Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2013, 33(105) pp. 100–105
ISSN 1733-8670

2013, 33(105) s. 100–105

Computer aided maintenance management of electronic equipment used in transport

Mirosław Siergiejczyk, Adam Rosiński

Politechnika Warszawska, Wydział Transportu, Zakład Telekomunikacji w Transporcie
00-662 Warszawa, ul. Koszykowa 75, e–mail: adro@it.pw.edu.pl

Key words: maintenance, reliability, routine inspections

Abstract
Electronic equipment used in transport operates under various conditions. Due to characteristic nature of their application, they should be highly reliable. This paper presents a methodology of optimising a bistable operation process of those systems factoring in economic factors, i.e. the funding allocated to routine inspections. Its practical application was also discussed, which would entail computer aided maintenance software.

Introduction

The issue of maintaining electronic equipment, particularly those used in transport is an important problem. This stems from the fact correct reliability and operating parameters have to be assured. Many renowned papers have already been written on the matter [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. By carrying out an adequate reliability analysis of systems, their reliability structures are determined which provide correct reliability parameters. This applies both to the entire system [12, 13, 14, 15, 16], as well as its constitution elements, e.g. power supply [17, 18] and transmission media [19]). Due to this approach, the designed system becomes more reliable. It does not, however, assure high enough availability of the system. Hence, maintenance analysis has to be carried out taking account of selected operating properties of the systems (e.g.: failure rate, routine maintenance intensity) [20]. Findings of that analysis enable to fine-tune the maintenance strategy, including rationalisation of routine inspections and their length relative to requirements to those systems in respect of their availability in the transport process [21, 22, 23, 24]. The costs it generates are also factored in by the strategy [25, 26, 27].

Computer aided maintenance is the latest trend in managing maintenance. This solution could be used in the subsystem of maintaining electronic equipment used in transport. From the standpoint of travel security this is an exceptionally important issue. If applied, computer systems collect data (databases containing information about operation of given equipment) and then process them. This enables to draw conclusions about basic operating parameters. Thus, optimum decisions concerning operation process could be made (e.g.: routine inspections and their length, overhaul), which assured to maximise the end effects provided given base conditions were met. Among the effects were maximised availability, minimised repair times, optimised servicing intensity. In face of limited funding for maintenance, a decisional issue arises: how to maintain continuity of operations (system's availability) with restricted financial resources whilst assuring desired security level and meeting all objectives (e.g.: maximisation of operating parameters, cost-cutting, maximisation of financial efficacy). The answer is creating many computer programmes, which support decision making.

Bistable maintenance strategy maximising availability

The availability rate is given by:

$$K_g = \frac{T_m}{T_m + T_n} \tag{1}$$

where: T_m – mean correct operation time between failures, T_n – mean time to repair.

The given relation shows that the system can be in one of two states (Fig. 1):

– usage state (S_0);
– repair state (S_1).

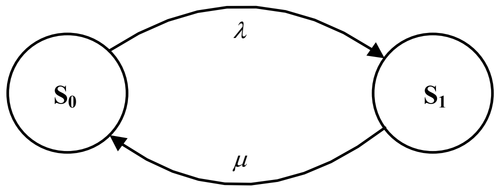

Fig. 1. Graph showing switching between usage and repair states; λ – failure rate, μ – repair rate

Through analysing electronic equipment operating in transport the following state were determined:

– usage state S_{00};
– repair state S_{10};
– I type inspection S_{01} (basic servicing required by specification);
– II type inspection S_{11} (extended servicing required by specification).

The graph in figure 2 illustrates switching between above states. Switching between states includes the coefficients:

- k_1 – I type inspection coefficient – determines linear relation between current I type inspection rate, and optimum I type inspection rate for which availability rate is maximum;
- k_2 – II type inspection coefficient – determines linear relation between current II type inspection rate, and optimum II type inspection rate for which availability rate is maximum.

An important issue occurring in practice, is limited funding allocated for routine inspections of electronic equipment used in transport, available to the user. Hence, the impact has to be determined of financial outlays allocated to routine inspections on availability rate of the system. Therefore, the C coefficient was introduced, which determined available financial resources allocated to I and II type inspections. Let us assume that:

– $C = 2$ for optimum I and II type inspection rates ($K_g = \max.$ for $\lambda_1 = \lambda_{1optym}$ and $\lambda_2 = \lambda_{2optym}$; because in equation (2) $k_1 \cdot C = 1$ and $k_2 \cdot C = 1$);
– $C = 0$ for I and II type inspection rates equal naught (no inspections; because in equation (2) $k_1 \cdot \lambda_{1optym} \cdot C = 0$ and $k_2 \cdot \lambda_{2optym} \cdot C = 0$).

By carrying out a mathematical analysis the following relation was obtained (2).

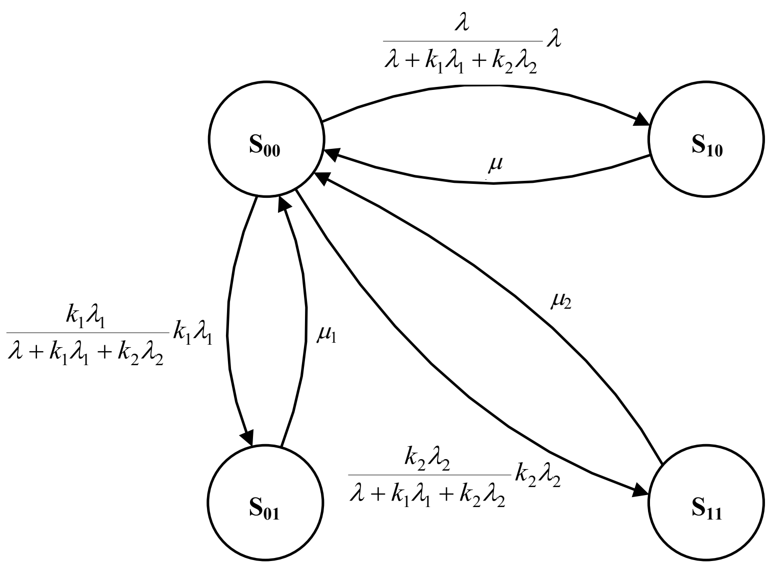

Fig. 2. Graph showing switching between usage state (S_{00}), repair state (S_{10}), I inspection state (S_{01}) and II inspection state (S_{11}); λ – failure rate, μ – repair rate, λ_1 – I type inspection rate, μ_1 – I type routine maintenance rate, λ_2 – II type inspection rate, μ_2 – II type routine maintenance rate, k_1 – I type inspection coefficient, k_2 – II type inspection coefficient

$$K_g = \frac{(\lambda + k_1\,\lambda_{1optym}\,C + k_2\,\lambda_{2optym}\,C)\,\mu\,\mu_1\,\mu_2}{(\lambda + k_1\lambda_{1optym}C + k_2\lambda_{2optym}C)\mu\mu_1\mu_2 + \lambda^2\mu_1\mu_2 + \left(k_1\lambda_{1optym}C\right)^2\mu\mu_2 + \left(k_2\lambda_{2optym}C\right)^2\mu\mu_1} \qquad (2)$$

$$K_g = \frac{(\lambda + k_1\,\lambda_{1optym}C + (1-k_1)\lambda_{2optym}C)\,\mu\,\mu_1\,\mu_2}{\left[\lambda + k_1\lambda_{1optym}C + (1-k_1)\lambda_{2optym}C\right]\mu\mu_1\mu_2 + \lambda^2\mu_1\mu_2 + \left(k_1\lambda_{1optym}C\right)^2\mu\mu_2 + \left[(1-k_1)\lambda_{2optym}C\right]^2\mu\mu_1} \qquad (3)$$

3D graphical representation of equation (2) is impossible due to three variables: k_1, k_2, C. Therefore, the following relation was used:

$$k_1 + k_2 = 1$$

and the following equation was obtained (3).

Example 1

Assumptions taken were:

– failure rate $\lambda = 1.2027 \cdot 10^{-5}$ [1/h] (representing system whose reliability is 0.9);
– repair rate $\mu = 0.0666$ [1/h] (representing repair time of 15 [h]);
– I type routine maintenance rate $\mu_1 = 0.5$ [1/h] (representing inspection time of 2 [h]);
– II type routine maintenance rate $\mu_2 = 0.1666$ [1/h] (representing inspection time of 6 [h]);
– I type inspection rate $\lambda_{1optym} = 2 \cdot 10^{-5}$ [1/h];
– II type inspection rate $\lambda_{2optym} = 6 \cdot 10^{-6}$ [1/h].

For the assumptions taken, a chart was obtained illustrated in figures 3 and 4.

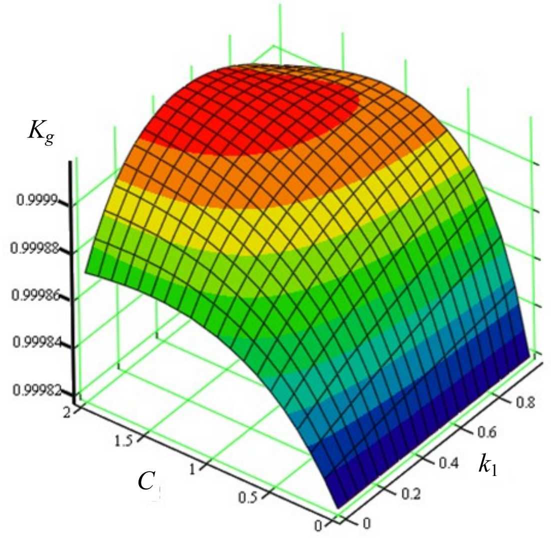

Fig. 3. Relation between availability rate K_g as function of I type inspection coefficient k_1 and financial outlays coefficient C (general view)

End of example 1.

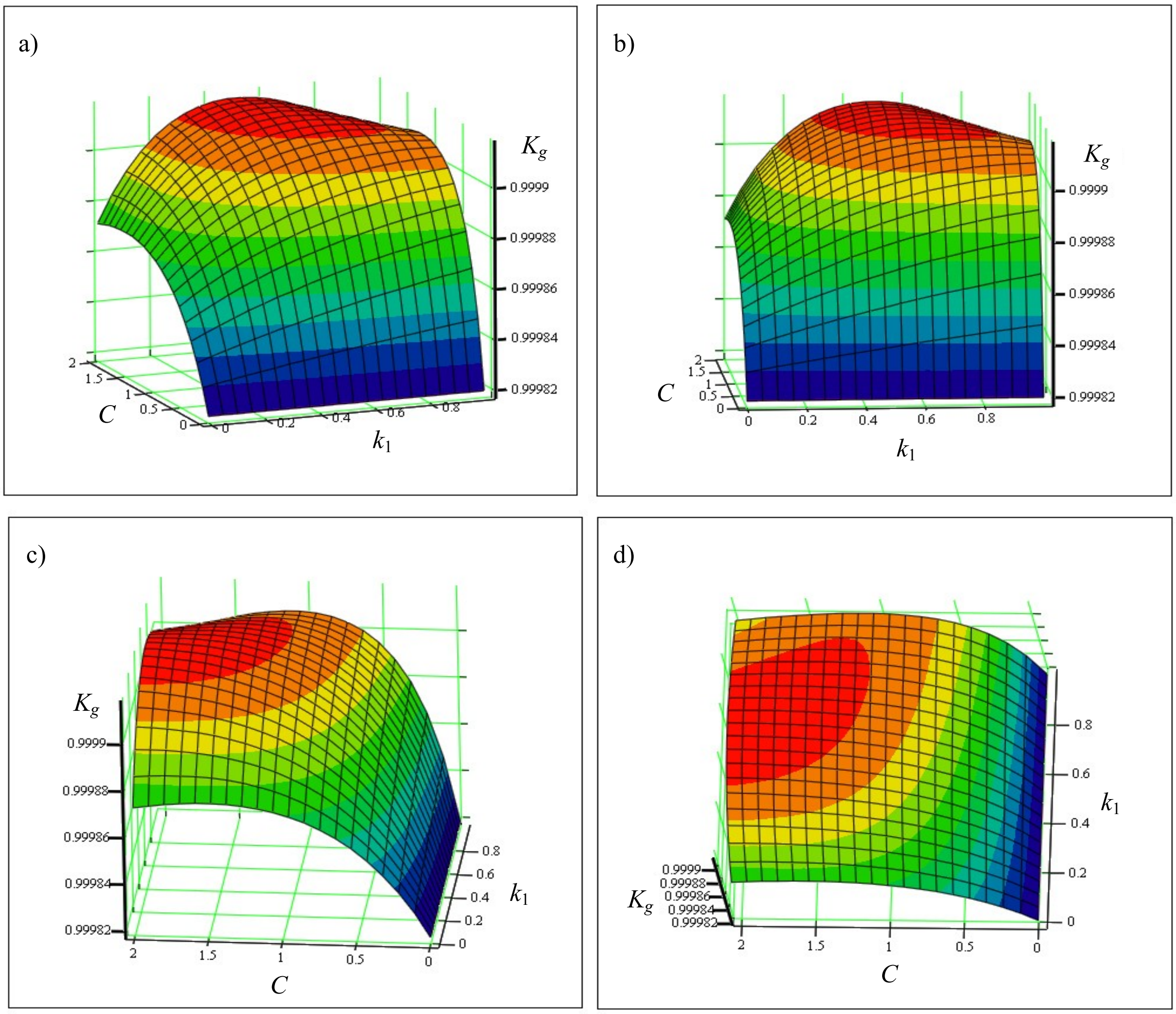

Fig. 4. Relation between availability rate K_g as function of I type inspection coefficient k_1 and financial outlays coefficient C: a, b – k_1 axis view, c, d – C axis view

By studying figures 3 and 4 the following could be concluded:

– availability rate K_g reaches its maximum for $C = 2$ and $k_1 = 0.5$. For lower C (lower financial outlays) K_g decreases;
– there is a non-linear relation between financial outlays coefficient C and inspection coefficient k_1. Therefore, in case of financial outlays lower than optimum to get the maximum K_g, one should determine new inspection rates for both types of inspections generating maximum availability rate.

Computer aided maintenance

In order to facilitate managing the maintenance and reliability process for users of electronic equipment used in transport, a programme has been developed: "Support of Maintenance Decisions in Transport Surveillance Systems" [27] (WDNETSN in short) (Fig. 5). Initial values:

– number of studied systems;
– time spent on studying systems;
– mean time to repair;
– mean time to completion of I type inspection;
– mean time to completion of II type inspection;
– financial outlays coefficient;
– number of elements damaged in studied system

and by using equations and relation given in the previous chapter, the programme determines the following:

– reliability of individual constitutive elements;
– reliability of the entire system;
– failure rate of individual constitutive elements;
– failure rate of the entire system;
– mean operating time of individual constitutive elements;
– availability rate of individual constitutive elements;
– availability rate of the entire system;
– for systems of mixed and parallel structure:
  • the likelihood function of system in state of full operational capability R_O;
  • the likelihood function of system in state of state of security threat Q_{ZBi};

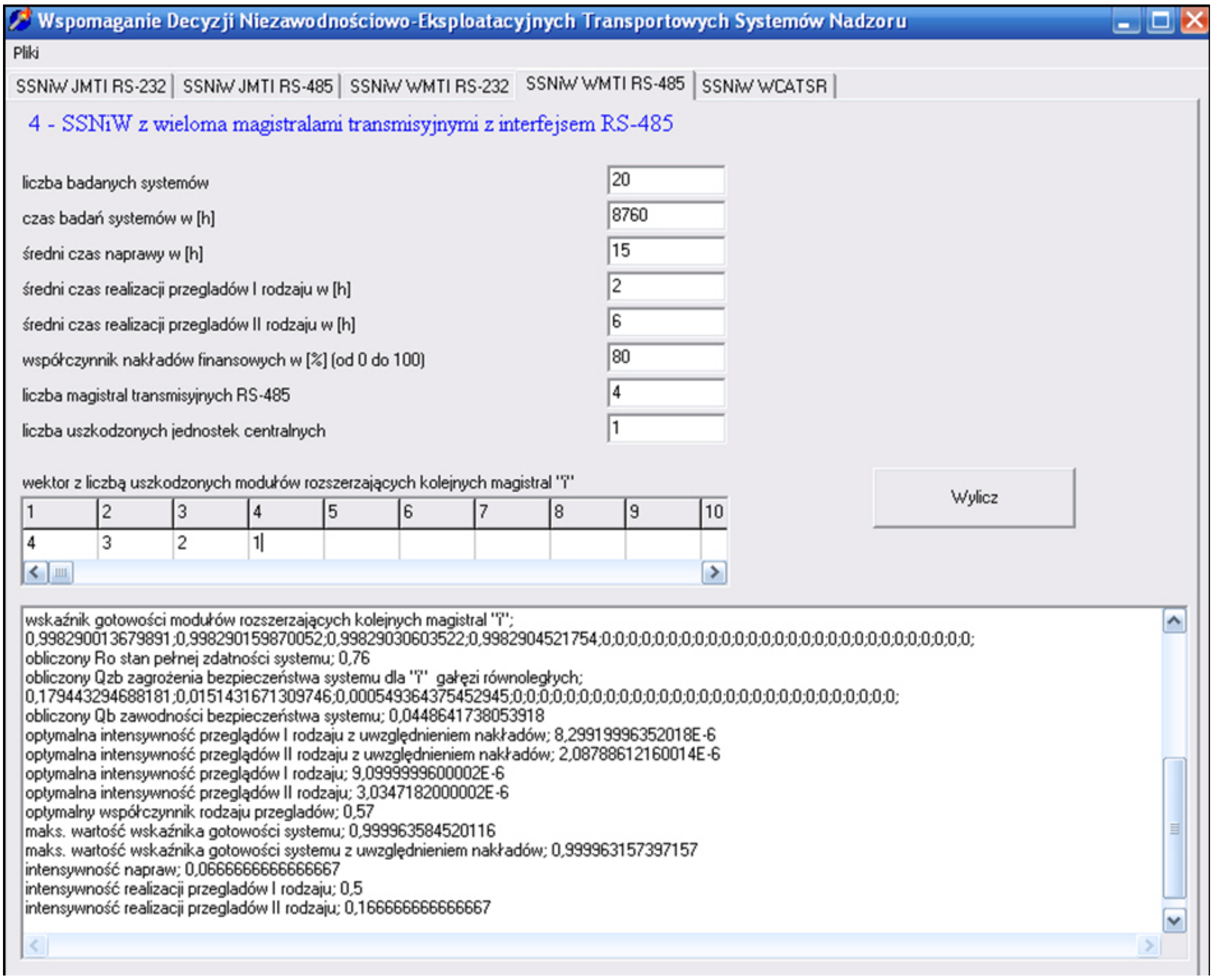

Fig. 5. Screenshot of "Support of Maintenance Decisions in Transport Surveillance Systems"

- the likelihood function of system in state of failing security Q_B;

– repair rate;
– I type inspection rate;
– II type inspection rate;
– max. availability rate of the system;
– optimum I and II type inspection rates for max. availability rate of the system;
– optimum coefficient of inspection types;
– availability rate of the system including financial outlays;
– optimum I and II type inspection rates for availability rate of the system including financial outlays.

Screenshot in figure 5 gives a glance at the programme.

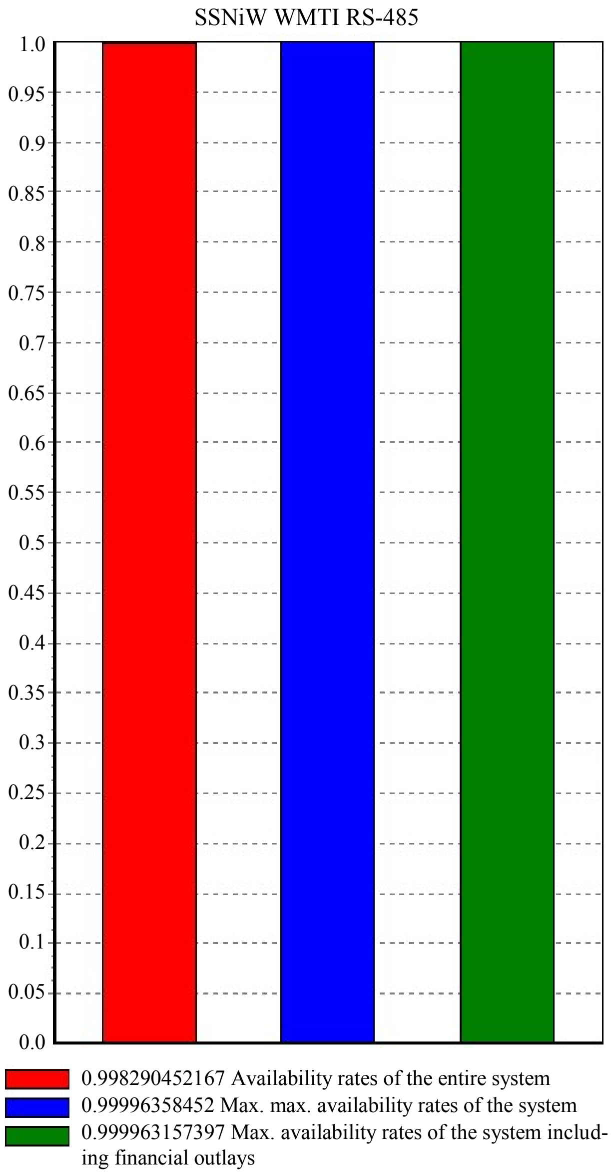

Fig. 6. Graphical representation of availability rates

Another function of the SMDTSS programme is visualisation of obtained results:

– comparison of all systems (Fig. 6):
  - availability rates of the entire system;
  - max. availability rates of the system;
  - availability rates of the system including financial outlays;
– comparison of likelihood function of system in following states, Fig. 7 (for systems of mixed and parallel structure):
  - full operational capability R_O;
  - security threat Q_{ZBi};
  - failing security Q_B.

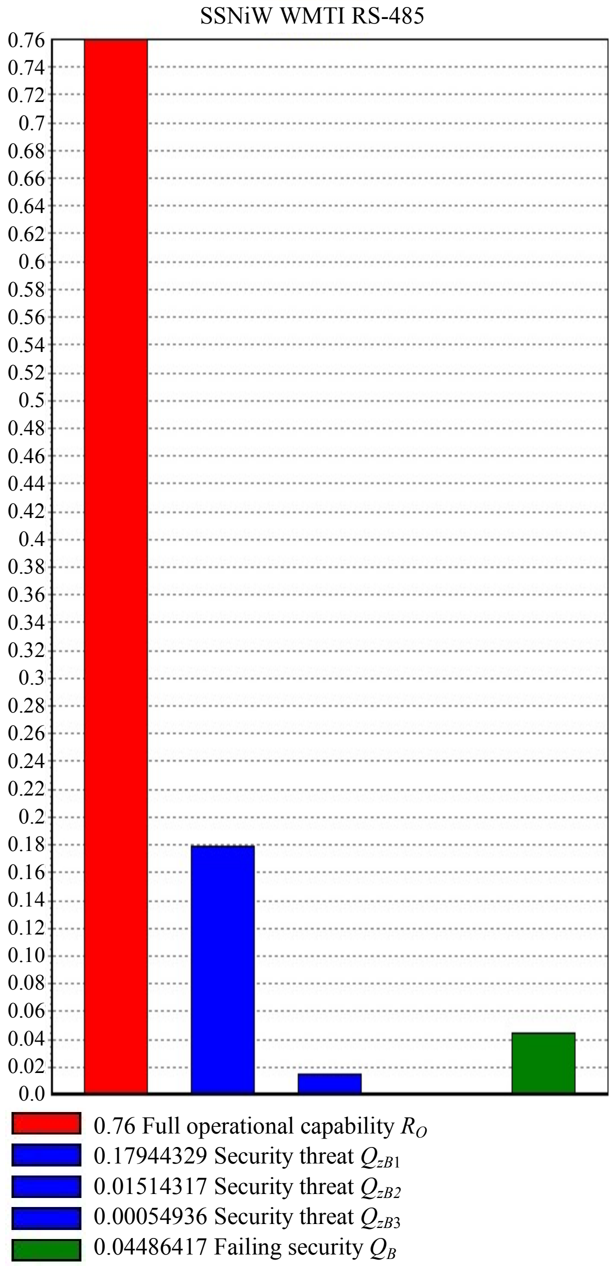

Fig. 7. Graphical representation of likelihood functions of the system in R_O, Q_{ZBi}, Q_B states

Conclusions

A method of optimising maintenance of electronic systems (for two types of routine inspections) was presented in this paper, which factors in selected reliability parameters (failure rate), operating parameters (repair rate, routine maintenance rate) and economic parameters (financial outlays on routine inspections). It enables to determine optimum routine inspection rates, provided the optimisation criterion is taken as maximisation of the availability rate.

In the author's computer application is used, among the others, the equation (3) which allows to determine analytically the values of intensity of periodic inspections for which the value of the avliability rate is maximal.

Presented computer application is being used as a learning aid by students at Faculty of Transport of Warsaw University of Technology (specialisation of Transport Telematics) and students at Faculty of Military Electronics of Warsaw Academy of Technology (specialisation of Security System Engineering). Hence they were able to acquaint themselves with reliability analysis and functional properties of different systems.

References

1. Będkowski L., Dąbrowski T.: The Basis of Exploitation. Part II: The Basis of Exploational Reliability. Military University of Technology, Warsaw 2006.
2. Dyduch J., Moczarki J.: Basics of maintaining the train traffic control system. Technical University of Radom, Radom 2009.
3. Dyduch J., Paś J., Rosiński A.: The basic of the exploitation of transport electronic systems. Technical University of Radom, Radom 2011.
4. Dyduch J., Rosiński A.: Selected aspect operation and reliabilty of security systems. Scientific Papers of Radom University of Technology 1(15) 2002, Radom 2002.
5. Jaźwiński J., Ważyńska-Fiok K.: Reliability of technical systems. PWN, Warsaw 1993.
6. Siergiejczyk M.: Maintenance Effectiveness of Transport Telematics Systems. Scientific Papers of Warsaw University of Technology, Transport series, No. 67, Warsaw 2009.
7. Smalko Z.: The basis of the technical exploitation of vehicles. OWPW, Warszawa 1998.
8. Wawrzyński W.: Safety of control systems used in transport. The Institute of Technology Exploitation, Radom 2004.
9. Ważyńska-Fiok K.: Fundamentals of the reliability theory in transport systems. WPW, Warsaw 1993.
10. Woropay M.: The basis of the rational exploitation of machine. ATR, Bydgoszcz 1996.
11. Żółtowski B., Niziński S.: Modelling processes of the exploitation of machin. ATR, Bydgoszcz 2002.
12. Rosiński A.: Reliability Analysis of Transportation Structures of Supervisory Systems. Scientific Papers of Radom University of Technology 3(23) 2005, Radom 2005.
13. Rosiński A.: Design of the electronic protection systems with utilization of the method of analysis of reliability structures. 19th International Conference on Systems Engineering (ICSEng 2008), Las Vegas, USA 2008.
14. Rosiński A.: Design of the transport supervision systems with utilization of the method of determination of reliability structures. TRANSCOM 2007, Žilina, Słowacja.
15. Rosiński A.: Reliability analysis of the electronic protection systems with mixed m–branches reliability structure. International Conference European Safety and Reliability (ESREL 2011), Troyes, France 2011. The paper publishes as: Rosiński A.: „Reliability analysis of the electronic protection systems with mixed m–branches reliability structure". „Advances in Safety, Reliability and Risk Management". Editors: Berenguer, Grall & Guedes Soares. Taylor & Francis Group, London, UK 2012.
16. Rosiński A.: Reliability analysis of the electronic protection systems with mixed – three branches reliability structure. International Conference European Safety and Reliability (ESREL 2009), Prague, Czech Republic 2009. The paper publishes as: Rosiński A.: „Reliability analysis of the electronic protection systems with mixed – three branches reliability structure". „Reliability, Risk and Safety. Theory and Applications. Volume 3". Editors: R. Bris, C. Guedes Soares & S. Martorell. CRC Press/Balkema, London, UK 2010.
17. Rosiński A., Dąbrowski T.: Modeling reliability of buffer power supplies. XL The Winter School Reliability, Szczyrk 2012.
18. Siergiejczyk M., Rosiński A.: Reliability analysis of power supply systems for devices used in transport telematic systems. The monograph „Modern Transport Telematics", editors: Jerzy Mikulski, given as the monographic publishing series – „Communications in Computer and Information Science", Vol. 239. The publisher: Springer-Verlag, Berlin Heidelberg 2011.
19. Siergiejczyk M., Rosiński A.: Reliability analysis of electronic protection systems using optical links. The monograph „Dependable Computer Systems", editors: Wojciech Zamojski, Janusz Kacprzyk, Jacek Mazurkiewicz, Jarosław Sugier i Tomasz Walkowiak, given as the monographic publishing series – „Advances in intelligent and soft computing", Vol. 97. The publisher: Springer-Verlag, Berlin Heidelberg 2011.
20. Rosiński A.: Diagnostics of the electronic security systems. VII National Conference: „Technical Diagnostics of Devices and Systems – DIAG'2009", Ustroń 2009.
21. Rosiński A.: Exploational strategies in transport supervision systems. 10th International Conference „Computer Systems Aided Science, Industry and Transport" TRANSCOMP 2006, Zakopane 2006.
22. Rosiński A.: Exploitation strategies of monitoring transport systems. Diagnostics nr 2(38)/2006.
23. Rosiński A.: Maintenance strategies for transport surveillance systems. Scientific Papers of Warsaw University of Technology, Transport series, No. 62, Warsaw 2007.
24. Siergiejczyk M., Rosiński A.: Optimisation of transport telematics electronic systems operational process. Polish Journal of Environmental Studies. Stud. Vol. 20, 5A, 2011.
25. Rosiński A.: Exploitation strategies of monitoring transport systems with the regard of economic conditions. 4th International Congress on Technical Diagnostics, DIAGNOSTICS 2008, Olsztyn 2008.
26. Rosiński A.: Exploitation strategies of monitoring transport systems with the regard of the efficiency of financial expenditures. Diagnostics nr 1(45)/2008.
27. Rosiński A.: Maintenance strategies selection for transport surveillance systems. PhD dissertation. Warsaw University of Technology, Faculty of Transport, Warsaw 2007.