Situation-semantic Modeling a Risk Monitoring System in Urban Transport

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***Abstract*—The article deals with the actual problems of modeling of monitoring risks in urban transport. This monitoring involves determining the state of transport objects, as well as procedures for minimizing the consequences caused by the onset of risks.**

The article discusses the problems of effective creation of system for monitoring of risks in urban transport based on the use of appropriate models.

The article proposes modeling this system based on situational-semantic model. The approach proposed would contribute to recognition of risks and generation of management decisions to eliminate their consequences.

The proposed situational-semantic model allows: to predict the behavior of complex transport objects and transport infrastructure objects; take into account the possibility of emergence of new transport objects and processes for ensuring their functioning in conditions of minimizing possible risks; respond adequately to local and global factors of influence on transport objects; dynamically change the structure of the system; take into account new data to predict the development and improvement of relevant transport objects; predict the development of processes to ensure minimization of risks and the consequences of them.

***Keywords*—model, situational-semantic model, modeling, information system, risks in urban transport, monitoring of risks in urban transport.**

I. Introduction

Urban transport is always associated with certain risks. Studying these risks, determining the degree of their impact on the functioning of transport objects and transport infrastructure objects is a complex problem.

This is due to the fact that, firstly, there are several classes of risks in urban transport, in particular: technical (production, technological, innovative), economical (property, commercial, financial, credit and interest rate); social; environmental.

Each of the risks is associated with a large number of dynamically changing factors of influence. Therefore, the monitoring of risks, the development of appropriate information systems is an important and urgent problem.

The creation of such complex systems will be optimal if it is based on the use of models of objects and processes in urban transport.

Modeling of risk monitoring systems in urban transport would facilitate the timely recognition of risks and the generation of solutions to eliminate their consequences.

When building complex technical system, which is a system for monitoring of risks in the transport [1, 2], it is important to choose the method of presenting knowledge about the domain (urban transport).

Among the main types of models of knowledge representation should be noted [3 - 6]: production model; semantic network; frame model; ontological model [7, 8].

II. Modeling of Monitoring of Risks

The main goal of this work is to develop a model of the system for monitoring of risks in urban transport. As such a model, a situational-semantic model was proposed [9, 10].

The authors propose to use modeling based on a multi-level model of a special class of semantic networks (SM) - situational-semantic networks (SSM), in which situations determine not only the description of the model at any of its levels, but also the transition from one level to another.

The SM that is used is a system of knowledge of domain. This has certain content in the form of a coherent image of a specific network model of the system for monitoring of risks in the urban transport.

The nodes of this model correspond to transport objects or transport infrastructure objects (concepts of the subject area, system components, constituent elements of the process of ensuring the functioning of transport objects).

Arcs reflect the relationship between all objects of the considered domain.

When constructing SM, the number of elements and their connections is not limited, and the systematization of relations between transport objects and transport infrastructure objects of the network is necessary for the subsequent formalization of the processes of monitoring risks in urban transport.

Systematization of SM relations is a complex problem and depends not only on specific objects in urban transport, but also on the processes occurring in them and possible risks both as a result of their functioning and for their functioning.

When systematizing SM relations, an important role is played by the hierarchy of relations between objects, which can be divided into:

- generally valid (characteristic of almost all objects);
- significant (characteristic of many objects);
- specific (characteristic of individual objects).

Objects are understood as transport objects and/or transport infrastructure objects.

The authors propose SSM, which also takes into account the situational monitoring of the risks of objects in urban transport.

All situations, according to which modeling of the system for monitoring of risks in urban transport is carried out, can be divided into: regular, non-standard.

Standard situations can be divided into:

- generally significant;
- significant;
- specific.

The use of situations and their typification contributes to the multilevel structure of SSM of system for monitoring of risks in urban transport.

Formally, the SSM can be set as follows:

$$M_{ssm} = (G_{ssm}, H_{ssm}, U_{ssm}, S_{ssm}),$$

where

G_{ssm} – set of transport objects and transport infrastructure objects (nodes), $G_{ssm} \neq 0$;

H_{ssm}– set of connections between nodes (arcs),

$$H_{ssm} \subseteq (G_{ssm} \cup G_{ssm});$$

$$dom(H_{ssm}) \subseteq ran(H_{ssm}) = G_{ssm},$$

where

$dom(H_{ssm}) = (y \in G_{ssm} | \exists x \in G_{ssm}, (x, y) \in H_{ssm}),$

$$ran(H_{ssm}) = (y \in G_{ssm} | \exists x \in G_{ssm}, (x, y) \in H_{ssm}),$$

that is, any SSM node is incident to at least one SSM node;

U_{ssm} – set of loads on elements H_{ssm};

S_{ssm} – set of situations in which functioning occurs SSM.

$$G_{ssm} = (G^s_{ssmi}),$$

where G^s_{ssmi} - i-th node SSM;

$$H_{ssm} = (H^s_{ssmj}),$$

where H^s_{ssmj} - j-th arc SSM;

$$Ussm = U^s_{ssmj},$$

where U^s_{ssmj}– j-th load on the j-th arc SSM;

$$S_{ssm}. = (S^s_{ssmi}),$$

where

S^s_{ssmi}– situation that determines the semantics of the i-th node SSM.

Analysis of the functioning of a transport object based on the SSM provides quantitative and qualitative characteristics of its states.

If deficiencies are found in the SSM, then the model is modified several times until a model is obtained that is adequate to the transport object.

SSM components and their actions act as events. Examples of events can be, in particular: situational determination of the route on the SSM, according to which the values of the criteria that determine the situation are calculated.

The SSM of the system for monitoring of risks in urban transport should be:

- reliable;
- adequate;
- purposeful;
- simple and understandable for the user;
- complete;
- such that it assumes the possibility of modification.

To adequately reflect the connection between input and output in the SSM, the concepts "state" and "situation" are used.

The state $z(t_i)$ is a set of properties (states, situations) of the SSM, the knowledge of which at the moment of time $t > t_i$ allows us to determine its behavior at the moments of time $t > t_i$.

Modeling of system for monitoring of risks in urban transport, processes for ensuring the functioning of objects in urban transport in conditions of minimizing risks and/or eliminating their consequences should begin with:

- descriptions of all elements of the model of;
- determining the content of these components and areas of change.

For the full functioning of the system for monitoring of risks in urban transport, it is necessary to determine:

- the time interval in which the SSM;
- input and output impacts on possible risks and areas of their possible changes;
- the set of characteristics of the state of domain and the area of their possible changes.

Note that within the framework of one SSM, several variants of its submodels can be built (depending on situations, factors of influence, criteria for assessing risks, etc.)

The constructed model reflects expert knowledge about possible risks in transport, the reasons for their occurrence and and ways of their elimination or minimization.

There are two approaches to constructing an SSM.

1. "From above".

At the initial stage, the core of the SSM is built, which is further completed with the help of separate blocks of the model.

Individual components of the model can be dynamically completed to the core of the SSM.

2. "From below".

At the initial stage, the core of the SSM is built, which is further completed with the help of separate blocks of the model.

The model allows you to:

- clear cognitive analysis;
- dynamic modeling;
- forecasting trends in the development of the transport system and its individual subsystems (individual transport objects and transport infrastructure objects);
- forecasting the quantitative values of the criteria characterizing the risks in transport;
- analysis of model cycles, including life cycles;
- analysis of the stability of the process;
- analysis of structural resistance to disturbing and control influences;
- topological analysis of the structure of the model.

Topological analysis, calculation of system indicators of transport objects and transport infrastructure objects can also be carried out for the SSM.

The formation of control actions involves the implementation of the adjustment of the SSM.

A model correction is understood as:

- changing the structure of the model (adding or removing any objects, factors and relationships (connections) between them);
- change in values characterizing objects, factors and connections.

Users are prompted to make one of the following decisions:

- make adjustments to the initial SSM;
- to develop a new SSM.

Let's consider an example of risk assessment.

To build the SSM of the system for monitoring of risks in the transport, the factors necessary for assessing risks, the relationship between them, and their significance were identified.

At subsequent stages, when constructing an SSM, factors that characterize the individuality of transport objects and transport infrastructure objects can be used.

The values of the connections between the vertices are assigned based on expert knowledge (their opinions, judgments, forecasts, etc.).

The judgments were obtained by interviewing experts in the subject area under consideration - the urban transport.

Fig. 1 shows the risk assessment model using the principle "from below". Here:

v1 – the number of tasks;

v2 – the speed of execution of work to eliminate the consequences caused by the risks;

v3 – the number of expert assessments of risks and their consequences;

v4 – the onset of a situation caused by the emergence of a risk;

v5 – minimization of economic risks;

v6 – system reliability;

v7 – the ability of transport objects and objects of the transport system to function without the manifestation of negative environmental consequences;

v8 – external factors affecting transport objects and transport infrastructure objects;

v9 – the number of errors made by users of the system;

v10 – the time taken to create the system;

v11 - financial costs for creating the system;

v12 – the number of system users;

v13 – qualification of system users;

v14 – violation of normal operation;

v15 – emergency.

The relationships shown in Fig. 1 can be interpreted as follows:

- – for example, the relationship v3 $\rightarrow$ v6 with a weight of 0.9 means that if the value of the parameter of the vertex v3 increases (decreases) by 10 percent, then the value of the parameter of the vertex v6 increases (decreases) (sign "+") by 9 percent;
- the relationship v10 $\rightarrow$ v9 with a weight of – 0.7 means that if the value of the vertex parameter v10 decreases by 10 percent, then the value of the vertex parameter v9 will increase (sign "–") by 7 percent.

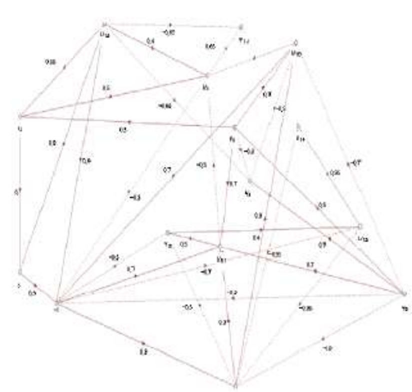

Figure 1. Risk Assessment Model.

III. Conclusions

The proposed situational-semantic model (SSM) of system for monitoring of risks in urban transport:

- allows predicting of the behavior of complex transport objects and transport infrastructure objects in the context of monitoring possible risks;
- takes into account (due to its dynamism) the possibility of the emergence of a new type of transport objects (and transport infrastructure objects) and processes for ensuring their functioning in conditions of minimizing possible risks;
- responds adequately to local and global factors of influence on transport objects and transport infrastructure objects;
- dynamically changes its structure;
- allows you to take into account new data for more accurate forecasting of the development and improvement of the relevant transport objects and transport infrastructure objects;
- allows predicting of the development and improvement of processes to ensure minimization of risks, their complete absence or elimination and minimization of consequences due to the onset of situations caused by the emergence of risks.

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Ситуационно-семантическое моделирование системы мониторинга рисков на городском транспорте

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В статье рассматриваются актуальные проблемы моделирования мониторинга рисков на городском транспорте. Этот мониторинг предполагает определение состояния транспортных объектов, а также процедуры минимизации последствий, вызванных наступлением рисков.

В статье рассматриваются проблемы эффективного создания системы мониторинга рисков на городском транспорте на основе использования соответствующих моделей.

В статье предлагается моделировать данную систему на основе ситуационно-семантической модели. Предлагаемый подход будет способствовать признанию рисков и выработке управленческих решений по устранению их последствий.

Предлагаемая ситуационно-семантическая модель позволяет: прогнозировать поведение сложных транспортных объектов и объектов транспортной инфраструктуры; учитывать возможность появления новых транспортных объектов и процессов для обеспечения их функционирования в условиях минимизации возможных рисков; адекватно реагировать на локальные и глобальные факторы воздействия на транспортные объекты; динамически изменять структуру системы; учитывать новые данные для прогнозирования развития и совершенствования соответствующих транспортных объектов; прогнозировать развитие процессов, обеспечивающих минимизацию рисков и их последствий.

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