Janusz Dyduch
Prof. dr hab. inż.
Kierownik Zakładu Systemów
Sterowania w Transporcie
Uniwersytet Technologiczno-Humanistyczny w Radomiu

Mieczysław Kornaszewski
Dr hab. inż., prof. nadzw.
Zakład Systemów Sterowania
w Transporcie
Uniwersytet Technologiczno-Humanistyczny w Radomiu

DOI: 10.35117/A_ENG_19_05_04

Selection of exploitation data from railway traffic control devices for the purposes of gathering and analyzing data processes from railway transport objects

Abstract: The evaluation of the technical systems reliability and safety requires collecting and processing of reliable data which characterizes the processes. The data from current exploitation is particularly important for decision-making processes. It can be used for creation of occurring exploitation phenomena models and allows to determine the expected object behaviour in the future. The railway traffic control devices often work in very difficult exploitation and environmental conditions. The information about their technical condition can be gathered and used for a proper prophylaxis as well as a predictive maintenance of railway traffic. It will allow to choose a maintenance strategy which will consist in optimal use of railway traffic control devices.

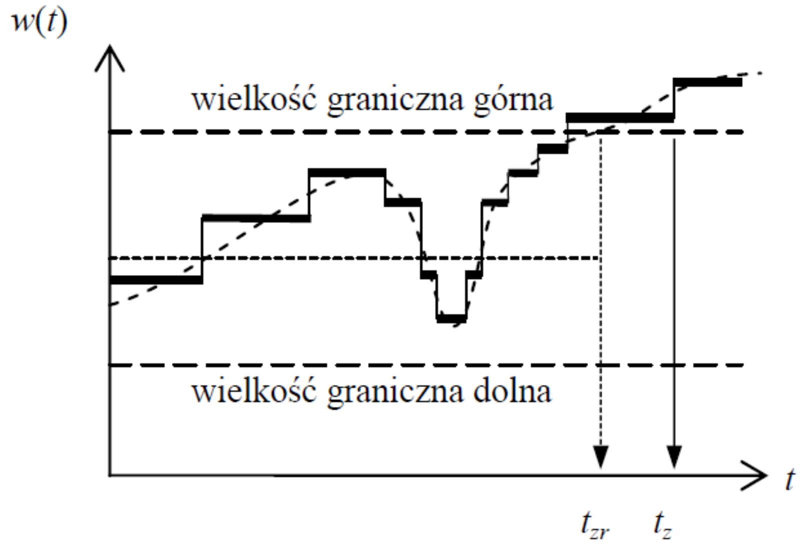
Keywords: Railway traffic control devices; Exploitation data; data selection; Information gathering and analysing

Introduction

Rail traffic control devices usually work in varied, often extreme operating conditions. Many years of experience in the operation of these systems confirm the dependence of their operation on the correct operation of individual components and effective management of their operation. The selection of exploitation data of railway traffic control objects is a particularly important point of analysis of operational data from these facilities.

Operational data of technical facilities are usually collected in order to determine their origin, their location in the exploitation system and their relations with other objects. It is also good to know the limit values of the functional properties of these objects.

Interesting in the aspect of operational management is the phenomena of exceeding the limit, admissible levels of variation. Fig. **1** shows a fragment of a continuous course of attribute variability and a possible transformation into a step function. The figure illustrates the moment of the actual exceeding of the upper limit level t_{zr} and the approximation of the moment of observation of this event t_z [8].



1. Actual t_{zr} and model t_z when the event occurred, where *w (t)* - the value of the attribute at the moment *t* [8]

Gathering and analysis of operational data from railway traffic control devices belong to the basic organizational projects in the process of controlling train traffic, allowing for [2]:

- comparing the quality of operation of the same srk devices by various service providers;
- determining the period of adaptation, normal use as well as wear and aging;
- selection of a mathematical model of time schedules for correct operation between failures, repair time and preventive maintenance time for each of the designated periods;
- estimation of the damage intensity of individual railway traffic control objects and on this basis the detection of more damaging objects;
- analysis of the causes of more damaging srk objects;
- extraction of exploitation applications aimed at preventing some damage;
- development of proposals for the improvement of the construction of individual components, systems, subassemblies and railway traffic control devices;
- determination of reasonable sets of spare parts and supply plans;
- designating periods of preventive inspections and repairs;
- exchange of experience between technical services regarding the methodology of prevention, detection and removal of defects.

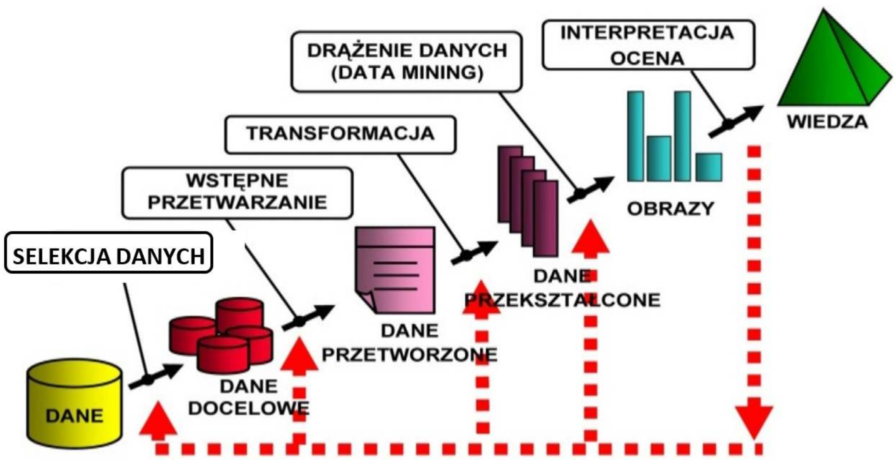
Organization of gathering and analysis of operational data from railway traffic control devices

Data characterizing the processes of wear and aging of objects as well as information about defects and damages are collected as a result of observation of the operation process carried out in a passive or active manner. Passive observation of exploitation consists in collecting data existing and recorded in routine documentation, whereas the active one allows for collecting data determined in terms of meeting the research objective, which requires the use of special procedures and data carriers. Unfortunately, using each of these methods, it is possible to obtain an incorrect or incomplete set of information resulting from, for example, a human error or a recording system.

Properly organized gathering and analysis of operating data from railway traffic control devices do not interfere with the operation and working conditions of the entire system, it allows the study of large and complex systems, including the influence of the environment. A well-functioning system for collecting operating data from srk devices enables [11]:

1. Determination of general numerical reliability measures, such as total working time, total repair time, total number of failures in a given range of operation time.
2. Determination of functional reliability measures, such as: reliability function, failure intensity function, failure stream parameter, leading function of the distribution, etc.
3. Determining the parametric reliability of the srk object, e.g. the probability of compliance of the measurable and non-measurable features of the object with the requirements, in the given time of operation.
4. Determination of damage models based on physico-chemical analysis of processes occurring in the facility (wear, corrosion, fatigue).
5. Diagnosing the current reliability status of the srk facility, e.g. determining the trend of changes in reliability indicators, determining weak links, etc. For the diagnosis of the current reliability of a railway traffic control facility, information gathered from various operational periods is required for the effects of damage due to safety, performance tasks, expenses incurred for repairs, etc.
6. Forecasting reliability states of srk objects based on mathematical models of predicted damage processes.
7. Effective execution of exploitation sets, e.g. detection of damages in various services (technical condition control, prevention), sufficiency of spare parts, usage of service tools, etc.

After having worked through a given railway traffic control facility for a specified number of hours or a period of one calendar period, you can proceed to the statistical preparation of data from the operation of individual srk facilities. These data usually include a part of the operated srk devices (the so-called sample), because the current statistical analysis of the entire set of serial devices is very difficult and requires a lot of effort [13].



2. The process of discovering knowledge [13]

Statistical development of operation data of railway traffic control objects can be divided into the following stages (Figure **2**) [13]:

1. Initial analysis of the operational data obtained.
2. Collective list of damage and repair data.
3. Determination of operating periods of the tested srk devices.
4. Development of distribution series.
5. Verification of the hypothesis about the shape of the T time distribution between failures, T_n repair time and preventive maintenance time T_p.
6. Estimation of the parameters of the surveyed sets, mainly of medium ones: work time between failures $\overline{T}$, repair time $\overline{T_n}$ and preventive check-up time $\overline{T_p}$.

Preselection of operating data from railway traffic control objects

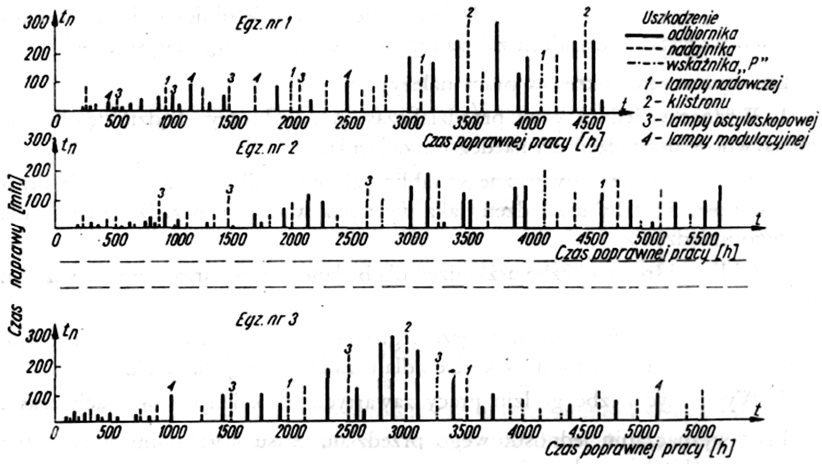
Initial analysis of the obtained data from railway traffic control facilities is aimed at conducting the so-called preselection of operating data, i.e. the selection of these data by eliminating unreliable data from the statistical work, checking their formal correctness and segregating the data from individual facilities according to the respective periods of their work.

An extremely important problem is adherence to the reliability and accuracy of the collected operational data. Often, data from SRK devices due to the negligence of service or deficiencies in the operating documentation do not reflect the actual number of damages and the time of their repair. Sometimes such data are written from memory and often only concern the most important damage. In addition, there are railway traffic control devices that work in very different operating conditions, e.g. they are installed and operate in conditions of increased humidity, or occurrence of mechanical vibrations (e.g. track-side devices), etc. This could have caused unusual damage, related to excessive influence of climatic, mechanical factors, etc.

Media and transmission media for operational data can be varied:

- traditional source documents, which are "damage cards", are filled in by employees. These documents are delivered to the logic module of the processing of the exploitation system;
- electronic data that is collected "online" by sensor systems installed in specific locations and sent directly to the operational data collection system or entered from the keyboard by employees supervising specific devices;
- mixed system, the most common solution.

Gathering information on the operation process of railway traffic control facilities and submitting them to the unit coordinating operational tests takes place on the basis of special source documents, so-called cards. Cards containing information on the use and renewal of railway traffic control facilities should be completed periodically, eg in 24-hour cycles, based on current information from operational services [1].The factor facilitating preliminary analysis and preselection of operating data is to present them in graphic form, as in Fig. **3**.



3. Example of a graphical summary of damage and repair data of selected railway traffic control objects [10]

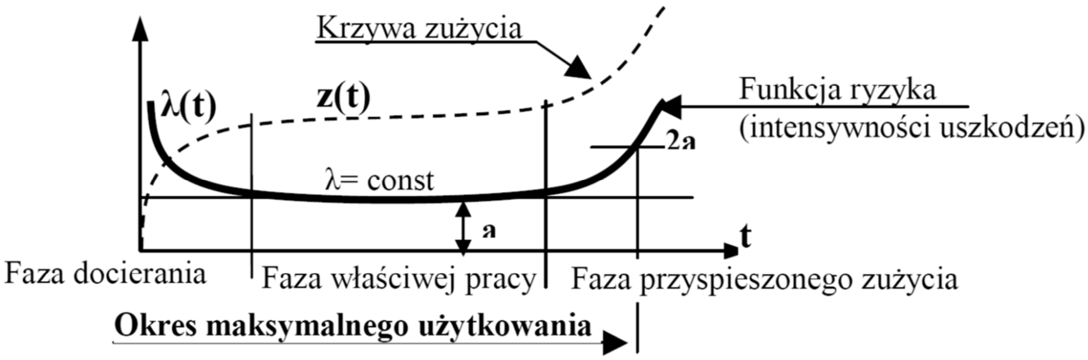
Fig. **3** shows, after what time the device was working, damage occurred, how long the repair lasted and what was damaged. The type of damaged element or srk device can be appropriately marked with the appropriate legend in the figure. The data on damages and repairs of srk objects presented in this way make it easier to preselect operational data and significantly simplify further calculations, both the reliability indices of entire devices, as well as estimating the intensity of damage to individual components or subassemblies.

When making the initial selection, data from such copies of the same type of srk device is rejected, which suggests that the service filled out the forms inexpensively. For example, data from srk objects are rejected, in which the number of damages differs by at least an order of magnitude compared to the average number of damages in other copies, data about damages unevenly accumulated over time in individual operational periods (e.g. a long period of no damage, and then immediately a large number of damages), etc. Railway traffic control equipment operating in significantly different operating conditions will show an excessive number of damage of the same type, e.g. mechanical, due to excessive shocks, an excessive number of breakthrough voltage, etc., due to increased humidity, e.g. after installation near a water body [9].

Determining the periods of operation of railway traffic control devices is aimed at identifying typical periods of operation of the device (the so-called bathtub curve in Figure **4**), i.e.:

- the period of adaptation (lapping),
- normal operation (proper work),
- aging period (accelerated wear).

The curve $\lambda(t)$ in Fig. **4**, it may have a different course depending on the nature of the dominant damage. The size λ, in this case, means the intensity of damage to the railway traffic control objects. Most often, however, it is assumed that the curve has a form similar to a bathtub and is therefore called a bath curve. The decreasing damage intensity function means that adaptation processes are created in the object, the intensity constant of failures means the stabilization of physical processes (disappearance of adaptation), the growing function λ (t) indicates that the object is aging (wear, degradation).



4. A typical course of the damage intensity function λ(t) [4]

Damage intensity is characterized by the probability of damage to the srk body at the moment *(t+Δt)*, provided that at time t the object was in the state of fitness. Damage intensity means the relative decrease in the reliability of the rail traffic control system per unit of time. In other words, it is a fraction of damaged srk objects related to the number of objects distinguished in the srk system, existing at the beginning of the test interval.

If the data from the operation of a series of tested srk devices has been provided since the devices started to work, then the determination of equipment operation periods is significantly simplified, because the damage data of all devices qualified for statistical analysis will be calculated simultaneously.

To determine the operating periods of rail traffic control devices belong [3]:

1. Determine the unit time interval Δt_i, for which the damage intensity will be calculated for each srk device.
2. Compare statistical data in the table for individual devices in the form of the number of failures that occurred in a given time interval for each srk device.
3. Calculate the average number of failures for the type of device tested in each time interval.
4. Plot as a function of time the courses of mean number of defects per time unit, i.e. the intensity of damage for repairs of railway traffic control equipment.
5. Determine the number of working hours contained in the examined periods of time.

In practice, the work time intervals of the rail traffic control devices are different, but the srk device is more complex, the shorter the times.

The average number of defects in each unit time interval is calculated using the formula:

$$\Delta m_{śr}(\Delta t_i) = \frac{1}{N}\sum_{j=1}^{N}\Delta m_j(\Delta t_i) \tag{1}$$

where:

$\Delta m_{śr}(\Delta t_i)$ - average number of failures in the i-th unit time interval,

N - number of srk type devices classified for statistical analysis,

$\Delta m_j(\Delta t_i)$ - the number of failures in the i-th compartment of the j-th srk device of the same type.

If it turns out that the removed mileages have an irregular, zigzag character, not allowing conclusions to be drawn as to the length of the designated periods, then the unit time interval is increased by 2- and 3 times, and sometimes even by 5 times. The above analysis is qualitative. However, it can be based on strict premises by using mathematical statistics, e.g. by verifying the hypothesis about the validity of assumption $\Lambda_P(t) = \Lambda_P$ = const. during the period of work under consideration

If the tested rail traffic control devices have differing numbers of hours worked, then the above calculations are made after the initial rearrangement of these devices according to the hours worked. After such pre-selection of operation data of railway traffic control devices and preliminary preparation of the collected operational data, it is possible to proceed with their further statistical elaboration [12].

The aim of statistical analysis of the results of operational tests of railway traffic control devices should be inference about the probabilistic properties of the whole set of srk devices represented by a part of this set, called a sample.

In the case of unrecoverable objects of railway traffic control (e.g. a light bulb in a trackside light signaling device), the number of experiments is most often the number of working and damaged srk facilities within a given time. In the case of repairs of railway traffic control devices, this will be the number of damage observed in a given time interval (repairs, preventive inspections, etc.) in the tested group of railway equipment srk.

Statistical inference about the collection of srk devices based on the results of the study representing the sample may depend on [12]:

- verification of a specific statistical hypothesis concerning the functional form of the distribution of a random variable or numerical values of parameters of this distribution;
- estimating (estimating) unknown numerical values of specified probabilistic parameters of the considered set.

Frequently, such a random variable is time, so depending on the need it can be, for example, the time of correct work to damage or between damage T, repair time T_n or the time of preventive inspection T_p.

Operating data with a gross error

Gross errors in operating data may occur, among others during the registration of results, when entering them into databases and have their source, e.g. when moving a comma when saving a result or when exchanging units. The notion of error, occurring in scientific measurement, is closely connected with unattainable uncertainty, which is inseparably connected with the essence of measuring using a given method. Therefore, one should strive to minimize the size of errors and find a way to estimate their size.

To detect a result with a gross error and find an outlier, i.e. a point, object, value, significantly out of the rest in the data set, assuming the normality of the distribution of the sample under investigation, appropriate tests, e.g. Grubbs (T-test) or Q-Dixon test (Q-test) [6].

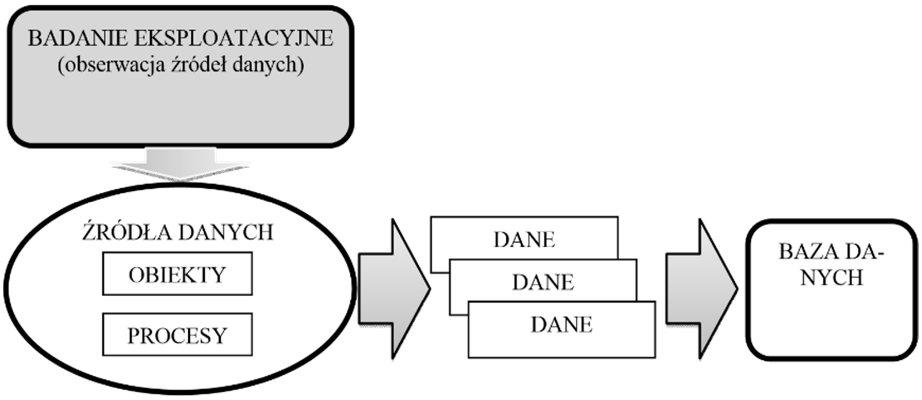
The largest or smallest value of the result in the analyzed sample operational data may be a gross error. The Grubbs test, as in the case of the Q Dixon test, gives the possibility of detecting one outliers (by comparing with the critical parameter). Therefore, it should be repeated until no further values from the other results are observed in the data set.

Results with gross errors should be removed from the sample due to the fact that they may disturb the results of possible statistical analysis.

Data obtained from operational tests

Operational tests are oriented primarily on the determination of appropriate measures (indicators) and assessment of the technical object operated in a particular system of operation, ie according to the assumed operation process. The result of the assessment is direct information in the process of making operational decisions.

Data sources may be a set of objects subject to observation during operational tests. These observations provide data in the form of images of exploitation phenomena performed during operational tests, mapping their attributes through the values of the respective variables. Relationships between exploited objects are represented by numerical relationships between variables and collected in databases (Figure **5**). The appearance of information requiring archiving may take place in an active manner (diagnosis, routine observation of objects and their parameters) or passive (damage, random events). The research system should "notice" such information, pre-analyze its credibility and archive it. The use of collected data usually takes place with a certain delay resulting from the need to save more data [7].



5. The idea of obtaining data from data sources [7]

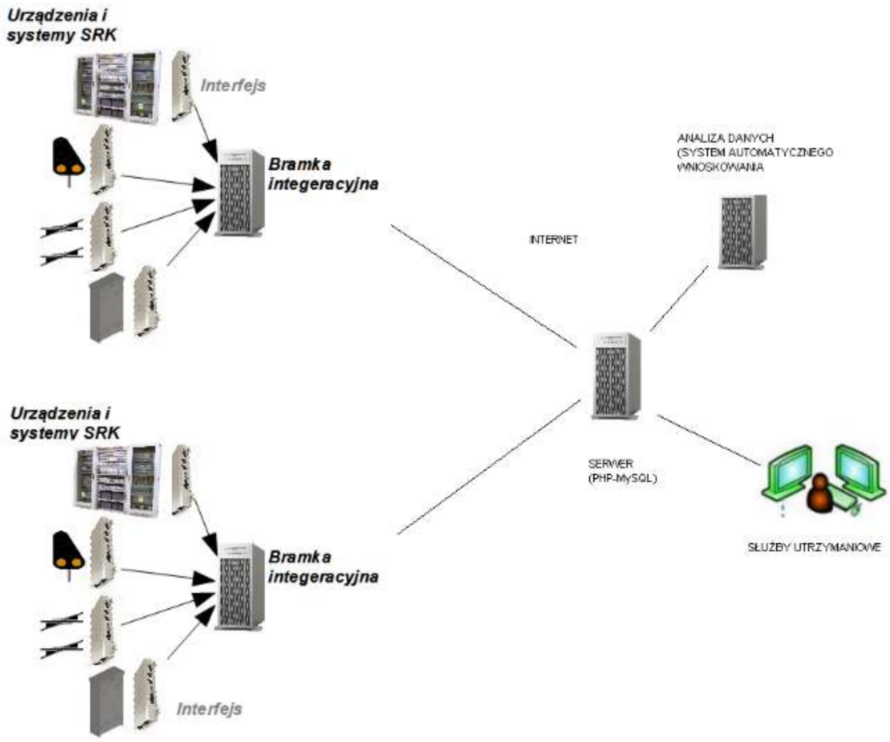
Data on the exploitation of technical facilities are classified depending on the adopted criteria in relation to objects and is distinguished:

- identification data, permanent, referring to objects at a higher level of complexity (enterprise, installation, permanent identification numbers, installation dates, modifications, deletions, special properties and accessories),
- data on current use (regular, generated in the process of use),
- data on random operating disturbances (damage, repairs, preventive maintenance, modernization).

The most important data due to the operational management are data from current operation because on their basis you can build models of operational phenomena and determine the expected behaviour of the system or process in the future.

The structure of a typical system for collecting data from railway traffic control devices and systems

Data collection systems, e.g. from railway traffic control devices and systems, are most often based on dedicated tracking, registration, and analysis software, the purpose of which is to collect and display the status of devices from the railway network on a single software platform for maintenance purposes (Figure **6**).



6. The structure of a typical system for collecting data from devices and srk systems [5]

Information about the status of srk devices can be collected via interfaces directly from these devices or from dedicated diagnostic systems by manufacturers. This information is sent via links to integration gateways that perform the functions of local data buffers. This unit collects data on the status of devices from a particular area of the railway network. After encryption, device status information is sent to the central server. Information gathered in a central database on an ongoing basis is analyzed and can be used by appropriate systems of automatic inference [5].

Conclusions

The assessment of the reliability and safety of technical systems requires the collection and processing of reliable data characterizing the processes taking place. Data obtained from operational observations are often subject to considerable uncertainty resulting from their incompleteness, limitations, and non-compliance with test conditions and adulteration. The uncertainty of operational data is related to the process of their acquisition, archiving and processing. Modeling of exploitation phenomena requires the introduction of model assumptions and limitations regarding the perception of objects and their behaviour in time and space. Models then need to describe the attributes of objects and their states over time.

Unfortunately, such factors as limited observation time, natural variability of processes, obtaining incomplete data (including data trapping), lack of information about the causes of events or subjective decision making contribute to introducing uncertainty to the collected data.

Data obtained from srk facilities, which did not break during the observation period or the time of their damage is not strictly determined, is most often analyzed using the maximum likelihood method. Acquiring and processing of operating data is often associated with the discovery of knowledge, which is aimed at identifying the regularity of existing data in the database.

Selection of exploitation data of railway traffic control objects by eliminating unreliable data (e.g. gross errors), verification of their formal correctness and segregation of operational data from individual railway stations, such as: railway interlock (signaling devices and track indicators, switches and scaffolders) , track vacancy and turnout controls elements, control and monitoring elements, power supply elements, interfaces), line block (track vacancy and rail turnout control elements, track signaling devices, control and control elements, power supply elements, interfaces), crossing signaling (detection elements rail vehicle, drives and toll bars, traffic lights, track signaling devices, control and control elements, power elements, interfaces), track-vehicle devices (elements of point information transfer, control and control elements, power elements, interface), remote control devices (control and control elements, power elements, interfaces) will significantly facilitate and accelerate the process of analysis of operational data and statistical calculations and increase the possibility of predicting their states (e.g. based on simulation).

Source materials

[1] Dyduch J., Kornaszewski M.: *Badania eksploatacyjne miarodajnym źródłem informacji o pracy urządzeń systemów automatyki przejazdowej*. Prace Naukowe TRANSPORT Nr 15, Wydawnictwo Politechniki Radomskiej. Radom 2002.

[2] Dyduch J., Moczarski J.: *Podstawy eksploatacji systemów sterowania ruchem kolejowym.* Wydawnictwo Politechniki Radomskiej, Radom 2008.

[3] Kaźmierczak J.: *Eksploatacja systemów technicznych*. Wydawnictwo Politechniki Śląskiej, Gliwice 2000.

[4] Kornaszewski M.: *Modelowanie odnowy systemów sterowania ruchem kolejowym w procesie eksploatacji*. Wydawnictwo Uniwersytetu Technologiczno-Humanistycznego, Radom 2013.

[5] Kornaszewski M., Pniewski R.: *Komputerowe wspomaganie procesu eksploatacji systemów srk*, Logistyka 06/2014.

[6] Lach S.: *Wykrywanie oraz eliminacja błędów grubych w pomiarach piezometrycznych dla zapory Koronowo w latach 2010-2015*. Badania i rozwój młodych naukowców w Polsce: nauki techniczne i inżynieryjne, Cz. 5, Poznań 2017.

[7] Młyńczak M.: *Analiza danych eksploatacyjnych w badaniach niezawodności obiektów technicznych*. Zeszyty Naukowe WSOWL Nr 1 (159), Wrocław 2011.

[8] Młyńczak M.: *Metodyka badań eksploatacyjnych obiektów mechanicznych*. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2012.

[9] Prażewska M. (red): *Niezawodność urządzeń elektronicznych.* Wydawnictwo Komunikacji i Łączności, Warszawa 1987.
[10] Sztarski M.: *Niezawodność i eksploatacja urządzeń elektronicznych*. Wydawnictwo Komunikacji i Łączności, Warszawa 1972.
[11] Ważyńska-Fiok. K.: *Niezawodność systemów technicznych*. PWN, Warszawa 1990.
[12] Ważyńska-Fiok K.: *Podstawy teorii eksploatacji i niezawodności systemów transportowych*. Wydawnictwo Politechniki Warszawskiej, Warszawa 1993.
[13] Żółtowski B.: *Doskonalenie systemów eksploatacji maszyn*. Problemy Eksploatacji Nr 2, Radom 2012.