Досліджено, що для вдосконалення ефективності функціонування необхідно комплексне вирішення множини задач, при раціональному використанні трудових, матеріальних та трудових ресурсів.

Розглянуто комплекс множини задач, які спрямовані на покращення та забезпечення визначено рівня ефективності функціонування об'єктів і систем рейкового транспорту.

Досліджено, що для досягнення необхідного рівня ефективності функціонування рухомого складу потрібно вдосконалити процес управління за допомогою системної модель множини задач ефективності використання виробничо-технологічного потенціалу роботи рейкового транспорту. У результаті вирішення поставленої проблеми було запропоновано математичну модель множини задач, яка стала основою для побудови системної моделі множини задач. При побудові системної моделі використовували метод декомпозиції та програмне забезпечення AllFusion Process Modeler.

В роботі розглянуто задачу щодо забезпечення необхідного рівня ефективності використання виробничо-технологічного потенціалу рухомого складу рейкового транспорту та запропоновані шляхи її вирішення. Також наведено комплексний розгляд об'єктів, систем і процесів, який передбачає їх ідентифікацію, що забезпечує формалізований опис. На основі чого було запропоновано модель та метод діагностики, що відкривають можливість взаємодії управління підсистемою діагностики та планування роботи об'єктів і систем рухомого складу на основі фактичного технічного стану. Вирішення таким шляхом дозволить підвищити показники основних аспектів виробничо-технологічного потенціал, що є метою даної роботи.

Ключові слова: *метод діагностики, модель, декомпозиція, системний аналіз, система, виробничо-технологічний потенціал.*