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COMPUTER AIDED MAINTENANCE MANAGEMENT FOR TRANSPORT TELEMATICS SYSTEMS

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Abstract

Issues concerning maintenance of transport telematics systems were presented in this paper. They normally operate under various conditions. They need to be reliable as they are required for transport processes to be uninterrupted. Make sure key reliability and maintenance parameters are sustained is on of chief issues. Up to this point, the authors carried out reliability and maintenance analyses of transport telematics systems. They were also successful in developing a computer application supporting strategy for maximising the availability factor.

Introduction

The term telematics comes from French *télématique*. The term „Telematics" first appeared in literature at the beginning of 70's last century. It was coined using two French words: telecommunications (Fr. *Télécommunications*) and information technology (Fr. *informatique*). At the end of seventies of the twentieth century it started to be used in English, but it did not make it into the mainstream. Only when EU programmes aimed at developing telematics and deploying it in different areas, the term became more recognisable and popular. This dates back to the 90's. Today the term telematics used to describe sciences integrating telecommunications and IT solutions. That combination is used everywhere where considerable benefits could be reaped from using it, compared to isolated solutions (e.g. through achieving synergy). It is used in the following areas:

- transport telematics,
- medical telematics,

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- environment protection telematics,
- urban telematics,
- financial telematics,
- library telematics,
- operational telematics,
- industrial telematics,
- domestic telematics,
- post telematics.

From among different areas of application, one of the biggest and most developing (in Poland, Europe and worldwide) is transport. Transport telematics marked its presence in Polish publications as late as in mid-nineties.

Transport telematics is defined as a field of knowledge and technical activity integrating IT with telecommunications, intended to address transport systems' needs. There several areas where it found its application:

- road telematics (highway and urban telematics),
- rail telematics,
- air telematics,
- maritime telematics.

Decision-making processes are used in many theories and academic disciplines, including the system maintenance theory. The term decision is usually described through definition of the decision making process (decision-making process). In the context of maintenance, the decision making process involves choosing a goal-driven action, which is intended to facilitate achieving that goal. This process is based on a closed set of maintenance events.

In the maintenance subsystem, high in the hierarchy are decision problems concerning refurbishment of a technical objects part of the transmission of telematics-based information system. Lower in the hierarchy, are decision problems concerning the scopes and schedules of replacement, repair and ongoing servicing of technical objects, scheduling inspections and preventative replacement of elements as well as how and in what quantities the maintenance subsystem is supplied with spare parts.

Further analysis and any possible standardisation of the maintenance decision-making system would be only feasible for specific decision-making systems.

It should be emphasised that objectives of the maintenance decision-making system are aligned with objectives of the superior system i.e. objectives of the transport system. A logical consequence of the above is alignment of maintenance subsystem's objectives with operation subsystem's (transport route) objectives.

There are two fundamental problem classes in the maintenance decision-making process for transport telematics systems (SIERGIEJCZYK 2011):

- operational decision-making problem class,
- maintenance decision-making problem class,

Therefore there are two fundamental maintenance decision-making subsystems – operational subsystem and maintenance subsystem. Each of those two subsystems encompasses characteristic types of decision-making problems varying by timeframes i.e. constituting a decision hierarchy. The above mentioned factors and issues give the rationale to standardise the subsystems in question.

Transport telematic systems operate under various conditions (DYDUCH et al. 2011, SIERGIEJCZYK 2009). They need to be reliable as they are required for transport processes to be uninterrupted. One of the most important issues is assuring adequate reliability and maintenance parameters (SIERGIEJCZYK, ROSIŃSKI 2014a, SIERGIEJCZYK, ROSIŃSKI 2014b). Therefore it is critical to carry out a reliability and maintenance analysis of transport telematics systems. It will make possible to design a strategy for maximising the availability factor. Also, it seems warranted to develop an original computer application whereby its user could quickly and accurately deploy the strategy without having to be knowledgeable about the issues of reliability and maintenance.

Maintenance strategy maximising availability factor

One could influence reliability parameters when designing transport telematics systems by e.g. designing the system so that its reliability structure reflects desired values of parameters (ROSIŃSKI 2008, ROSIŃSKI 2010, ROSIŃSKI 2012). That is the way that the failure rate of designed system could be improved (SIERGIEJCZYK, ROSIŃSKI 2011b). The strategy for maximising availability factor draws on availability factor definition presented among other in papers (WOROPAY 1996, ŻÓŁTOWSKI, NIZIŃSKI 2002).

The formula for the availability factor may look as follows:

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

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

The given relationship shows that the system can be in one of two state (Fig. 1) (JAŹWIŃSKI, WAŻYŃSKA-FIOK 1993, WAŻYŃSKA-FIOK 1993):

- usage state S_0,
- repair state S_1,

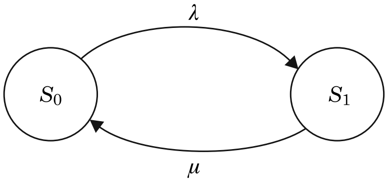


Fig. 1. Graph showing switching between usage and repair states. Denotations in figures: λ – failure rate, μ – repair rate

Figure 1 presents a graph showing switching between states which do not include all possible and actual states occurring during transport telematics operation. Hence the following two states were add (Fig. 2) (ROSIŃSKI 2006, ROSIŃSKI 2007, SIERGIEJCZYK, ROSIŃSKI 2011a):

– usage state (S_0),

– repair state (S_1),

– state of I type inspection (S_{01}) (during which performs the necessary tasks within the scope of the inspection of the first type),

– state of II type inspection (S_{10}) (during which performs the necessary tasks within the scope of the inspection of the second type).

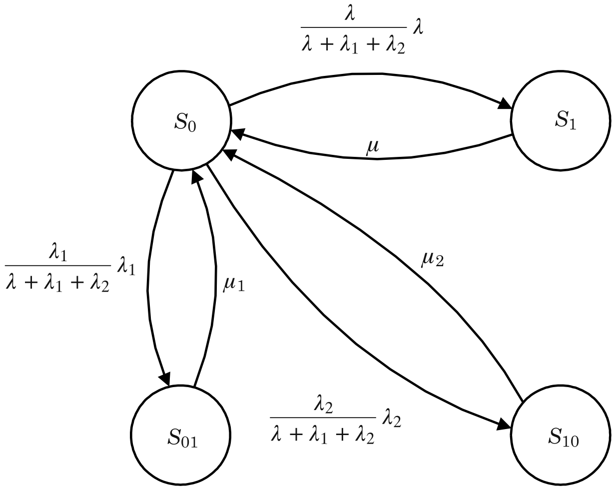


Fig. 2. Graph showing switching between usage state, repair state and I and II type inspection state (the adjustment coefficient factored in). Denotations in figures: λ – failure rate, μ – repair rate, $\lambda 1$ – I type inspection rate, μ_1 – I type routine maintenance rate (BĘDKOWSKI, DĄBROWSKI 2006), λ_2 – II type inspection rate, μ_2 – II type routine maintenance rate

For the graph shown in Figure 2 the following equations hold:

$$-\lambda \cdot \frac{\lambda}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 + \mu \cdot P_1 - \lambda_1 \cdot \frac{\lambda_1}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 + \mu_1 \cdot P_{01} - \lambda_2 \cdot$$

$$\cdot \frac{\lambda_2}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 + \mu_2 \cdot P_{10} = 0$$

$$\lambda \cdot \frac{\lambda}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 \, \mu \cdot P_1 = 0 \tag{2}$$

$$\lambda_1 \cdot \frac{\lambda_1}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 \, \mu_1 \cdot P_{01} = 0$$

$$\lambda_2 \cdot \frac{\lambda_2}{\lambda + \lambda_1 + \lambda_2} \cdot P_0 \, \mu_2 \cdot P_{10} = 0$$

By rearranging we get:

$$P_1 = \frac{\lambda}{\lambda + \lambda_1 + \lambda_2} \cdot \frac{\lambda}{\mu} \cdot P_0$$

$$P_{01} = \frac{\lambda_1}{\lambda + \lambda_1 + \lambda_2} \cdot \frac{\lambda_1}{\mu_1} \cdot P_0 \tag{3}$$

$$P_{10} = \frac{\lambda_2}{\lambda + \lambda_1 + \lambda_2} \cdot \frac{\lambda_2}{\mu_2} \cdot P_0$$

Note:

$$P_0 + P_1 + P_{01} + P_{10} = 1 \tag{4}$$

Thus:

$$K_g = P_0 = \frac{(\lambda + \lambda_1 + \lambda_2) \cdot \mu + \mu_1 + \mu_2}{(\lambda + \lambda_1 + \lambda_2) \cdot \mu \cdot \mu_1 \cdot \mu_2 + \lambda^2 \cdot \mu_1 + \mu_2 + \lambda_1^2 \cdot \mu \cdot \mu_2 + \lambda_2^2 \cdot \mu \cdot \mu_1} \tag{5}$$

The relationship obtained describes impact of pending I and II type inspection rates on availability factor of given system (given failure rate, repair rate and I and II type routine maintenance rates were known). Should the function have a maximum, it is recommended to determine corresponding coordinates i.e. I type inspection rate and II type inspection rate, since it will increase the availability factor. Those values would have been then optimum values, maximising the availability factor.

A condition necessary for the function $P_0(\lambda_1,\lambda_2)$ to have extremum at $P_0(\lambda_{1\text{optym.}},\lambda_{2\text{optym.}})$, is that first partial derivatives of the function at that point have to equal zero, i.e.:

$$\begin{cases} \dfrac{\mathrm{d}P_0}{\mathrm{d}\lambda_1}(\lambda_{1\text{optym.}},\lambda_{2\text{optym.}}) = 0 \\ \dfrac{\mathrm{d}P_0}{\mathrm{d}\lambda_2}(\lambda_{1\text{optym.}},\lambda_{2\text{optym.}}) = 0 \end{cases} \tag{6}$$

Determining an analytical solution of the system of equations (6) is a complex exercise. Therefore LabView 2011 was deployed to computer aid the process in order to develop a computer application which would support the transport telematics system maintenance (SIERGIEJCZYK, CHMIEL, ROSIŃSKI 2012, SIERGIEJCZYK, ROSIŃSKI 2013).

Computer application supporting availability factor maximising strategy

LabView is programming environment intended for developing software for control and measuring systems. A given process is visualised on computer screen as a virtual measuring apparatus (e.g. oscilloscope, multimeter, set of indicator lights) and/or a control panel (e.g. buttons, potentiometers, controllers). Hence it is often referred to as a *virtual instrument* (VI). Computer application developed in LabView coded in G visual programming language was presented in this paper.

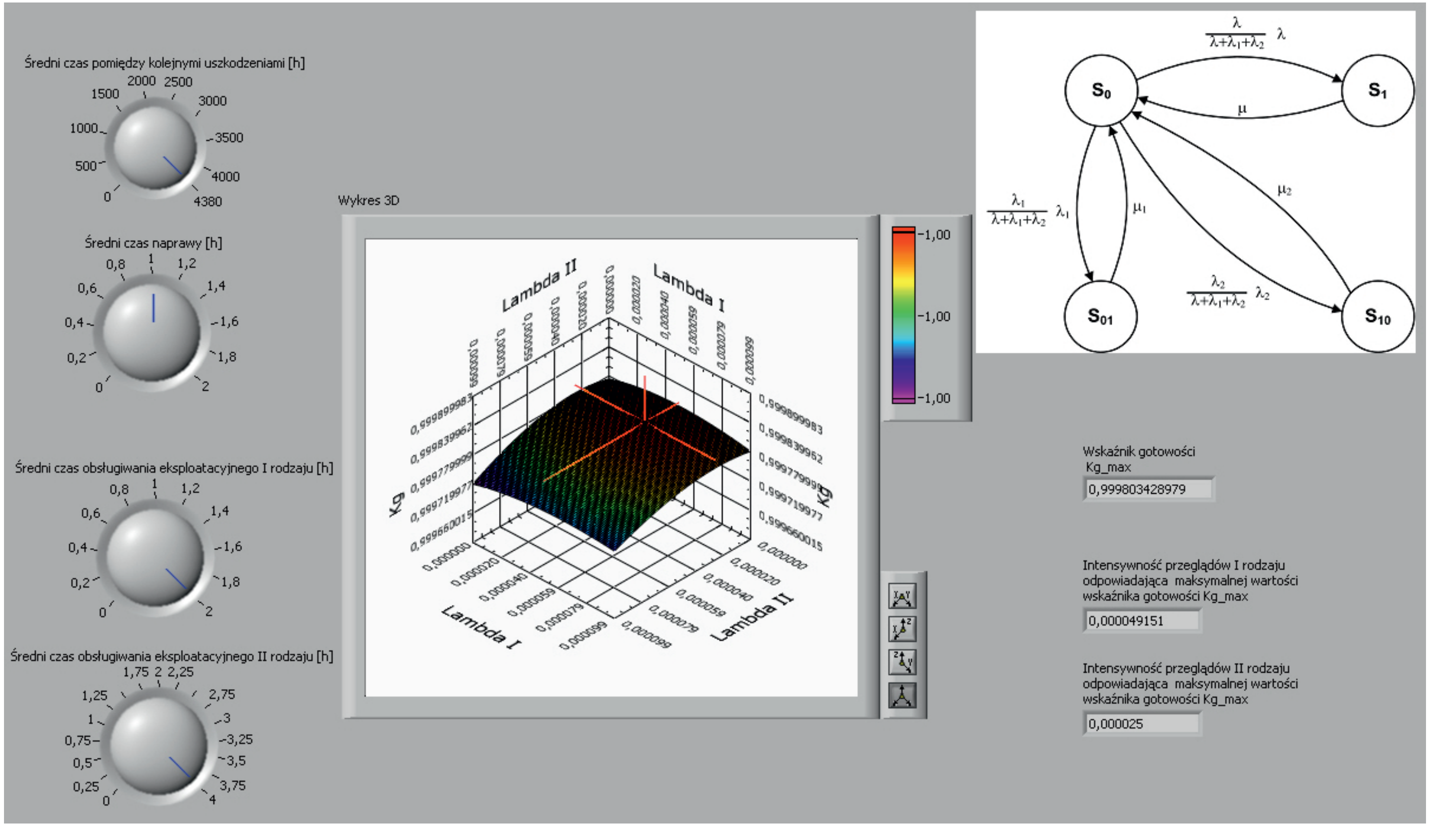
After launching LabView and selecting new project option, two windows come up:

- Front Panel,
- Block Diagram,

They are intertwined and inherently linked with each other.

The front panel provides graphical user interface between the VI application and the user. By using certain elements (e.g. switches, displays) it is possible to recreate the front panel of the actual instrument.

The block diagram window gives a graphical representation of the source code behind the application recreating the virtual instrument. It uses the G visual programming language, which as opposed to textual programming language employs block diagrams. It is therefore possible to design control



Wskaźnik gotowości
Kg_max
0,999803428979

Intensywność przeglądów I rodzaju odpowiadająca maksymalnej wartości wskaźnika gotowości Kg_max
0,000049151

Intensywność przeglądów II rodzaju odpowiadająca maksymalnej wartości wskaźnika gotowości Kg_max
0,000025

Fig. 3. Home screen of computer application

algorithms fast. All elements found on the front panel are represented in this window (inputs and outputs of the VI). Relationships between those elements need to correspond to default tasks performed by the virtual instrument. In order to do so, different functions and structures are used which make it possible to recreate relationships between inputs and outputs.

Figure 3 illustrates front panel of computer application supporting the strategy maximising availability factor. By providing the following input data:

- mean time between failures,
- mean time to repair,
- I type maintenance meantime,
- II type maintenance meantime,

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

- maximum availability factor $K_{g\text{-max}}$,
- I type inspection rate corresponding to maximum value of availability factor $K_{g\text{-max}}$,
- II type inspection rate corresponding to maximum value of availability factor $K_{g\text{-max}}$,

The relationship between availability factor as a function of I type inspection rate and II type inspection rate was also illustrated graphically (3D diagram in Figure 4).

In previous versions of the computer application, optimum values of I and II type inspection rates corresponding to maximum values of the availability factor were given numerically. This caused on some occasions misinterpretation of results by users of this method. Hence the application was updated with visualisation of results – as depicted in Figure 4.

A point representing the maximum value of availability factor $K_g = 0{,}999803428979$ was shown in Figure 4 for I and II type inspection rates: Lambda I = 0,000049151, Lambda II = 0,000025. The following values were substituted as input data:

- mean time between failures = 4380 [h],
- mean time to repair = 1 [h],
- I type maintenance mean time = 2 [h],
- II type maintenance mean time = 4 [h],

Functionality was added to produce three-dimensional representation of results in order to provide an accurate image of the relationship between the availability factor K_g as a function of I and II type inspection rate. This surface represents the relationship $K_g = f(\lambda_1, \lambda_2)$.

Based on visualisations shown in Figure 5, it becomes possible to determine the influence of:

- I type inspection rate on value of availability factor,
- II type inspection rate on value of availability factor,

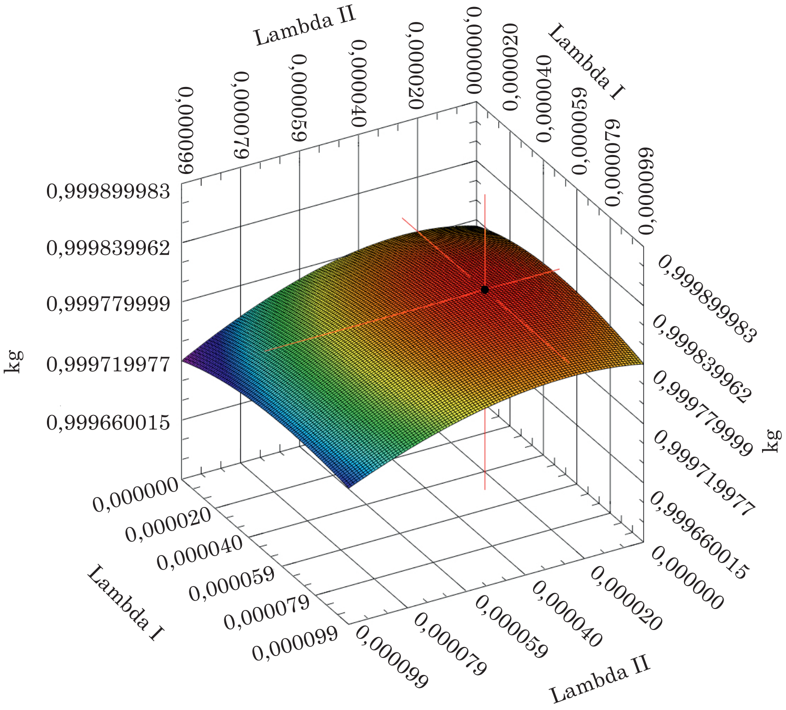


Fig. 4. Relationship between availability factor as function of I type inspection rate and II type inspection rate

– I type inspection rate and II type inspection rate on value of availability factor.

Correctly designed decision support systems effectively help to mitigate the risk of making wrong decisions. The user is provided with reliable information in an easily digestible form. The following postulates could be put forward on the back of experiences in designing maintenance decision support systems for transport telematics equipment:

– developing a support system that allows to improve maintenance process of transport telematics equipment and its management,

– building a knowledge base about transport telematics reliability, including analytical reliability algorithms and heuristic algorithms for analysing, assess and plan the maintenance process,

– building a database of reliability characteristics of transport telematics equipment,

– building a database of individual subsystems facilitating data exchange between databases,

– developing an expert system for generating proposals on how to maintain transport telematics systems.

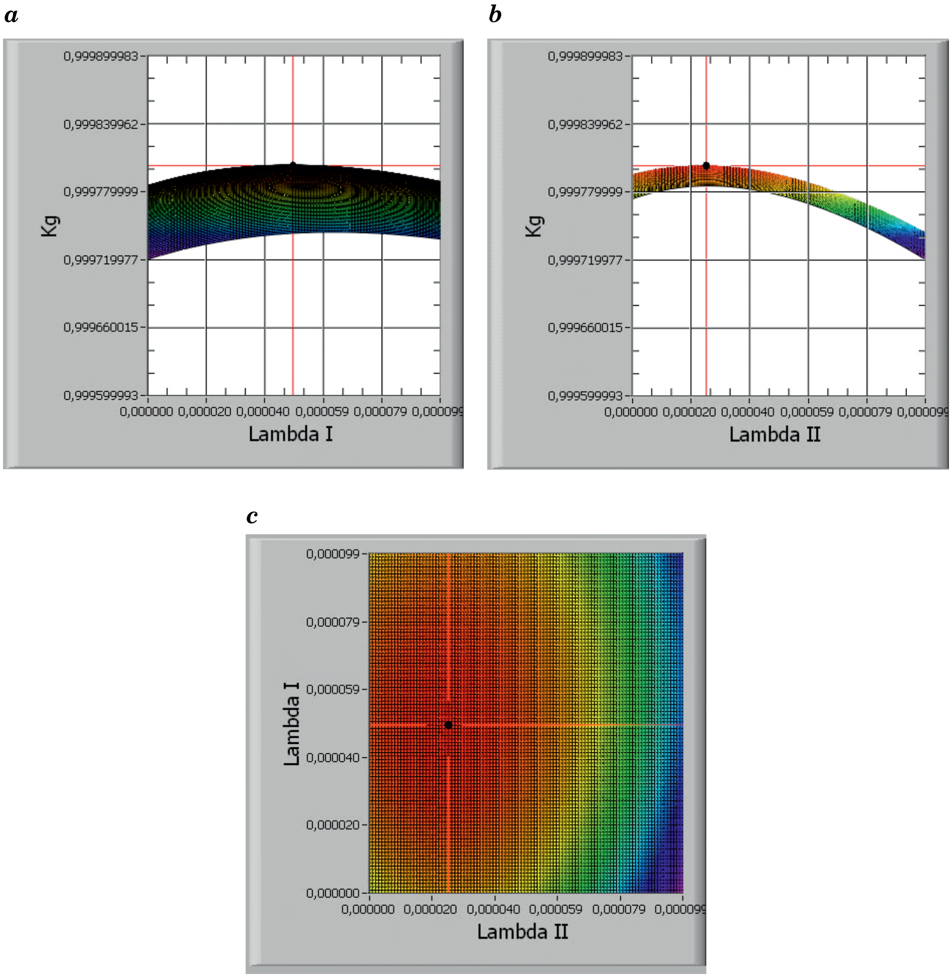


Fig. 5. Relationship between availability factor K_g as function of I type inspection rate and II type inspection coefficient – views: *a* – from I type inspection rate axis, *b* – from II type inspection rate axis, *c* – top view

Conclusions

Availability factor maximisation strategy was presented in this paper which factors in reliability parameters (failure rate) and maintenance parameters (repair rate, routine maintenance rate). It enables to determine optimum routine inspection rates both when it is and is not feasible to assure optimum values. Optimisation criterion maximises the values of availability factor.

An original computer application supporting the transport telematics system maintenance process was also presented in this paper. It represents a computer exemplification of maintenance decision support for transport telematics systems. It makes it possible for decision makers to deploy the developed method without having to be particularly knowledgeable about reliability and maintenance of transport telematics systems. Further research envisages expanding the application with information collection functionality to gather data on system status then used to estimate values of reliability and maintenance parameters.

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