Application of Fuzzy Situational Networks in Decision Support Systems in the Transport Industry

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Abstract. The article deals with the design of decision support systems in the transport industry based on fuzzy situational networks, which are parameterized by a set of states and transitions between them. The proposed model is represented as a fuzzy hierarchical situational-event network. A mechanism for the dynamic formation of fuzzy situational networks has been developed. The obtained optimal estimates of control decisions that come out of the network nodes represent the basic mechanism for generating transition estimates. In the general case, the use of situational networks as a basic technology for creating decision support systems presupposes the existence of a knowledge base with a structure corresponding to the description of knowledge in the formed model of a fuzzy situational network.

1. Introduction
In the transport systems of large cities, transport development problems are most acutely expressed. And local features, such as the nature of development, the configuration of the transport network, the level of development and quality of the transport system, also require additional regional regulations that complement the federal ones, establishing the methodology for the development of transport in local conditions.

In the current practice of territorial and urban planning in Russia, according to experts, there is insufficient attention to the planning stage of transport infrastructure development [1-10]. Among the reasons, both those specific to our country and those characteristic of many other countries stand out.

2. Relevance of the research
The process of integrated transport planning is based on multi-level strategic planning, which implies an integrated approach to solving existing problems of the transport system of the city and the region, as well as forecasting and ensuring sustainable development in the future.

The planning is structured as follows [11]:
• planning for the short term;
• solution of priority problems;
• quick elimination of current capacity deficits;
• planning for the medium and long term;
• functional and sustainable transport system;
• overcoming the negative effects of traffic;
• forecasting and accounting for structural changes in the future.

The method of integrated transport planning takes into account the following levels of process integration [12]. Vertical spatial integration, i.e. consistency with regional and federal plans for transport development in order to avoid the emergence of systemic inconsistencies and "bottlenecks".

Horizontal spatial integration, i.e. consistency with the transport development of neighboring territorial entities, consistency in the development of export of transport services.

3. Statement of the problem
Planning and operational management of the construction of large distributed ones belongs to rather complex classes of system planning problems, which is associated with solving a number of poorly formalized problems [13]:
• severe restrictions on the efficiency and quality of management decisions;
• variable information flows in the process of forming decisions;
• a large number of functional aspects;
• dynamism and variability of management objectives;
• the uniqueness of the conditions for the formation of decisions, etc.

Recently, the concept of using situational analysis based on fuzzy situational networks (FSN) has been quite strongly advanced in practical applications. An FSN is understood as a certain structure that is parameterized by a set of states and transitions between them. In this case, the transitions are determined by a set of control actions.

In terms of technology for constructing the FSN, there are static and dynamic. The static FSN is presented in the form of a graph. This is for cases of visibility of the entire set of alternative solutions and comparability with a set of nodes. For a dynamic network, a subset of the graph structure is formed, and the node corresponding to the display of the initial data is taken as the initial node. Then the node is associated with new states that correspond to the nodes of the network, and the procedure is repeated recursively. FSN with a rigid mechanism for obtaining situational features are based on a static list of objects and their properties. For an FSN with a flexible mechanism it assumes that the adaptation of the network to new conditions.

4. Theoretical part
The model is supposed to be represented in the form of a fuzzy hierarchical situational-event network, which represents the seven:

\[ \langle W, AG, V, Re, s, A, O, S, ID \rangle \] (1)

where \( W = \{w_1, w_2, ..., w_N\} \) is the set of FSN nodes, which are determined by triples \( w_k = \{P_k, u_k, t_k\} \), \( k = 1..N_w \), \( t_k = 0..T_G \), where \( P_k \) characterizes the value of the fuzzy probability for the states \( u_k \), \( u_k \) - i.e. the state at the moment \( t_k \) (\( t_k \) is the model time for the entire depth of modeling \( T_G \) corresponding to progress in the state space and is considered as a discrete quantity with discretization \( AG = \{Ag_1, Ag_2, ..., Ag_{Nag}\} \) represents a set of control decisions that are determined by the "object-action" pair:

\[ Ags = \{(a_{id}^1, o_1), ..., (a_{id}^j, o_j), ..., (a_{id}^{Nags}, o_{Nags})\} \] (2)

where \( d = 1..N_{ag}, j = 1..N_{ags}, a_{id}^j \in A, o_j \in O \), \( O = \{o_1, o_2, ..., o_{N_0}\} \) is the set of objects of the controlled system, and \( A = \{a_1, a_2, ..., a_{N_a}\} \) is the set of actions of the system, which differs in functional aspects \( A_v = \{a_1^v, a_2^v, ..., a_{N_{av}}^v\} \).
These actions are formalized by a linguistic lottery with an outcome representing the results of this action:

\[ a_e^v = \{ \text{Res}_e, \text{Rob}_h \}, \quad e \in 1..N_{\text{res}_e} \]  

(3)

At the same time, a general solution is formed:

\[ \text{Ags}_d : \text{VRes}^d = \{ \text{Res}^d_m, \text{Rob}^d_m \} \in \text{VRes}, \quad d \in 1..N_{\text{ag}}, \quad m \in 1..N_{\text{vread}}. \]  

(4)

Each component "outcome-probability" corresponds to one of the decisive nodes, which are the resulting:

\[ \{ \text{Res}^d_m, \text{Rob}^d_m \} : w^v_e = \{ P_k, u_k, t_k \} \rightarrow w^v_h = \{ P_h, u_h, t_h \}. \]  

(5)

where \( d \in 1..N_{\text{ag}}, \quad m \in 1..N_{\text{vread}}, \quad k, h \in 1..N_w, \quad t_k \in 0..T, -1, \quad t_h = t_k + 1. \)

Formation of correspondence between management decisions and states is performed based on the use of a set of reference situations

\[ S = \bigcup_{r=1}^{N_S} S^r, \quad S^r = \{ s^r_1, s^r_2, ..., s^r_{R} \} \]  

which in turn represents a combination of basic \( S^{\text{v}}_{\text{v}} \) and auxiliary situations \( S^{\text{w}}_{\text{w}} \), divided into subsets in accordance with the classification of situational features

In this case, all groups of situations of the upper level (main groups) for the selected aspect of management are assigned a set of actions, and each individual situation of this group is assigned a subset of these actions:

\[ S^v_{\text{w}} \leftrightarrow A^v, \quad v \in 1..V, \quad S^{w}_{\text{w}}, q \in 1..N_{\text{w}} \]  

(6)

After these network transformations, \( ID \) is used - a mechanism for adapting the situational network to the variability of the composition of the controlled system. The mechanism

\[ ID: (S, u_k) \rightarrow AG' \subseteq AG \]  

for each current state binds one of the reference situation, which ultimately allows for this state to generate a set of admissible control decisions

Further, the mechanism of dynamic formation of the FSN is considered (fig. 1), which, after the formation of the initial conditions, selects the next current node of the considered fragment.

For the resulting set of manifested situations, a set of actions is generated for the studied object of the primary type. Then, on the basis of the next generated version, a new node is added, for which a list of future events is formed with the moments of performing actions, as well as using the results of these actions [10-14].
As a result, the transition arc is a combination of two possible transitions, namely: controlled and uncontrolled (or group and private transitions, respectively). This grouping leads to the subsequent generation of the next fragment of the network (fig. 2)
The execution of each action takes several steps of the recurrent scheme, after which the functional of the results obtained will correspond to the attributes of the system objects, which requires the determination of the start time of the action $t_0$ relative to the primary object.

5. **Practical significance, proposals and results of implementations, results of experimental studies**

Today, the city of Krasnoyarsk uses intelligent software in the field of transport planning and modeling. Preparations are underway for the formation of the instrument of the state information system "Transport model of Krasnoyarsk", which should subsequently be integrated into the general Transport model of the Russian Federation.

The planning system for the city of Krasnoyarsk was tested on the example of the reconstruction of Kirov Street without major changes, only with temporary objects and markings.

The current situation: two lanes, each more than 6 meters wide, cars go in one lane, sometimes in 1 row, then in 2, a long straight line, limited view, poorly readable environment.

The traffic light is equipped with a call button to turn on the pedestrian phase, which stands out poorly; unknowingly, you can decide that the pedestrian phase is not working.

Solution: the formation of an S-shaped narrowing of the carriageway up to 3 meters (fig. 3), transferring the traffic light to a standard mode of operation without a calling phase, which will reduce...
the speed of traffic and make the situation clear and predictable (installation of a speed bump is possible).

Figure 3. Proposed activities on st. Kirov.

An example of the reconstruction of Kirov Street without major changes only with temporary objects and markings shows the expediency of using the planning system for the city of Krasnoyarsk.

6. Conclusions
Using the generated model for assessing the states of the situational network control system, an assessment of the set of nodes representing the upper layer of the FSN is performed. Further, governing decisions assess the actions to which they lead. These estimates are formed on the basis of the estimates of the network nodes based on one of the selected solution strategies, namely:

- optimistic - in which the best is taken as an estimate;
- pessimistic - the estimate is based on the worst;
- increasing the probability of winning;
- risk reduction - the assessment is also carried out on the basis of the total value of fuzzy probabilities that determine possible transitions to the resulting nodes of the situational network (while the assessment itself remains below the specified threshold value);
- weighted - based on the formation of a weighted sum of the resulting estimates (weight coefficients represent the probabilities of transitions to these states).

The obtained optimal estimates of control decisions that come out of the network nodes represent the basic mechanism for generating estimates of transitions at the lower network level.

In general, the use of situational networks as a basic technology for creating a planning system presupposes the existence of a knowledge base with a structure corresponding to the description of knowledge in the generated FSN model.

7. References
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