Proceedings of 23rd International Scientific Conference. Transport Means 2019.

Consideration of Dependent Failures Impact on Selecting the System of Locomotive Maintenance

B. Bodnar[1], O. Ochkasov[1], T. Hryscheckina[1], E. Bodnar[1], R. Skvireckas[2]

[1]*Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan St., 2, 49010 Dnipro, Ukraine, E-mail: abochkasov@gmail.com*
[2]*Kaunas University of Technology, Studentu st. 56, 51424, Kaunas, Lithuania, E-mail: ramunas.skvireckas@ktu.lt*

Abstract

Modern measures aimed at reducing the operating costs are closely related to such concepts as life cycle cost (LCC) and RAMS-approach (Reliability, Availability, Maintainability, Safety). The article analyzes the existing standards that regulate their usage. The purpose of the study is to improve the procedure for determining the renewal costs of locomotive nodes with due regard to dependent failures. To describe the propagation of dependent failures in the system, the authors propose to use the wave approach. The impact of dependent failures on the system is determined on the basis of information about the relationship between elements and data from a technological-economic map concerning the renewal costы of locomotive nodes. To take into account the probabilistic nature, the authors suggest using the methods of expert research for determining the probability of failures of dependent elements. The authors proposed the procedure for determining the probability of the locomotive nodes breakdown considering the dependent failures. The method of calculating an average price of the unplanned repair, considering the dependent failures of interrelated elements was improved. For the first time, a recurrence relation on a set is deduced, by which the volume of damage is calculated at dependent failures of elements in a complex system. The factor, which will allow assessing the impact of dependent failures on the maintenance system and the life cycle cost of a locomotive, is proposed. On the basis of the proposed method, the calculations for the electric equipment of electric locomotives, DE1 series were made. A comparison of the renewal costs of the electrical equipment without/with considering the dependent failures of related elements was made.
KEY WORDS: *life cycle cost; locomotive; dependent failures; impact of dependent failures on renewal costs*

1. Introduction

Among the main measures aimed at increasing the efficiency of railway transport, is the activity for reducing the operating costs and maintenance of vehicles [1].

Decision making by transport companies for the acquisition and modernization of rolling stock is implemented through not only comparing of technical characteristics and costs of acquisition (or modernization). Gradually, the indicator «Life Cycle Cost» (LCC) of a locomotive becomes an obligatory element of calculations. The value of capitalized expenses for the acquisition of the new traction rolling stock begins to be substituted by the costs in all phases of the life cycle of a locomotive [14-16]. In world practice the most common approach when developing the life cycle control systems is using RAMS (Reliability, Availability, Maintainability, Safety) one.

The principal features, designation and key terminology related to RAMS and LCC of rail transport facilities are provided in European Standard NF EN 50126-1-2000 [2]. The mathematical expressions for reliability, availability, serviceability and maintenance support are given in IEC 61703: 2016 [3]. Life cycle cost calculations are given in IEC 60300-3-3: 2017 "Reliability Control. Part 3-3. Implementation Guidance. Calculation of the life cycle cost" [4]

The LCC concept is widely used in the development of decision-making models upon modernizing the traction rolling stock, factoring in the characteristics of RAMS, performance indicators and environmental friendliness [1].

An example of the practical application of RAMS approach to assess the security status of a locomotive facility using the integral index is given in [5, 6].

One of the LCC elements is the costs of servicing the locomotive, the value of these expenses depends on the figures of merit and the adopted maintenance work system. Reduction of operational costs and increase in reliability is achieved by the introduction of modern means of technical diagnostics at all stages of the life cycle of a locomotive. Approaches and examples in the implementation of technical diagnostic tools and their impact on the operating cost of rolling stock are presented in [17, 19]. Procedures for assessing the cost effectiveness of a locomotive maintenance system and their relationship with diagnostic systems are presented in [7, 8, 13, 17]. In order to advance the procedure for calculating the cost of the locomotive maintenance system, the authors propose to consider dependent failures of nodes. The dependent failure is defined in [9] as a failure of an object, caused directly/indirectly by a failure of malfunction of another object.

In the complex technical system dependent failures are discussed in relation to the impact of one element failure on the reliability of its dependent elements, planning in the supply of spare parts, optimization of the rolling stock fleet [10-13, 20-22]. That is, a failure of one element can lead to malfunction of the associated elements in the system. In

The obtained values in assessing the node failure impact on the renewal costs of the locomotive is appropriate to use in the development of locomotive diagnostic systems. The nodes that have the highest value of the impact factor, if technically possible, it is advisable to equip with technical diagnostic tools. An economic assessment of the feasibility in implementing technical diagnostic tools can also be performed by comparing the cost of the technical means with the possible costs for restoring the locomotive.

References

1. **Tulecki, A.; Szkoda, M.** 2017. Ecology, energy efficiency and resource efficiency as the objectives of rail vehicles renewal, Transportation Research Procedia 25: 386-406. doi: 10.1016/j.trpro.2017.05.416 https://ac.els-cdn.com/S2352146517307238/1-s2.0-S2352146517307238-main.pdf?_tid=d9c2f60a-9f5a-4b57-8a79-51f6469be39c&acdnat=1546683427_fa02bd4b7ed2b93820e71b5b731cc5ad
2. Cenelec-EN50126. Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) Part 1: Basic requirements and generic process [online cit.: 2016-05-17]. Available from: https://standards.globalspec.com/std/1272146/cenelec-en-50126-1
3. International Electrotechnical Commission (IEC), “Mathematical expressions for reliability, availability, maintainability and maintenance support terms. n. 61703”, International Electrotechnical Commission, Geneva, 2001.
4. IEC 60300-3-3:2017, “Dependability management – Part 3-3: Application guide – Life cycle costing”. 2017. International Standard, 92 p.
5. **Bodnar, B.; Ochkasov, O.; Bodnar, Ye.; Hryshechkina, T.; Keršys, R.** 2018. Safety Performance Analysis of the Movement and Operation of Locomotives, Transport Means 2018, Proceedings of the 22nd International Scientific Conference II: 839-843.
6. **Bodnar, B.; Bolzhelarskyi, Ya.; Ochkasov, O.; Hryshechkina, T.; Černiauskaitė, L.** 2018. Determination of Integrated Indicator for Analysis of the Traffic Safety Condition for Traction Rolling Stock: [preprint], Intelligent Technologies in Logistics and Mechatronics Systems (ITELMS’2018): The 12th International Scientific Conference, April 26–27, 2018, Panevėžys, Kaunas University of Technology, 45-54.
7. **Bodnar, E.B.** 2004. Improving the operational reliability of locomotives by introduction of the rational maintenance system: dissertation: 05.22.07, Dnipropetrovsk: DNURT, 161 p. (In Ukrainian).
8. **Hryshechkina, T.** 2017. Mathematical model of the rational maintenance system of railway transport technical objects, Transport Systems and Transportation Technologies 14: 30-35. (in Ukrainian).
9. SSU 2860-94. Reliability technology. Terms and Definitions. Accepted December 28, 1994. Signed into law January 01, 1996. (in Russian).
10. **Bosov, A.A.; Hryshechkina, T.B.; Savchenko, K.N.** 2010. The impact of dependent failures on the technical systems safety using the example of the accidents analysis from 2005 to 2008, Locomotive-Inform 1: 5-8. (in Russian).
11. **Hryshechkina, T.S.** 2015. Modeling of Dependent Failures of Complex Technical Systems Elements, Труды РГУПС Proceedings of Rostov State Transport University 3: 50-56. (in Russian).
12. **Xie, L.; Lundteigen, M. A.; Liu, Y.L**. 2018. Common cause failures and cascading failures in technical systems: Similarities, differences and barriers Safety and Reliability, Safe Societies in a Changing World, Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018, 2401-2408.
13. **Lee, H.; Cha, J. H.** 2016. Stochastic modeling of cascading failures in k-out-of-n system, Risk, Reliability and Safety: Innovating Theory and Practice, Proceedings of the 26th European Safety and Reliability Conference, 417.
14. **Osyaev, A.T.; Nikiforov, V.A.** 2012. About the system of locomotives servicing abroad, Vestnik of the Railway Research Institute (Vestnik VNIIZHT) 2: 56-62. (in Russian).
15. **Chigirik, N.; Sumtsov, A.; Biletskiy, U.** 2015. Experience of Technical Manual Traction Rolling The Railways of Europe, Visnik of the Volodymyr Dahl East Ukrainian National University,1(218): 29-31 (in Ukrainian).
16. **Falendysh, A.; Kharlamov, P.; Kletska, O.; Volodarets, N.** 2016. Calculation of the parameters of hybrid shunting locomotive, Transportation Research Procedia 14: 665-671. doi: 10.1016/j.trpro.2016.05.325
17. **Bodnar, B.; Ochkasov, O.** 2017. System Choice of the Technical Maintenance of Locomotives Equipped with on-Board Diagnostic Systems, Transport Means: Proceedings of 21st International Scientific Conference I: 43-47.
18. **Bodnar, B.E.; Ochkasov, O.B.; Hryshechkina, T.S.; Bodnar, Ye.B.** 2018. Choosing the System of Locomotive Maintenance in View of the Effect of Dependent Failures, Наука та прогрес транспорту 6(78): 47-58. – doi: 10.15802/stp2018/154823.
19. **Myamlin, S.; Kalivoda, J.; Neduzha, L.** 2017. Testing of Railway Vehicles Using Roller Rigs. Procedia Engineering, Proceedings of 10th International Scientific Conference “Transbaltica 2017”, 187: 688-695. doi: 10.1016/j.proeng.2017.04.439
20. **Brezavšček, A**. 2016. Stochastic Approach to Planning of Spares for Complex Deteriorating Industrial System, Quality Technology and Quantitative Management, 12(4): 465-480. doi: 10.1080/16843703.2015.11673431
21. **Kim, W.; Chang, Y.; Kim, D; Kim, J.** 2018. Life cycle cost comparative analysis for main conversion system in 8200 series electric locomotive, The Transactions of the Korean Institute of Electrical Engineers 67(12): 1717-22.
22. **Rawat, M.; Kumar Lad, B**. 2018. Novel approach for machine tool maintenance modelling and optimization using fleet system architecture, Computers & Industrial Engineering 126: 47-62, doi: 10.1016/j.cie.2018.09.006