*10. Međunarodna Konferencija*
*„Bezbednost saobraćaja u lokalnoj zajednici“*
*Srbija, Kragujevac, Hotel Kragujevac,*
*22-25. april 2015.*

*10th International Conference*
*ROAD SAFETY IN LOCAL COMMUNITY*
*Serbia, Kragujevac, Hotel Kragujevac,*
*April 22 – 25, 2015.*

# INTELLIGENT DATA ANALYSIS APPLICATION FOR RELIABILITY AND SAFETY OF CITY TRANSPORT SYSTEM

**Irina Makarova[1], Rifat Khabibullin[2], Dmitry Zhdanov[3], Eduard Belyaev[4]**

**Abstract:** This paper considers a possibility of intelligent data analysis application for reliability and safety of city transport system operation. Application of simulating models enables to make a reasonable option of optimal traffic schemes and to make changes to a street network configuration. Characteristic analysis of a transport stream in places where road accidents are mostly concentrated with use of models enables to establish the reasons of their origin. It is shown that this umbrella approach promotes a sustainable development concept implementation of city transport system. The given examples of such solutions and a situation analysis after their implementation testify to adequacy of the proposed method.

**Keywords:** safety of city transport system, intellectual data analysis, simulating modeling, road accidents, optimal traffic schemes

## 1. INTRODUCTION

Analysis of city transport system status and functioning in Russia indicates that its stability and security have been declining with every year because of inconsistent growth rates of motorization to a level of infrastructure development of the street and road network (SRN). These trends remain the same, despite the measures taken to ensure transport

[1] Professor, Makarova Irina, Doctor of Technical Science, Department «Service of Transport System», Kazan Federal University, Russian Federation, Naberezhnye Chelny, Prospekt Syumbike, 10A, kamIVM@mail.ru
[2] Professor, Khabibullin Rifat, Doctor of Technical Science, Dean of Automotive Faculty, Head of Department «Service of Transport System», Kazan Federal University, Russian Federation, Naberezhnye Chelny, Prospekt Syumbike, 10A, hrg_kampi@mail.ru
[3] Ass. Professor, Mukhametdinov Eduard, Candidate of Technical Science, Department «Service of Transport System», Kazan Federal University, Russian Federation, Naberezhnye Chelny, Prospekt Syumbike, 10A, funte@mail.ru
[4] Ass. Professor, Belyae Eduard, Candidate of Technical Science, Department «Service of Transport System», Kazan Federal University, Russian Federation, Naberezhnye Chelny, Prospekt Syumbike, 10A, bomund@mail.ru

safety, as well as the fact that the level of motorization in Russia is far from similar indicators in Europe.

Infrastructure development, particularly street and road network should go ahead or at least match the changes of the motorization level for the safe functioning of the transport system.

To predict changes of motor traffic volume on SRN of the city is difficult because it is necessary to take into account large number of stochastic factors. Usually SRN reconstruction is carried out without taking into account growth in traffic volume and density, so the expansion of roads making additional lanes, construction of new U-turns sometimes not improve the situation on the roads but lead to its deterioration.

The growth of the automobile fleet is often not taken into account in construction of centers of population attraction. This causes problems for drivers and pedestrians at entry points to the territory of new shopping centers and recreational areas, causes an increase of road accidents and probability of traffic jams.

Since the transport system belongs to a class of large systems, the optimization of processes in them associated with the processing of large data and processes modeling. This involves the use the information and communications technologies. No coincidence that such research is united by a single term “Intelligent transport systems”. Along with the systems of artificial intelligence this area of research is one of the most dynamic and combines a variety of task classes.

Sustainability of transport systems of large towns and cities is determined by the stability of their constituent subsystems and sustainable linkages between them. This is largely ensured by quality control. Currently, the management of large systems create special tools such as decision support systems, expert systems and information control systems. Such systems are intended for purposes of strategic management, and to solve local tactical tasks. Rational management not only improves the economic performance of the system, but also solves social tasks by improving public transport services, as well as reduces the negative impact of the transport sector for the environment.

## 1. DESTINATIONS AND RESEARCH METHODS OF TRANSPORT SYSTEMS

Development of intelligent transport systems (ITS) methodologically based on a systematic approach, which creates ITS just as a system instead of individual modules (services). An integrated open architecture of the system are formed, together with protocols for information exchange, forms of transportation documents, standardization parameters of the technical means of communication, control and management, management procedures.

20 destinations of global action has been allocated to promote the use of ITS in the justification "roadmap" UNECE about ITS 2012-2020[5]. These directions envisage both actions to develop a common terminology and a common understanding the essence and objectives of the ITS, and measures to introduce developments in the field of ITS. This applies both to the technical component (the development of communication technologies: vehicle-infrastructure, vehicle-vehicle, integration of different modes of transport) and

[5] http://www.unece.org/trans/publications/its_sustainable_mobility.html, 18.12.2014

activities in the field of management and improving the safety of the transport system, including ecological and carrying out analytical work and the development of various techniques.

Research with use ITS can be carried out in several ways:

1. Analysis of real situations that arise on street and road network (e.g, accident, cleaning works) on a simulation model considering the average speed and traffic flow volume, time waiting in queues (delay in transit) of vehicles and passengers
2. The research of optimal solving problems motion control with choice changeable parameters (such as time of switching of traffic lights, the number of lanes, etc.). The objective function in this case may be the average speed at the analyzed site of the street and road network, the waiting time at intersections, etc.
3. Predicting the influence of changing the topology of street and road network (construction of bypass roads, the introduction of presence sensors vehicles at an intersection, change of types of intersections, etc.) on the important characteristics of the traffic flow.
4. The fight against traffic jams on the roads. This problem is solved by adjusting the intensity of motion in a given direction; for example, redirect the route of passenger transport to alternative roads.

Intelligence of transport systems is aimed at improving its safety and efficiency through information services, and through the means and methods allowing carrying out data mining and making decisions based on it. Considering ITS as an informational service, the study authors (Annino et al, 2005:9) report that primarily, such systems need to alert the driver about the parameters of traffic flow on the route. ITS means used to ensure safety of road users - in intelligent onboard systems (active safety systems) (Ivanov et al, 2002:6) and pedestrian detection systems (Truong Cong et al, 2011:14). Development of warning systems associated with the development of technology and communication infrastructure (Ma, Y. et al, 2009:16), which are used for traffic control (Zhou, Y. et al, 2011:14).

Assessing the significance of ITS for perfection the functioning of the transport system, the study authors note that ITS contribute to enhancing its effectiveness (Xia, J. et al, 2007:10), ensure sustainable development of the territories (Fengqi, Z., Jun, S. 2010:13), are used for reduce the negative impacts of the transport sector for the environment, as well as for reduce power consumption. Currently, ITS becomes a tool for transport planning, applied to conducting surveys (Tayyaran, M.R. et al, 2003:23), to reducing traffic congestion (Harb, R. et al, 2011:10) and planning joint visits (Gärling, T. et al, 2004:6). ITS helps to reduce accidents and ensures safe operation of transport systems (Jarašūnienė, A., Batarlienė, N., 2013:11).

## 2. THE RESULTS OF THE CITY TRANSPORT SYSTEM IMPROVEMENT

### 2.1. Conceptual design of Decision Support System

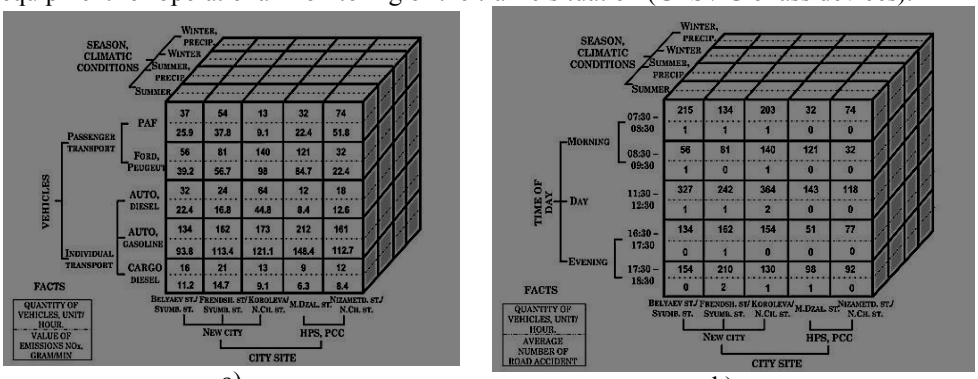
Since the quality of decisions on management of large systems depends on the quality of information, the adequacy of its analysis methods, as well as an effective tool for working with large data arrays, for these purposes are created decision support systems (DSS). These are computer automated systems that combine properties and capabilities of management information systems and database management systems. The information

retrieval, data mining, search of knowledge in databases, reasoning on the basis of precedents, simulation, evolutionary computing and genetic algorithms, neural networks, situational analysis, cognitive modeling are used in DSS for analysis and make recommendations. DSS which is based on methods of artificial intelligence, this is intelligent DSS, or IDSS. DSS design significantly depends on the type of tasks for which it is designed, from the available data, information and knowledge, as well as the users of the system. Herewith in the DSS distinguish three main parts:

1. Data system to collect and store information from internal and external sources, as a rule, the data repository.
2. Dialogue system that allows the user to specify what data to select and how to handle them.
3. System models - ideas, algorithms and procedures that enable you to process the data and analyze them. The user has the experience, knows the situation and guided by certain considerations when selecting data. In processing the data is used different procedures, from the simple summation to statistical analysis and nonlinear optimization.

Since the decisions are based on real data about the object, for analysis and strategic decision-making used the aggregated information for its storage a data warehouse (DW) is created. Multidimensional intelligent data model (OLAP-cube) is set in the control center of the traffic situation and is used to collect, store and formalization of road network parameters (Fig. 1).

For the correct playback the model of real situations requires operative information that may come from various sources: from the servers of municipal enterprises, from equipment for operational monitoring of the traffic situation (GPS / Glonass devices).




a) b)

***Figure 1.*** *OLAP-cube: a) measurement "mode of transport"; b) measurement "time of the day».*

Information storage in the form of OLAP-cube and its subsequent processing allows assessing the dynamics of street and road network on the different dimensions (number of vehicles, a section of road, time of year, the average speed, the presence of traffic lights, etc.) with high precision parameters. This makes it possible to predict probable changes in the situation on the city roads in subsequent periods, and choose the best solution and form a knowledge base of best solutions for fixed parameters of traffic flow and the

environment. Such databases are used for operational management decision-making in case of emergencies in the transport system.

Simulation models are often used as DSS intellectual core. This allows to make not only qualitative analysis of processes, but also to explore the effects of changes in the vehicle. Furthermore, it enables to select variant satisfying all the constraints and obtain system parameters optimal for the given conditions (Makarova, I. et al, 2013:11).

The software that is developing for this purpose allows to build models that display processes as they were in reality, and then carry out a series of virtual experiments, setting the model time. It is possible to study the process by using a single test, or setting their array, which allows finding the optimal process parameters. The results will be determined by random nature.

## 2.2. Design solutions for the improvement of the street and road network in Naberezhnye Chelny.

The studies were conducted in the city of Naberezhnye Chelny - the second largest and largest city of the Republic of Tatarstan. This big industrial center and a major transportation hub of the country. Like other big cities, Naberezhnye Chelny are characterized by growth of motorization, and each 1 thousand residents of the city have about 300 cars. The transport planning structure of a city is made by the longitudinal highways connecting residential areas of a city that gives the grounds to carry floor-plan diagram of a city SRN to the rectangular. According to the destination and to transport loads, the most important existing transport highways of a city are the following streets:

- In longitudinal direction: Musa Dzhalil avenue, Naberezhnochelninsky avenue, Mira avenue, Moskovsky avenue, Syuyumbike avenue, Chulman avenue;
- In latitudinal direction: Korolyov street, Druzhby Narodov avenue, Hasana Tufana avenue, Vahitova avenue, Avtozavodsky avenue, Yashlek avenue.

These mainline streets, perform the functions intercity flow distribution of mass passenger and freight transport, service the surrounding areas and delivery of workers to their working places. Since the city is actively developing, the following tasks of analysis and forecast passenger and traffic flows on street and road network of the city are relevant:

- Assessment of planning decisions on the transport parameters: assessment of planning decisions on the transport parameters: the level of loading areas and nodes, speed of posts, availability, number of accidents.
- Identification of sites and nodes of the street and road network requiring redevelopment (change of geometrical parameters, the adjustment of modes of traffic lights).
- Determining required capacity of reconstructed and newly constructed sites and nodes.

Optimal method for solving the aforementioned problems is simulation modelling. For the adequate description the current situation, the preparatory phase includes:

- Collect information about the city as a whole.
- Charting the existing street and road network of the city.
- Exploring plans for the reconstruction of street and road network.
- Monitoring of passenger traffic and transport flows.
- Collect data on the level of air pollution by motor transport on city roads.

For working with database was developed a set of software modules, including special forms of information gathering. They systematize groups of factors that affect the situation on the road, and also provide general data necessary for statistical analysis (Fig. 2).

To investigate the problem areas and zones of the street and road network simulation model of the city was developed. For constructing a simulation model we used data statistical analysis of information obtained from natural observations. This allowed performing verification and ensuring accuracy of the forecast at carrying out optimization experiments, which was in average 95-97%. Thus, in the justification of the need to change the topology of the street and road network you can obtain optimal solutions without resorting to full-scale experiments. It gives the opportunity to make recommendations on the development of the street and road network of the city and in planning activities for its development.

Analysis of the concentration areas accidents with subsequent experiments on the model showed that incorrect or irrational planning decisions may not only adversely affect the efficiency of the transport system, but also to create emergencies for certain parameters of traffic flow.

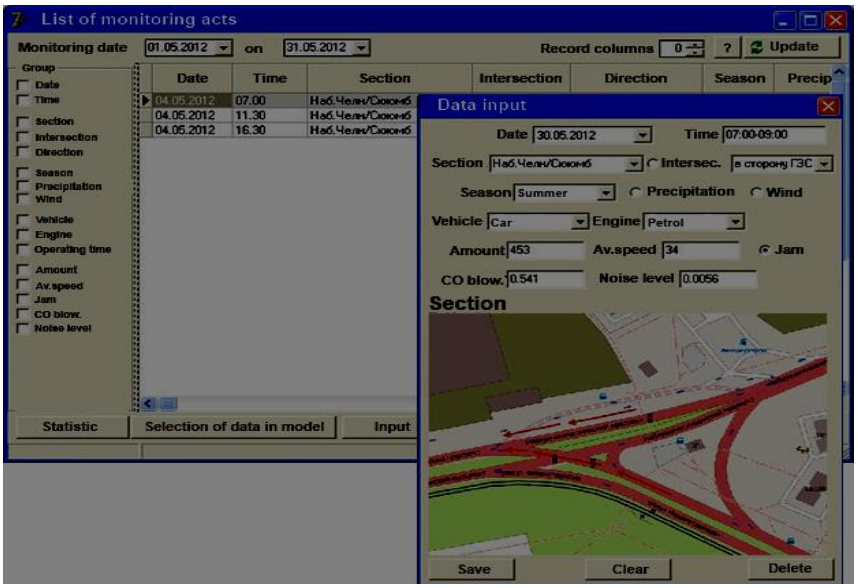



***Figure 2.*** *The program module for filling and analysis of transport streams parameters*

One of the problem areas is a complex road junction formed by the intersection of Mira avenue, Druzhby Narodov avenue and Syuyumbike avenue (Fig. 3). Road accident statistical analysis showed that this site is a place with its high concentration. This creates problems for the proper functioning of the transport system and the environment, as constant traffic congestion situations worsen negative impact of transport on the environment. Changing the configuration of the tram network created additional problems on this site. To reduce the accident rate in this area, it was decided to change the configuration of SRN. The experiment that conducted on the model, showed that at the

same traffic flow volume a speed rate of road section would increase by approximately 10%, and the probability of road accidents decreased by 16%. And the number of conflict points also decreases(Figure 3).

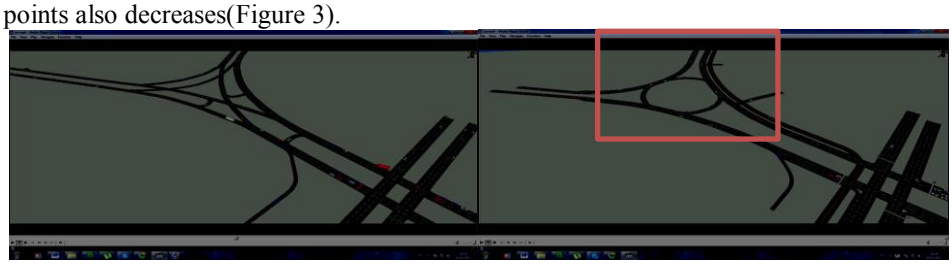


***Figure 3.*** *Changing configuration of a complex road junction*

Another place of traffic accidents concentration is the site behind the crossing of Mira avenue with Vakhitov avenue, which represents a two-level road junction. High traffic volume in this sector driven by several factors (Fig. 3):

- Flow is formed through the merger of flow moving in the forward direction on Mira avenue (1), and two flows with the interchange at Vakhitov avenue (2, 3);
- The area of Mira avenue from Rais Belyaev avenue to turning after the Vakhitov avenue has not traffic lights, so the traffic flow volume is nearly constant.
- Several public transport stops are located at the specified site, which also affect the traffic flow volume.

Experiments carried out on models showed that in significant traffic flow volume during peak hours there is a high probability of occurrence of emergencies, which is confirmed in practice. For this area required redevelopment of the street and road network in accordance with the actual parameters of traffic flow.

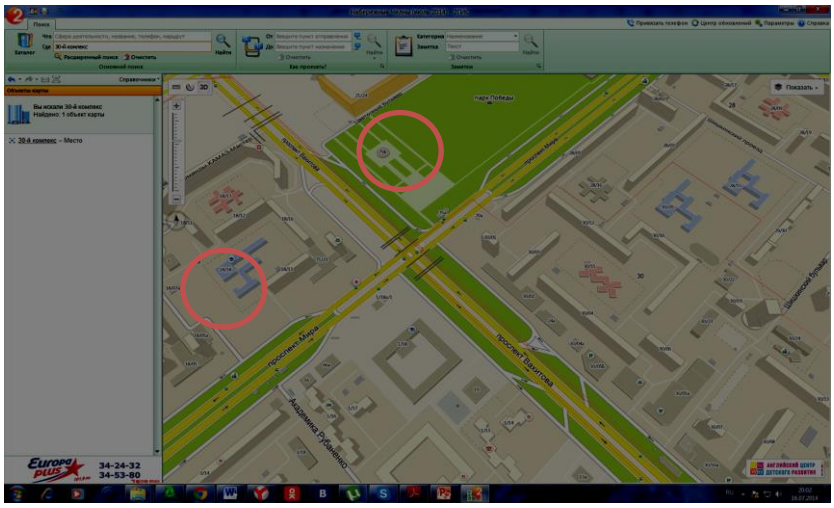


***Figure 4.*** *Place of concentration of traffic accidents*

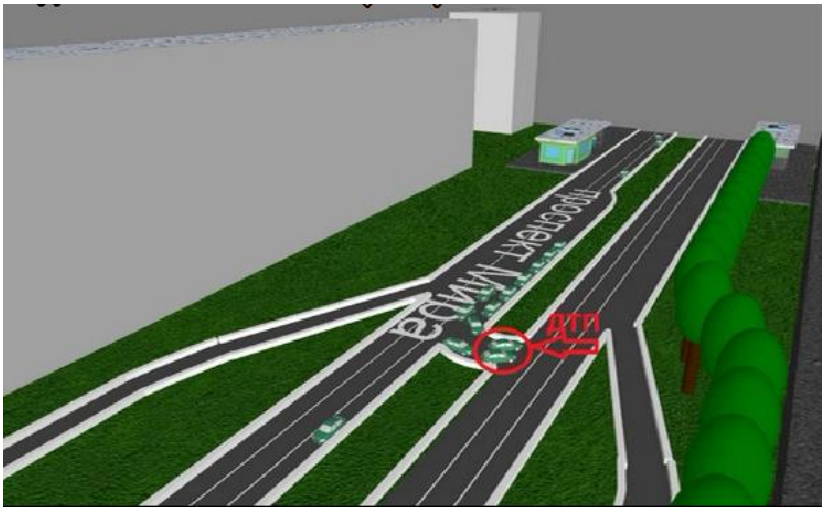



***Figure 5.*** *Incident imitation on a U-turn (number of cars – 10, average speed – 18 km/h)*

## 3. CONCLUSION

Proposed variants for SRN reconstruction after careful study were agreed with the traffic police and some of proposals have already been implemented. It allows to increase TS safety of the city, as well as to reduce the negative environmental impact on the environment.

The examples made here show that simulation modeling is a good tool for decision-making on increase of TS functioning safety and efficiency in a city. Thus, in redevelopment of urban areas, construction of new attraction centers, planning of new transport infrastructure, simulation models contribute to finding optimal solutions and help avoid serious errors.

## 4. BIBLIOGRAPHY

[1] ITS for sustainable mobility. Geneva (2012) 123 p. URL: http://www.unece.org/trans/publications/its_sustainable_mobility.html, 18.12.2014
[2] Annino, J.M., Cromley, R. (2005). Intelligent Transportation Systems and Travel Behavior in Connecticut. The Professional Geographer, 57(1), 106-114.
[3] Ivanov, V., Boutylin, V. (2002). The intelligent systems of automotive active safety. Transport. 17(5), 182-187.
[4] Truong Cong, D.N., Khoudour, L., Achard, C., Bruyelle, J.L. (2011). Intelligent Distributed Surveillance System for People Reidentification in a Transportation Environment. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 15(3), 133-146.
[5] Ma, Y., Zhoub, Y., Chowdhury, M., Wangb, K.C., Friesc, R.N. (2009). A Framework for Performance Evaluation of Communication Alternatives for Intelligent Transportation

Systems. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 13(3), 111-126.

[6] Zhou, Y., Evans, G.H., Chowdhury, M., Wang, K.C., Fries, R. (2011). Wireless Communication Alternatives for Intelligent Transportation Systems: A Case Study. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 15(3), 147-160.

[7] Xia, J., Chen, M. (2007). Defining Traffic Flow Phases Using Intelligent Transportation Systems-Generated Data. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 11(1), 15-24.

[8] Fengqi, Z., Jun, S. (2010). Deploying an Intelligent Transportation System in Chongming County, Shanghai Journal of Urban Technology, 17(3) Special Issue: Urban Sustainability in China, 39-51.

[9] Tayyaran, M.R., Khan, A.M., Anderson, D.A. (2003). Impact of telecommuting and intelligent transportation systems on residential location choice. Transportation Planning and Technology, 26(2), 171-193.

[10] Harb, R., Radwan, E. Abdel-Aty, M., Su, X. (2011). Two Simplified Intelligent Transportation System-Based Lane Management Strategies for Short-Term Work Zones. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 15(1), 52-61.

[11] Gärling, T., Jakobsson, C., Loukopoulos, P., Fujii, S. (2004). Adaptation of Private Car Use in Response to Travel Demand Management Measures: Potential Roles of Intelligent Transportation Systems. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 8(4), 189-194.

[12] Jarašūnienė, A., Batarlienė, N. (2013). Lithuanian road safety solutions based on intelligent transport systems Transport, 28(1), 97-107.

[13] Makarova, I., Khabibullin, R., Belyaev, E., Zhdanov, D. (2013). Intellectualization of transport systems for the benefit of safety and the sustainable development of territories. Journal of International Scientific Publications: Ecology&Safety, 7(3), Bulgaria. 189-199. http://www.scientific-publications.net/ download/ecology-and-safety-2013-3.pdf