Algorithmic support for the dynamic functioning of transport systems in the region

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Abstract. The article deals with the development of algorithmic support for the implementation of the process of functioning of transport systems in the region with a dynamic change in the conditions of functioning of regional management of transport systems as a result of timely decision-making. In managing the functioning of transport systems in the region, systematic and integrated approaches are not fully used in the formation of a set of management decisions aimed at ensuring the safety of transport systems, namely, there are no models that would establish a one-to-one correspondence between the situation (generating potential threats), information and analytical activities (identifying potential threats) and the system for ensuring the safety of transport systems, designed to develop an adequate management decision and its development. The proposed algorithmic software allows us to overcome these disadvantages in the managing the functioning of transport systems in the region.

1. Introduction
Currently, the region is becoming the main subject of economic and political relations. Most of the important tasks of functioning of transport systems in the region should be solved at the level of state authorities of the subjects of the Russian Federation and local self-government bodies.

However, due to the scale of implementation of the management of social and economic resources of transport systems in the region, territorial diversity and limited financial and time resources, there are conditions that lead to the destruction of the vital activity of transport systems in the region.

In [1] a new approach of mathematical modeling of particle flows in the one-dimensional one-way supports was proposed. It allows designing distributed systems of monitoring and management for transport flows on complex networks by using modern information and communication technologies. The system with mobile phones, as terminal devices, collects structured information, distributed over the whole network, processes it, analyzes and makes decisions. These ideas were developed for analysis of real-time characteristics of saturated flows [2] and [3-5], and may also be used to control a group of clients on network from a central location [6].

Now great attention is given to problems of transport. One of urgent problems is optimization model of transportation in a region. In distributed systems, the response services have to get necessary link between a moving object position and the edges of the road network graph [7]. There are relevant models for other kinds of transport, such as sea transport [8].

Analysis of information flows of transport management bodies shows that only 10-15% of the available information is used for making transport management decisions today. Only 6 to 10% of managerial labor costs are used for transport planning and forecasting functions, and 25-30% for transport control functions.
This leads to abnormal conditions in the transport systems of the region as a result of untimely decision-making by decision-making person (DMP) due to a variety of heterogeneous DMP, a variety of heterogeneous resources, inconsistent actions of DMP in time, long time intervals for coordinating plans between DMP.

Untimely transport management of DMP r in the region leads to disruption of exchange processes and destruction of vital activity of transport systems in the region.

Using the state probabilities in system management presented in the works of V Burlov [9-18]. Management complex systems and performance of functionality are considered in the works O Lepeshkin [19-21].

2. Algorithmic support of the managing the functioning of transport systems in the region

2.1. The state probabilities social and economic resources of transport systems

To develop algorithmic support for the implementation of the process of functioning of social and economic resources of transport systems in the region when the operating conditions change, we consider the probability that a dangerous event will be identified by the information transport management system and neutralized by the DMP as an efficiency indicator.

Evaluation requires:

- typify the losses caused by the impact of DMP on the social and economic resources of transport systems in the region;
- to establish the level of losses due to the impact of DMP on the social and economic resources of transport systems in the region;
- to develop a methodology for justifying ways to reduce potential losses in case of untimely transport management of DMP on the social and economic resources of transport systems in the region to an acceptable level.

Evaluation allows you to:

- to justify the rational actions of DMP and ways to implement them based on basic concepts, basic dependencies of achieving results, basic logical rules.

Let's define that the time intervals between the moments when the facts of abnormal States are detected are random values. The detected abnormal States in time form a flow that is very close to the Poisson flow. The processing time for data about the required attribute is a random value. The data on attributes processed in the system is further distributed among the allocated forces and means that solve the corresponding target tasks.

The paper considers the case when the time of residence of the required signs (facts) of abnormal States in the area of operation of transport systems in the region is very limited and is commensurate with the time required for their identification, as well as data processing and taking adequate actions on these signs. Therefore, this complex system can be considered in the first approximation as a system with failures.

The state probabilities social and economic resources of transport systems marked:

- P00– information system (IS) of social and economic resources of transport systems of the region (supervisory divisions) and information management system (IMS) of social and economic resources of transport systems of the region, eliminating the identified factors are free from servicing negative factors;
- P10– IS is busy getting information about a single factor (event), and it is free from maintenance;
- P01– IS is free, and the IMS is busy processing information about the factor and working out a solution for the use of forces and means;
- P11– both systems are busy.
2.2. Differential equations of the States of social and economic resources of transport systems in the region

It is necessary to create differential equations of the States of social and economic resources of transport systems in the region. The system States are designated accordingly: A00, A10, A01, A11.

State A00 is possible in the following incompatible cases:

- at time t, the information system and control system are free. During the time interval Δt, no factor was detected in the scope of the IMS. The probability of this event is equal to
  \[ P_{00}(t) (1 - \lambda \Delta t) \]
- at time t, the IMS was in state A01. During the time of Δt, data about the required factor is transmitted to the forces and means of influence. The probability of this event is equal to
  \[ P_{01}(t) \nu_2 \Delta t \]

Then the ratio for state A00 is written as follows:

\[ P_{00}(t + \Delta t) = P_{00}(t)(1 - \lambda \Delta t) + P_{01}(t) \nu_2 \Delta t \]

After the corresponding transformations and the transition to the limit at \( \Delta t \to 0 \), we get:

\[ P(t) = - P(t) \lambda + P(t)\nu \]

Consider the state of the IMS A01. It is possible in the following incompatible cases:

- the IMS at time t is in state A01, during the time interval Δt, no new factor has appeared in the IMS area of operation and the identified violations have not been eliminated by the appropriate forces and means. The probability of this event is equal to
  \[ P_{01}(t) (1 - \lambda \Delta t)(1 - \nu_2 \Delta t) \]
- at time t, the IMS was in state A10, during the time Δt, the IS detected and issued data about the required IMS factor
  \[ P_{10}(t) \nu_1 \Delta t \]
- at time t, the IMS was in state A11, during the time Δt, the is detected and issued data about the required IMS factor, but the IMS did not use them, because it was busy processing data on the previous fact. And so, the data obtained were irrevocably lost due to the short duration of the factor's stay in the scope of the IMS.

The probability of this event is equal to

\[ P_{11}(t) \nu_1 \Delta t \]

Then the ratio for state A01 is written as follows:

\[ \frac{d}{dt} P_{01}(t) = - P_{01}(t)(\lambda + \nu_2) + P_{11}(t) \nu_1 + P_{10}(t) \nu_1 \]

When drawing up a differential equation, the state of IMS A10 must be assumed that it is possible in the following incompatible cases:

- at time t, the IMS was in state A00, during the time interval Δt, the required factor appeared in the IMS scope and was identified by the IC. The probability of this event is equal to
  \[ P_{00}(t) \lambda \Delta t \]
• at time t, the IMS was in state A10, during the time Δt, the required factor appeared in the scope of the IMS and it was not identified by the IC and the data was not transmitted to the system of management (SM). The probability of this event is equal to

\[ P10 (t)(1 - v_1 \Delta t) \]

• at time t, the IMS was in state A11, and during Δt, the SM issued data for the effect of the corresponding forces and means on the corresponding factor. The probability of this event is equal to

\[ P11 (t) v_2 \Delta t \]

Then the ratio for state A10 is written as follows:

\[ \frac{d}{dt} P10 (t) = P00 (t) \lambda - P10 (t)v_1 + P11 (t)v_2 \]

Finally, the last state of IMS A11 is possible in the following incompatible cases:

• at time t, the IMS was in state A01, and new data on the required features were obtained during Δt. The probability of this event is equal to

\[ C (t) \lambda \Delta t \]

• at time t, the IMS was in state A11, and during the time interval Δt, data on the required IS and SM factors were not processed. new dangerous event appeared in the area of the protective subsystem. The probability of this event is equal to

\[ P11 (t) (1 - (v_1 + v_2) \Delta t) \]

Then the ratio for state A11 is written as follows:

\[ \frac{d}{dt} P11 (t) = P01 (t) \lambda - P11 (t) (v_1 + v_2) \]

The general system of equations describing all possible IMS states is represented as follows from four differential equations:

\[ \frac{d}{dt} P00 (t) = - P00 (t) \lambda + P01 (t) v_2 \]

\[ \frac{d}{dt} P00 (t) = - P01 (t) (\lambda + v_2) + P11 (t) v_1 + P10 (t) v_1 \]

\[ \frac{d}{dt} P10 (t) = P00 (t) \lambda - P10 (t) v_1 + P11 (t) v_2 \]

\[ \frac{d}{dt} P11 (t) = P01 (t) \lambda - P11 (t) (v_1 + v_2) \]

For stationary processes, we assume that there are no transients in the system. This allows you to make the following property entry for transition probabilities:

\[ t \to \infty, \quad \frac{d}{dt} Pi j (t) \to 0, \quad Pi j (t) = Pi j = \text{const.} \]

Then the system of differential equations is transformed into a system of algebraic equations:

\[ P00 (t) \lambda = P01 (t) v_2; \]

\[ P01 (t) (\lambda + v_2) = P11 (t) v_1 + P10 (t) v_1; \]

\[ P10 (t) v_1 = P00 (t) \lambda + P11 (t) v_2; \]

\[ P11 (t) (v_1 + v_2) = P01 (t) \lambda, \]
where: $\lambda$ – intensity of the flow of dangerous events;
$v_1$ – intensity of detection of negative factors (events);
$v_2$ – the intensity of activities aimed at eliminating identified violations, factors and events.

Solution of this system of algebraic equations:

$$
P_{00} = \frac{v_1v_2}{\lambda(\lambda + v_1 + v_2) + v_1v_2}
$$

$$
P_{10} = \frac{\lambda v_2(\lambda + v_1 + v_2)}{(v_1 + v_1)(\lambda(\lambda + v_1 + v_2) + v_1v_2)}
$$

$$
P_{01} = \frac{v_1\lambda}{\lambda(\lambda + v_1 + v_2) + v_1v_2}
$$

$$
P_{11} = \frac{\lambda v_1}{(v_1 + v_2)(\lambda(\lambda + v_1 + v_2) + v_1v_2)}
$$

The probability that a hazard will be identified by the IS and neutralized by the SM is determined by the following ratio:

$$
P_s = \left[1 - (P_{10} + P_{11})\right] \times \left[1 - (P_{01} + P_{11})\right]
$$

Physically, the process consists of "thinning" the flow of negative factors. $\lambda^*$ – the flow of unorganized and unintended accidents and emergency situation. Defined as follows:

$$
\lambda^* = \lambda \cdot P_d,
$$

where $P_d$ – probability that the hazard will not be neutralized.

$$
P_d = 1 - P_s
$$

With data on the values of $\lambda^*$, $v_1$, $v_2$ and based on the formulas (1 – 4), it is possible to estimate $\lambda$ (the flow of dangerous events). Based on the obtained value of $\lambda$, the probability of neutralizing negative factors is determined.

Figure 1 shows the dependence of the fact that negative factors will be identified and served by the IMS, taking into account the intensity of activities aimed at eliminating the identified violations, factors and events $v_2$.

**Figure 1.** Dependence of the probability of neutralizing negative factors in the functioning of social and economic resources of transport systems in the region on the intensity of its detection and the intensity of activities to neutralize it.
3. Conclusions
One of the priorities of scientific research the goal of research in a given subject area is to develop methods for timely and reliable detection of destructive factors in the functioning of transport systems in the region.

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