Modeling of intelligent transport systems maintenance processes

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Abstract. The paper describes the problems of modeling of technical support systems of transport systems related to organizational and technical systems based on the implementation of the system approach to information technologies. It gives the theoretical basis for the description of technical maintenance of intelligent transport systems taking into account cybernetic representation. The paper also justifies the formalization of the process of technical maintenance of information systems, which include intelligent transport systems. It shows that a modern maintenance system of intelligent systems should be able to quickly adapt to needs and, if necessary, increase the amount of recovery works without disrupting the existing mode of operation.

1. Introduction

One of the central research problems is the creation and introduction of new modern methods of making management decisions on the technical maintenance of intelligent transport systems based on the development of information, algorithmic and software systems for solving various management tasks [1–3]. The main promising issues of these problems are as follows:

• creation of conceptual models of systems maintenance process structures [4–8];
• development of mathematical models of the maintenance process of intelligent systems, maintenance, logistics and technical operation;
• development of decision-making methods based on mathematical and conceptual models of technical maintenance;
• evaluation of the efficiency of the made technical maintenance decisions based on computational experiments.

The methodology of management processes of transport systems technical maintenance is based on the allocation, modeling, decision on actions and results of recovery services during the entire life cycle of intelligent systems. This requires solving the problem of system modeling, optimization, and unification of maintenance subsystems most common in various areas of technical maintenance, which perform certain recovery work to ensure system maintenance [9–12].

2. Materials and Methods

The analysis of the issues in this area showed that the methods of conceptual modeling, structural synthesis of solving problems of technical maintenance are least developed at the upper levels of decision-making in systems having the greatest influence on the final result.
Considering that any decision on technical maintenance management is related to the need to develop alternatives, let us consider the elements of system modeling of intelligent transport systems by formalizing many alternative models based on the analysis of execution functions in technical maintenance and structuring many decision elements in the property space.

The system description of the information model of decision making with technical maintenance of transport systems on the basis of a theoretical-multiple representation is determined by the following levels: (target) => (principle of functioning, performance of services) => (structure) => (organization) => (system quality) => (assessment) => (decision making, synthesis management).

The decomposition of the transport system maintenance model and the decision-making process are carried out at each level taking into account the limitations in the form of a fixed number of components of the respective sets. A tuple of system-forming elements is adopted to build a model of the technical maintenance system [13–16]:

$$S \rightarrow (W, R, C, O, Q)$$

where

- $S$ – maintenance system;
- $W$ – target;
- $R$ – principle of operation, performance of technical maintenance services;
- $C$ – structure implementing the principle of service execution;
- $O$ – operator of functioning organization;
- $Q$ – parameters characterizing properties and operation modes of the system and its elements (actions, results).

The target characterizes the need of the subsystem, determines the need to create a technical maintenance system and its further development. Target $W$ means the set $W(s) : W = \{W(s) = (W_1(s))\}; W(s) \subset W$ of possible structurally parametric states of the developed (existing) technical maintenance system $S(Q) = \{S_1(Q), \ldots, S_m(Q)\}$ satisfying subsystems and achieved in various ways:

$$O : R(C(Q)) \rightarrow W(s)$$

Let us use the display

$$G : I \rightarrow W(I),$$

where $I$ – set of initial information about the subsystem, the needs of which are fulfilled by achieving the target $W$.

The targets of the subsystem defining control include various types of repairs, maintenance, modernization, material support, post-repair and warranty maintenance of a system and its functional complexes. The results of target decomposition into sub-targets are displayed as a graph

$$D_\ast = (W, G_\ast),$$

which reflects the relationships of the selected set of targets. The sequence of target decomposition ends with the selection of individual tasks $V$, which must be solved to implement the necessary target functions in the technical maintenance system of transport systems, which is displayed in the form of a graph.

$$G_d = (V, D_d)$$

Thus, there are many arcs that may be described as a display

$$a_i : W \rightarrow V$$

linking targets and tasks.

Each $i$ target (task) is characterized by setting available values of characteristics (evaluation criteria) of the technical maintenance system of a set of parameters (internal, external, controlled, output, etc.), which evaluate the efficiency of the target function by the system. Obviously, the result of highlighting the display criteria as a graph $G_d(Q, D_\ast)$ is represented by displaying

$$a_2 : W \rightarrow Q,$$

linking targets and criteria.

3. Results

Knowing a set of targets, tasks and criteria, as well as a set of organizational and analytical structures for the implementation of recovery services, it is possible to distinguish a number of elements $D = \{d_i\}, i \in N, r \in R$, where $i$ – type of element, $r$ – type of service that solve the set target for the technical maintenance of the transport system. In other words, there is a display
linking evaluation criteria to a set of elements.

To form the structure of the technical maintenance system of intelligent transport systems, it is proposed to identify a set of their properties \( Z = \{z_k\} \) on a set of elements, which may be used to ensure this process. By appropriately structuring the elements from \( D \) on a set of their properties from \( Z \) [17–20], the decision maker accordingly influences the properties of the formed technical maintenance system to realize the desired technical maintenance target of the system. Thus, there is a display

\[
a_i : D \rightarrow Z,
\]

linking a set of elements and their properties in accordance with criteria of technical maintenance management processes.

Based on the above, the achievement of target states

\[
S(Q) \in W(s),
\]

is possible in different ways – strategies

\[
\Omega = \{\phi \}, \phi = \{\phi_1(w), \ldots, \phi_j(w)\},
\]

realizing the target \( W(s) \). The set \( \Omega \) is evaluated by the evaluation vector \( E(\Omega) \), which on the one hand is formed by the properties of the result (the efficiency of the state vector \( S(Q) \)), on the other hand – directly by the properties of the strategies (for example, the execution time of recovery services, the cost of performing recovery services, the quality of services including repair work, etc.). In this case, the elements of the set

\[
D = \{d_0\}
\]

are the cost and time resources of technical maintenance that are currently taking place.

To realize the needs for recovery services, i.e. when implementing the objective function of the entire system of technical maintenance of transport intelligent systems – \( S \).

The theoretical basis for the description of technical maintenance is a magic apparatus in the form of a specialized algebra [21].

\[
A = (A, F_A),
\]

where \( A \) – set of elements, actions, results reflecting transformations in the maintenance system;

\( F_A \) – signature of an algebraic system.

The formation of a set of alternative models when making decisions in the transport maintenance system is caused by the presence or occurrence of connections between the elements of this system, which determine the choice of a variant of the system \( S \) that most effectively performs the target function of the technical readiness and the state of the transport intelligent system.

The overall assessment of the efficiency of intelligent transport systems maintenance processes is related to the assessment of the set of recovery operations estimated by the triad (time, cost, quality). Each recovery operation \( a_{ij} \) corresponds to numerical estimates of time, cost and quality, where \( i \) is the number of the technical means; \( j \) – routine service number.

These estimates are \( c_{ij}, t_{ij}, k_{ij} \), respectively.

In general, transport system maintenance processes are sequential, parallel, cyclic algorithms that take into account the multivariability of their implementation in the technical maintenance system. Mathematical models of these processes are formed in the basis of the proposed algebra of events and make it possible both to qualitatively evaluate the accepted algorithm for restoring the technical means, and to make a decision on its change taking into account the actual situation in the technical maintenance system determined by the required amount of recovery services and the capabilities of the repair complex, both in terms of cost and quality and time of the recovery work.

Thus, one of the most important types of technical maintenance of transport intelligent systems and various technical means (different types of transport, equipment, machinery, etc.) is routine and technical maintenance of the recovered equipment.

The essence of routine and technical maintenance consists in performing certain inspections both on operating time and at certain intervals. In general, the procedures for operating time and operating
time maintenance are of the same type and are determined by the manufacturer’s requirements to ensure a warranty life.

4. Discussion
The difficulty of solving the problem of technical maintenance of transport intelligent systems is that it is not possible to find an analytical solution due to the multidimensional space of relations that connect the elements of the technical maintenance system, and the use of the stochastic apparatus is very problematic. It should also be noted that no field experiments of such a volumetric and complex system are possible and are even dangerous. The only possible way to find solutions is a model-representative method of studying this kind of large organizational and technical systems. Besides, it must be borne in mind that the creation of a complete model for a complex system is almost impossible, since by virtue of the Turing’s theorem, such a model will be as complex as the system itself. The way out is a representation of a complex system by a finite set of narrowly oriented simplified models, each of which reflects a certain facet of its essence.

5. Conclusion
The model representation of the transport systems maintenance using a limited set of problem-oriented models for solving system problems is quite real and has predecessors in the practice of modeling complex systems. The difficulties of this approach are related to the choice and use of a model-building apparatus taking into account the nature of the tasks being solved.

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