Jarosław Moczarski
Warsaw University of Technology, Faculty of Transport
Railway Scientific and Technical Centre

CLASSIFICATION OF TECHNICAL STATES FOR SIGNALING SYSTEMS IN EXPLOITATIONAL PRACTICE

Summary: Changes of the signaling devices technical state are the result of the ageing and wearing process of its components, as well as of the realization of targeted maintenances. Information about adverse change of the technical state gives rise to the decision-making problem. Its solution involves defining the aim of necessary maintenance operations and to establish the timing and extent of their implementation. In practice of signaling systems exploitation, it is a lack of mechanisms for speedy solution of such problems. To effectively manage the maintenance process are useful the methods of operations sequence modeling.
Keywords: signaling systems, exploitation, process modeling

1. INTRODUCTION

Exploitation of signaling systems and devices is a purposeful, conscious human activity aimed at providing transportation tasks by the organizers of the transport process.
Functioning of the devices is accompanied by environmental influences and interactions of components and subassemblies. They are destructive influence leading to changes in the state technical devices. They may have a significant influence on the effectiveness of control and safety of the trains movement. The changing state of signaling devices may lead to a number of threats.
The destructive processes occurring in the signaling devices are the result of the environment, rolling stock, freight, other signaling systems influences, as well as the impact of the working factors supporting the functioning of each device.

External factors come from the surrounding of signaling systems. Particularly important are the influences of physical and technical environment, in which we may show other signaling systems impact and associated with it methods of exploitation, the applicable technical standards, environmental impact, and so. conversion factors mainly related to the implementation of new signaling systems into existing environments (ensure proper co-operation with the existing "old" signaling systems).

Factors affecting on signaling devices can be divided into two groups:

- general, which are occurring always and everywhere, and applies to any device and operating system,
- special (specific) resulting from the devices construction, operating principles, construction materials used; may be different for different devices and their components.

Range of influence of individual factors and their effect on change the signaling devices and systems technical states is very diverse. The differences arise primarily from:

- devices and systems construction, components and relationships between structure elements,
- principles of operation and used of physics effects and energy conversion systems,
- type and quality of the materials from which the components of devices were made, used precision machining, geometric shape and dimensions,
- devices and systems usage intensity,
- the place of usage.

On signaling devices and systems affect also working stresses (internal). Differential influences of these factors result from the construction and operating principles of individual devices and systems, the factors of working and construction materials, production technology, as well as the intensity of their use.

As an example of working factors affecting the signaling device we can indicate:

- drives tension wires,
- flow of electric current through the winding of relays, transformers, motors, light bulbs and fiber components,
- movement of moving crossover drives parts, shape signals, track retarders, relays, etc.

The internal and external influences initiate and sustain the processes of aging and wearing of signaling devices and systems.

Physical ageing process leads to irreversible changes in devices utility features. There are caused by the impact of external factors and internal (working) during usage and storage of the devices. The changes cover all the materials from which elements of signaling devices are made. Ageing are also lubricants (oils and greases), and oils used as a working factor.

Wear of signaling devices and systems causes negative processes in the upper layers of their components. They are caused by the interaction of elements surfaces and the effects of environment affection. Wear processes leads to changes in the devices construction properties, especially the weights, dimensions, elements surface shape and the structure of the material, stress state, etc.

According to the basic rights of exploitation, each device uses its exploitation potential and has a finished durability. The effect of physical or physic-chemical processes arising in materials are devices damage. Damage is defined [9] as an event, after which device fails (totally or partially) to comply with their functions. Becomes unable to work properly.

Signaling device failure may result from:

- slow, irreversible process of ageing and wearing occurring in their elements,

- reversible processes, caused by a momentary exceeding the permissible operating conditions,
- sudden and permanent change in the value of the essential properties of the device (exceeded constant sustainable limits).

Changes in signaling devices state caused by ageing and wearing processes requires human realization of purposeful, controllable processes and activities, enabling the reduction of the intensity of destructive influences, as well as restoring the devices up state in the event of damage. The signaling device must therefore be exposed to maintenance or replacement processes.

Effectiveness of maintenance procedure depends on the skills appropriate to define the existing needs for conservation, adjustment, maintenance or repairs. Managing the process of exploitation necessary is clear information describing the current, real device technical state. They allow to make correct decisions regarding the timing and extent of realization the necessary maintenance work.

2. CHANGE OF THE DEVICES TECHNICAL STATE IN EXPLOITATION PROCESS

Exploitation of signaling device can be described using the static approach - systemic (structural) or dynamic - process.

In terms of a static system of signaling devices exploitation can be described using the basic definition of the term "system" as a set of elements related to mutual relations and a set of aims justify its existence [3,4].

Process (lat. processus = conduct) [12] means a change the state, in turn successive stages of development of any system. The process of device exploitation can be presented [5] as a set of causally related events occurring between their phases of exploitation, exploitation states, events occurring within any state, as well as physic-chemical events occurring in the same device.

In the signaling devices exploitation system different processes are being realized. Realization of controllable processes, i.e. those in which a man sets out both the aims as well as ways of achieving them, is achieving the desired by the exploiter signaling devices systems states. Incontrollable processes - destructive, resulting mostly from the physical-chemical interactions of matter. They lead to adverse changes reducing exploitation potential of devices and systems and the effectiveness of their operation.

Each process is a sequence of *actions* (*functions*). Process and each action realization must be released (caused) by the corresponding occurrence of the *event*. An event is defined [1] as something that "occurs or is the result of something".

In the system of signaling devices exploitation we can indicate the tangible or intangible structures - including physical objects, organizational structures, data sets, or concepts relevant to the ongoing processes and their progress. They are called *entities*.

Under the influence of various effects following the entities transforming - change their state. For effective management of exploitation processes, each entity in it should generate information about the changing values of attributes that describe it (about its current state).

Occurrence of the relevant event causes a change the entity state (in this, for example, the states of available resources which are elements of the system), as well as changes in the overall exploitation system.

Denoted:

- ζ – event; $\zeta \in Z$,
- ε – entity in the system of exploitation; $\varepsilon \in E$,
- d – action caused by occurrence of the event; $d \in D$,
- s^{ε} – state of the entities ε ; $s^{\varepsilon} \in S^{\varepsilon}$.

Figure 2.1 shows the process of changing the state of entity ε under the influence of event ζ.

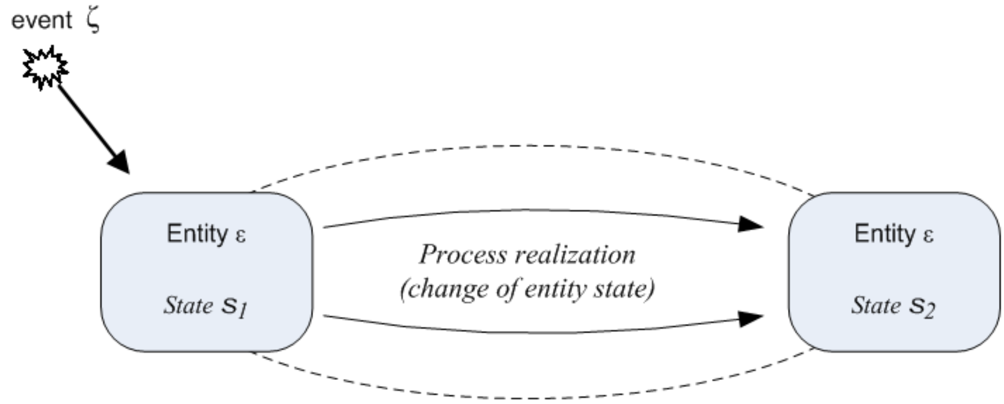

Figure 2.1. The process of change the entity state

The process of signaling devices exploitation can be showed as a sequence of events ζ describing the operation of the system, and as a sequence of actions d resulting in a change of the system properties values and achieve the new state. In the case of controllable processes, resulting from purposeful human activity - the new state of the system should be compatible with the man intended ones.

Controllable processes are sequences of the aimed actions d. Their realization is intended to achieve planned by a man, desired, new state (it operational / functional or technical) signaling devices.

Incontrollable processes that result in aging and wearing of the devices and their components, take place spontaneously. Events ζ initiating or supporting their realization are the physic-chemical surrounding influence, devices interaction and their components, or incompatible with the principles human activity. It comes to adverse change of the state that impedes or prevents the proper functioning of the device.

In the case of incontrollable processes (destructive) occurrence of the relevant events automatically trigger the execution of specific physic-chemical, tribological and erosion processes. They causes the change in the entity attributes values (object properties) - changes the signaling device state. For controllable processes resulting from aimed human activities, relevant event ζ occurrence does not immediate, automatic realize of action d

[6]. Direct effect of an event ζ is usually a rise of decision problem (Fig. 2.2). Resulting problem is to make decision, indicating what action and when to realized it. It should be noted that not every event generates a decision problem, but every problem arises from the occurrence of an event.

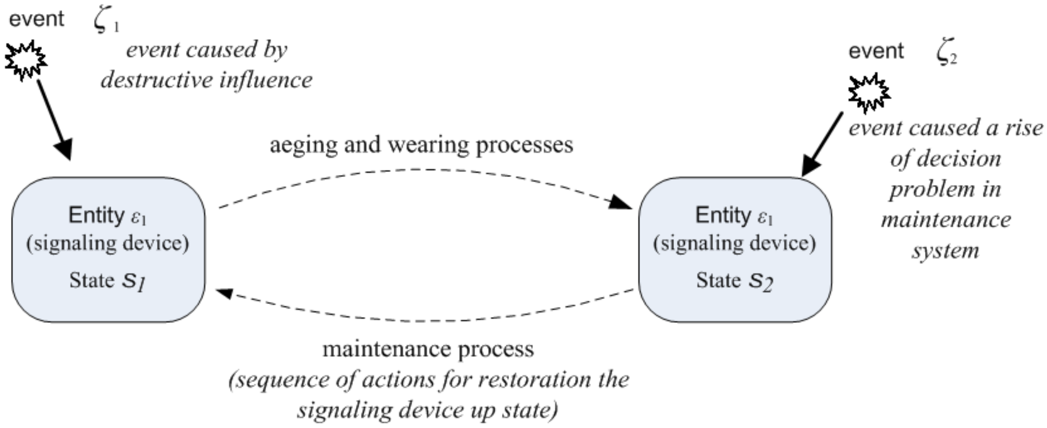

Figure 2.2. Change the entity state in the destructive and purposeful process

One of the events giving rise to the decision-making problem in the maintenance system may be obtaining information about the signaling device technical state. Perceive changes of technical state, caused by the impact factors of destructive or purposeful human action (e.g., use) creates a decision problem whose solution is aimed at achieving the proper maintenance and restoration of proper technical state of the device.

Changing the status of the device $s_1 \rightarrow s_2$ and $s_2 \rightarrow s_1$ is described as a *"transition"* [1]. The transition is initiated by an event ζ_1 or ζ_2 (Fig. 2.2) and carries two pieces of information: about the event, which launched its occurrence and the process (a sequence of actions or functions), which is implemented during the transition from one state to another.

Analysis of technical object state, and transitions between these states is desirable and beneficial if [1]:

- an object affects a number of external factors,
- sequence of events affects the behavior of the object,
- object must be able to exist in a different observable states,
- object is "sensitive for time", i.e. a reaction to an event occurring should be made within a specified period of time,
- external events can be generated by various sources,
- there are several technical objects that work together.

Described criteria meets signaling devices and systems, events and activities (functions) realized in the process of their exploitation.

Signaling devices are operated under different conditions prevailing on the train network. Also, external influences, and often internal (working) is different. Even for the same type signaling devices processes of aging and wearing of its components run with a different intensity and differing extent. Change of these devices technical state are frequently concerned by different properties. Therefore, the intensity and extent of the maintenance operations aimed at sustaining the up state of signaling devices or it restoration, should also be in all cases tailored to actual needs.

Solving decision problems in the operating system is primarily to define the aims and definition of terms and extent of the realization of specific activities and processes. Effectiveness of realization of signaling devices and systems maintenance processes, including the effectiveness of anti-progressive destructive processes depends on knowledge of the operator about the facilities technical state changes and the nature of these changes.

3. CLASSES OF SIGNALING DEVICES TECHNICAL STATE

Technical state of any object is described with a set of properly selected properties [2,10]. The number of properties and values that they can adopt, for the average signaling device or system can be very large. In practice, for assessing the technical state are used only those properties which sufficiently well describe the correct interaction of components and realization of the operating functions by the entire device. There are considered also appropriate range of variation values of these properties.

In signaling systems exploitation, among the properties describing the devices state are usually distinguished major and minor ones. Major properties describe values, upon which depends performing basic tasks by the system. Values of minor properties doesn't affect in this case to the functioning of the system.

According to the classification adopted by the European Organization for Quality Control **EOQC** (now the **EOQ -** European Organization for Quality) applies [8] distribution of objects properties according to their importance. There are:

- critical properties - such, which unacceptable deviation values can cause a threat to humans and structures and to irreversibly reduce the effectiveness of the object operation,
- important properties - such, which unacceptable deviation values may give threat to the construction (destruction), and significantly, but reversibly reduce the effectiveness of the object operation,
- properties of little importance - one that may cause minor and reversible reduction in the efficiency of the object operation,
- irrelevant properties - those that do not affect the objects behavior in the foreseeable conditions of use.

Selection of properties that allow you to assess the technical state of device should be preceded by an analysis of the threats that an adverse change in their value may cause. For signaling devices and systems, among the most important issues can be identified:

- threat to railway safety,
- reduce the efficiency of the device and disruption to train movements,
- accelerated wear or damage to device, damage to equipment cooperating,
- increase in operating costs of devices,
- financial loss to the carriers.

The operation of the signaling systems primary requirement is to ensure safety and minimize disruption to train movements. Due to the high cost of systems is also important to prevent damage to or destruction of individual devices or their components.

Using the presented classification of objects properties, for signaling devices and systems it is convenient to adopt [7] three classes of properties. We define it as: basic, secondary and auxiliary.

To *basic* properties we include those which correspond to the properties of critical and important by classification **EOQ.** Unacceptable deviation values of these properties may lead to a railway safety hazard, cause damage to devices or cooperating devices or irreversibly reduce the efficiency of its operation.

Secondary properties will be equivalent to the properties described as little importance, i.e. the deviation of each of them can cause minor and reversible reduction in the efficiency of the signaling devices.

Values of *auxiliary* properties (not relevant) don't directly affect the operation of devices in the foreseeable conditions of use. Unacceptable variations in their values may, however, in the long term lead to degradation of the device.

Treating signaling devices as entities of exploitation system we can assume that the signaling devices properties are these entities attributes. The impact of external and internal factors runs processes that lead to changes in attribute values (the values of properties) and changes in the signaling devices (changes the entity state).

Technical state is described as a set of instantaneous values of properties, called properties of state. Rising $\boldsymbol{\Theta}$ decision problem in the maintenance system and the type of this problem depends on the class of property, whose value has changed and the scope of changes in this value (the range of variation).

The problem arises when the change of the entity state (signaling device) causes a potential threat and forces to take appropriate action (execution of maintenance) restoring the desired technical state.

Let's create a set **C** of all analyzed properties of state. Properties in the set **C** we will renumber with the variable *l* in such a way that identifies the type

$$\mathbb{C} = \{c_1, ..., c_l, ... , c_L\} \tag{1}$$

where: $l \in \mathcal{N}$ – is the next number of properties c in the set **C** ,
$\mathcal{N}$ – set of natural numbers,
L - total number of properties which have been monitoring and evaluating.

The measurement of the individual properties values including their class (basic, secondary or auxiliary) enables to assess the technical state of device. On this basis, it can be stated:

- whether in the operating system was decision problem (whether there is a need for maintenance realization),
- what maintenance should be realized,
- when the maintenance should be implemented (the urgency of its execution).

Every property of state c_l of a number l can be described by a two-elements set of attributes

$$c_l = \{ \upsilon(c_l); \gamma(c_l) \} \tag{2}$$

where:

$\upsilon(c_l)$ – value of the state property $c_l \in \mathbf{C}$,
$\gamma(c_l)$ – class of the property c_l .

For a given property, the quantity of $\gamma(c_l)$ is constant, while the value $\upsilon(c_l)$ is in permissible range of variation and depends on the level of destructive influences or ongoing maintenance processes.

Technical state s_m of signaling device is described ordered L-set value of individual properties. Considering the division of the properties of state on the class $\gamma(c_l)$ can be written:

$$s_m = \left(\{ \upsilon(c_1); \gamma(c_1) \},\ldots, \{ \upsilon(c_l); \gamma(c_l) \},\ldots,\{ \upsilon(c_L); \gamma(c_L) \} \right)_m \tag{3}$$

where:

s_m – *m-th* technical state of device,
$\upsilon(c_l)$ – value of the properties state $c_l \in \mathbf{C}$,
$\gamma(c_l)$ – class of property c_l,
$l, m \in \mathcal{N}$.

In the case of signaling devices and systems, the size of the set **C** and the number of values to particular properties of state may take, is very large. Therefore, for solving decision problems it is convenient to create a set of technical states classes.

Space S of signaling device technical states divide into the classes of states S^k . Write

$$S = \bigcup_{k : k \in \mathbf{K} \subset \mathcal{N}} S^k \tag{4}$$

where:

S – space of signaling device technical states,
S^k – *k-th* class of signaling device technical state,
K – the set of numbers of technical states classes,
$\mathcal{N}$ – set of natural numbers.

The solution to the decision-making problem $\boldsymbol{\Theta}$ is the set of feasible solutions $\boldsymbol{\Delta_\Theta}$. Deciding δ_j means the choice of one of these solutions. The decision δ_j determines the type and term of maintenance, which is to be achieved.

Dividing technical state space S for the classes of states we assume that:

$$S^k = \{ s_1,\ldots, s_m,\ldots, s_M \} : \forall s_m \in S^k \ \exists\ \boldsymbol{\Theta}_i : \boldsymbol{\Theta}_i \rightarrow \boldsymbol{\Delta_{\Theta i}}. \quad i, k, m \in \mathcal{N} \tag{5}$$

where:

S – space of signaling devices technical states,
S^k – *k-th* class of signaling device technical state,
K – the set of numbers of technical states classes,
s_m – *m-th* technical state of signaling device,
Θ_i – *i-th* decision problem for device maintenance,
$\Delta_{\Theta i}$ – a set of feasible solutions of decision problem Θ_i,
$\mathcal{N}$ – set of natural numbers,
$i, k, m \in \mathcal{N}$.

So the *k-th* technical state class S^k form states that give rise to this *i-th* decision-making problem Θ_i , for which the set of feasible solutions is $\Delta_{\Theta i}$.

Determine in which class of states is the current technical state of signaling device allows rapid identification of caused decision-making problem and to establish a set of feasible solutions.

Deciding δ_j

$$\delta_j : \delta_j \in \Delta_{\Theta i} ; \; i, j \in \mathcal{N} \tag{6}$$

determining the timing and type of maintenance needed to realizing is based on the current value of the constraints in the maintenance system and in the system of signaling devices use. These constraints are described with values of various entities attributes highlighted in the exploitation system (e.g., resource availability, the possibility of closing the track for the duration of maintenance, etc.).

4. ORGANIZATION OF SIGNALING DEVICES MAINTENANCE

Basic organizational units which are directly involved in signaling devices exploitation process are:

- exploitation sections,
- diagnostic teams,
- fitter cells.

They form the so-called core team. Maintaining devices and signaling systems is carried out in accordance with the principles set out in the relevant instructions and regulations.

Instructions lay down general rules for exploitation of signaling devices, methods of implementation of maintenance work, the implementation of the diagnostic process and the organization of the periodic checks to determine the technical state of device.

In particular, instructions intended for diagnostic teams sets out the method of studies planning, their scope and required frequency of implementation. Instructions for conservation, servicing and repair of current signaling devices, intended for exploitation section, states, inter alia, the length of between maintenance periods for devices of various types.

Section staff worker has to implement maintenance (preventive and after damage), the rapid removal of failures affecting safety of trains movement, as well as the legalization of relays and repair of electronic components.

The area of operation of the exploitation section in range of devices maintenance is divided into the fitter cells. Fitter cell covers from 3 to 5 stations and section of the railway line to a length of 30 km. It is equipped with devices and measuring instruments, spare parts and transportation. Cell employees (fitters), who directs the automation master are realizing maintenance activities (surveys, conservations and running repairs) signaling devices, which are exploited on its territory.

The primarily task of the diagnostic team is to make planned conduct diagnostic tests of devices and of their technical state evaluation, and also to determine the causes of failures occurring. Tests are conducted on the basis of monthly and annual schedules.

Devices parameters (properties), which values are measured were divided according to the applicable instructions into two classes:

- the major parameters, this which are important to maintain the required level of railway safety,
- minor parameters that do not directly affect traffic safety, but have an impact on the durability of the device and may contribute to changes in major parameters values.

Comparing the actual values of controlled parameters with required, described in devices documents, has been done the assessment and classification of device technical state.

There are at this [11], four classes of technical states:

- *good condition* - if the values of the major and minor parameters do not exceed the limit,
- *sufficient condition* - if the device major parameters values do not exceed the limit,
- *unsatisfactory state* - if the values of major and minor parameters are the member of the set of boundary values,
- *insufficient state* - if the major parameters values of the device exceeded the limits.

Next steps in the process of diagnostic tests include: study design, their realization, analysis of measurement results, formulate a diagnosis identifying the device suitability to achieve the tasks and also inferences about the conditions for further exploitation, the implementation of maintenance or device upgrading.

Assessment and classification of the devices technical state is made in the diagnostic teams with the absence of clearly defined criteria. Its because instruction does not show how to assign a set of state properties and how their values affect the outcome of the evaluation of devices technical state assessment. An important role plays here diagnosticians subjective feelings. Also, the criteria for the parameters classification (state properties) and technical state of the signaling devices used in diagnostic teams are imprecise. The method of states classification is so general that some teams make up for their own purposes, treated as a secondary, additional quantitative assessment of the state.

Occurrence of the natural exploitation conflict requires an appropriate organization of actions implemented in the exploitation system. To determine the relationship existing between the usage and maintenance devices processes are used exploitation strategies. These are organization methods determining ways of effective achieving the usage and maintenance aims.

In particular, strategies determine ways of planning the moments and the extent of implementation of maintenance work needed to prevent dangerous changes in devices technical state, while not to make unnecessary distortions of the usage process and do not raise the cost of exploitation.

Exploitation sections are organizing maintenance activities of signaling systems. Maintenance works are carried out periodically, at regular intervals specified in the existing guidance. Length of periods between successive maintenance, varied for different types of devices, are constant throughout their life. Applied regular maintenance cycle strategy is a simplified version of the strategy *by resource.* Frequency of maintenance activities is expressed with the calendar time. Also, the implementation of each maintenance is pre-defined and described in the instructions.

A simplified strategy by resource helps to organize the signaling devices operation process. Planned implementation of predefined maintenance, makes it not necessary to solve decision-making problems. Operations support action d is the direct result of the ζ event calendar type. The resulting decision problem is limited to organizational issues (e.g. resource allocation). Simplified strategy by resource, however, is an inefficient strategy. Maintenance are carried out independently of the actual needs which depends on devices technical state. A more effective strategy, by the technical state, should be allowed by measurements and inspections carried out by diagnostic teams.

Diagnostic teams creation and carried control work does not mean, that maintenance of signaling devices shall be in accordance with the strategy by the technical state. In practice, the activities of the Sections and Teams takes place in an independent manner. The results of diagnostic tests are provided (inter alia, to exploitation section) in the form of a protocol containing recommendations on the mode of disposal of the identified deficiencies, and existing anomalies (Fig.4.1).

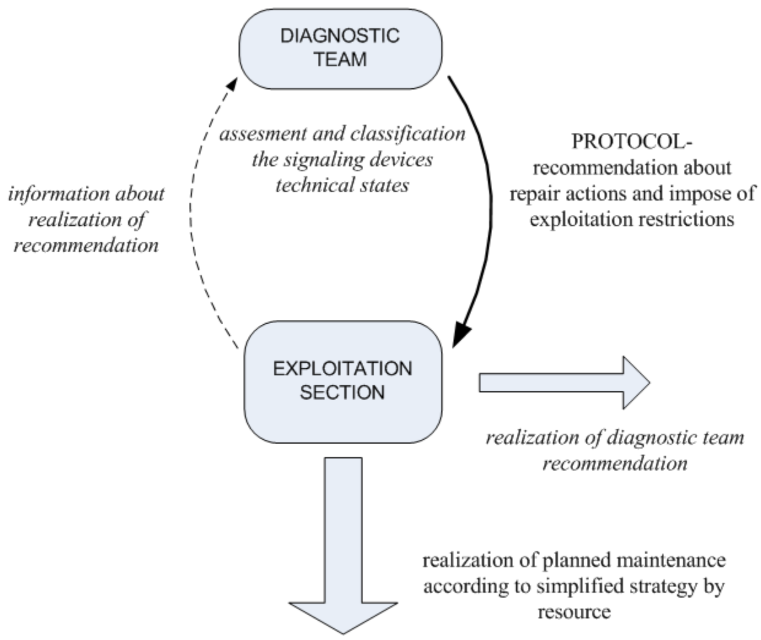

Figure 4.1. Realization of signaling devices maintenance process

Assessment of signaling devices state carried by diagnostic teams lies in periodic monitoring of selected parameters and in practice serves primarily to supervise the state and detect emergency threats. Preventive maintenance of signaling devices made by exploitation sections is still under the simplified strategy by resource. The frequency and range of the individual maintenance realization are determined by the records in the relevant instructions.

5. SUMMARY

Exploitation of signaling devices and systems is accompanied by processes of ageing and wearing of their elements. Qualitative and quantitative changes lead to lower of exploitation potential of device and changes their technical state. As a result, the device may become unfit to perform the desired functions.

Introduction to the organizational structure of Polish Railway Lines units named Diagnostic teams is an important step towards the implementation of the exploitation strategy by technical state. In practice, the results of measurements made by diagnosticians are used primarily to detect damage conditions. Devices maintenance is carried out in exploitation sections in accordance with simplified strategy by resource.

To implement the strategy by state it should be determined the set of state properties essential for each signaling device, and then develop clear criteria for evaluation and classification of their technical state on the basis of characteristics measurement results. Needed here is the ability of effective use of the results of a technical state classification. Information about the technical condition giving rise to the decision-making problem. His solution should determine the timing and range of realization the necessary maintenance. In practice, if there is an urgent need for implementation of maintenance, it is a lack of mechanisms for rapid resolution of this problem.

Modeling of processes (sequences of actions) carried out in the signaling device maintenance system, allow to specify how this system works, to assess the accuracy of its organizational structure, information flow, resource availability, etc. Creating such models should be done in the context of the aims formulated by the human in exploitation system.

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KLASYFIKACJA STANÓW TECHNICZNYCH SYSTEMÓW SRK W PRAKTYCE EKSPLOATACYJNEJ

Streszczenie: Zmiany stanu technicznego urządzeń srk są efektem procesów starzenia i zużycia ich elementów, a także realizacji celowych działań obsługowych. Informacja o niekorzystnej zmianie stanu technicznego powoduje powstanie problemu decyzyjnego. Jego rozwiązanie obejmuje zdefiniowanie celu niezbędnych działań obsługowych, a także określenie terminu i zakresu ich realizacji. W praktyce eksploatacyjnej systemów srk brak mechanizmów szybkiego rozwiązywania takich problemów. Do efektywnego kierowania procesem obsługiwania przydatne są metody modelowania realizowanych sekwencji działań.
Słowa kluczowe: systemy srk, eksploatacja, modelowanie procesów