

Increase of City Transport System Management Efficiency with Application of Modeling Methods and Data Intellectual Analysis

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Abstract To provide transition to “green economy,” it is necessary to increase the safety and reliability of transport system using Intelligent Transportation Systems. The modern intelligent transportation systems implementation requires communications, command, and control designed originally in vehicles and infrastructure. This paper makes the decision by perfecting vehicle and infrastructure of the transport system. A different way is to use rational management decisions based on the received real-time information. The paper also offers methods to improve the efficiency of the urban transport system.

1 Introduction

Positive changes in shape of world transport in 21 eyelids are accompanied by a number of negative consequences to which number growth of power consumption and negative influence on the environment, constantly growing delays of people and freights on all means of transport which are connected not so much with an objective lack of transport infrastructure capacities, how many with low level of transport streams organization and management belong. Scales and the importance of these problems are estimated as strategic calls national and even continental scale.

All these negative consequences contradict the principles of a sustainable development which the commission of the UN on a sustainable development defined as the society development, allowing to satisfy requirements of present generations, without causing thus damage to the opportunities left in inheritance to future generations for satisfaction of their own requirements [1]. The commission of the UN also defined various aspects of a sustainable development ensuring principles, among which major—the principles of territories sustainable development as the urbanization is one of the key factors influencing development of the modern world.

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The decision found today World transport community, consists any more in creation of control systems by transport, and in design and realization of such transport systems in which means of communication, management and control are built initially in vehicles and objects of infrastructure. In such systems of management (decision-making) possibility, on the basis of information received in real time, have to be available not only to the operators controlling transport, but also all participants of traffic. Problem of such system—integration of traffic all participants interaction: people—transport infrastructure—vehicles, with the maximum use of the latest management information technologies.

In the last decade the phrase “Intelligent Transportation Systems” and the corresponding abbreviations—ITS—became usual in strategic, political and program and target documents of the developed countries. Because the control of such systems is based on the analysis of data large amounts, and decisions must be made often in real time, it is important to provide the opportunity for professionals involved in developing strategies for the development of transport systems and operational planning processes.

While the processes of “intellectualization” affect all the objects of the transportation system: automotive, transport infrastructure such as traffic control, road network), and the object movement control (monitoring parameters of traffic flows, means of movement informing participants, and others). Development and improvement of these tools are aimed at increase of the transportation system functioning efficiency and the safety of all road users.

2 Strategy of UNECE in the Field of Intelligent Transport Systems Development

2.1 Role of Intelligent Transport Systems in a Sustainable Development of Territories

The rapid development of technologies that is a characteristic feature of the world economy in the new millennium requires significant amounts of resources and causes the appearance of an increasing number of sources of negative impact on the environment. In addition, the globalization of industrial production, the growth in the number and size of megacities, causing the necessity of organization of the movement of passengers and cargo, increase the volume of emissions of harmful substances into the environment as well. At the same time, an increasing number of adherents of transition to a green economy is growing, initiating the development of strategies and policy documents on sustainable development (SD) in all spheres of human activity.

The publication of the report “Our common future” of the world commission on environment and development in 1987 is considered to be the beginning of international discussions on SD [2]. In the new millennium a number of documents was adopted that identified new targets, the need to achieve which was caused by negative impacts of urbanization, development of the real sector of the economy

and often unjustified harmful human impact on the environment. The most significant of these documents are the following: the report of the UNEP Global green new deal (2009) [3, 4], and the Declaration of the summit Rio +20 “The Future we want” (2012) [2]. The major criterion of a sustainable development in the world is achievement of strategic balance between activity of the person and maintenance of reproducing possibilities of biosphere [6]. It is especially important for regional development since the region is the open difficult dynamic social ecological and economic system functioning under the influence of internal factors, realized through local governments, and external, caused by state economic and social policy [7].

Migratory activity of the population sharply increased in the XX century in connection with improvement of vehicles, time reduction in a way between settlements and the actual removal of distances problem when the globe became possible to be crossed in two 12-hour flights, worldwide.

The migrating population actively participates in economic and social life of the countries, and development of transport system directly determined economic recovery. So, after World War I Germany left crisis, including, at the expense of serious capital investments in development of a transport network, having solved, thus, a problem of unemployment and having provided economy development. In the advanced industrial countries the increase in transport mobility of the population was a direct consequence of its business activity growth.

Speed of construction automobile and tracks in the world since 1996 remains at a stable level—the gain of roads makes to the extent about 1.3–1.4 % a year.

In parallel time which the person spends on the way grows. By the XX century end for the city person there is actual a problem of jams—in 1990 time in a way to work one way in industrialized countries exceeded 20 min. In the most loaded megalopolises of 90 % of daily migration participants reach the downtown, creating jams and multikilometer traffic jams in rush hours.

The key question for the modern megalopolises of Russia consists in compliance of movement implementation requirements and opportunities. From the scientific point of view mobility is defined as mobility and ability to fast movement, opportunities for what on streets of big cities of our country every year becomes less. In this regard, the scientific community is anxious with the solution of questions: what it is possible to make for elimination of periodic collapses in the Russian cities and what already becomes of them for this purpose?

At the international seminar devoted to a sustainable development of city transport systems, the manager of department “Scientific ensuring development of the city transport complex” State Unitary Enterprise NIIPI Genplan of Moscow, Candidate of Technical Sciences Elena Borovik noted that from the philosophical point of view transport represents the dual and inconsistent phenomenon as only the transport sphere at the same time belongs and to productive forces of society, and at the same time to a services sector [8].

Transport allows to reveal mechanisms of the person activity, promoting understanding of town-planning, social and other processes. However, transport takes away from the citizen an invaluable and irreplaceable resource—life. The last researches NIIPI of the General plan of Moscow showed that in transport of people carries out

no more than 2 daily rated hours, and till 4–6 o'clock. And if city authorities can't achieve that the person reached from the house work in 5, 15 or 30 min, they should create comfort and in public transport, and in the privately owned vehicle.

Some directions of the listed problems, including, strategy of ensuring steady city mobility exist and is considered. It has increase in the amount of the transport sphere financing, and a system integrated approach to development of transport system development strategy, and introduction of the latest technologies in the transport sphere, and even work on established opinion change about guilt of designers in existence of a transport problem.

Around the world long ago, as theoretically, and on the basis of practical experience, the inefficiency of a road network productivity jams and increase elimination problems the solution by only traditional ways—physical expansion of road network and installation of traffic lights is proof. Even the developed countries can't expand a road network with the rates comparable to rates of vehicles gain. Innovative break in the solution of transport problems is necessary.

It doesn't exist and can't exist to generalize for every country and the cities of complex transport problems solution which the modern world faces. However, unprecedented development in the second half of the 20th eyelid of information and communication technologies opened for this purpose new opportunities. In the world active process of formation and development of the Intelligent Transport Systems (ITS) in transport sector of economy which led to obvious improvements in all means of transport work, in all countries where due attention was paid to it.

Intelligent transport systems are recognized in world practice as all-transport ideology of telematics achievements integration in all types of transport activity for the solution of economic and social character problems. Almost 20 years' experience of purposeful development of ITS in the USA, Japan, in the European union, China and other countries where serious successes are already achieved testifies to it, there were rather effective forms of stimulation and management of this process. Introduction of ITS has strategic character, defines as a whole competitiveness of the country in the world market. The transport policy of the developed countries of the world is based on development and advance of ITS-technologies, common information space creation in future multimodal networks.

Development of machinery and technologies, means of communications, and also globalization of economy are provided with dynamical development of transport and road branch, uniting transport systems of regions and the countries. In the report on a traffic security status in the world, prepared by World Health Organization (WHO), is underlined that «... promoting movement of the goods and people, road transportations benefit both to the countries, and separate persons. They facilitate access to workplaces, the economic markets, education, recreation centers and entertainments and to health services that, in turn, directly and indirectly has positive influence on population health. Nevertheless, growth of road transportations creates also considerable burden for health of people—in the form of a road and transport traumatism, diseases of respiratory tracts and consequences for the health, caused by reduction of physical activity. Air pollution, emissions of hotbed gases, consumption of non restorable resources, the

household inconveniences caused by the neighborhood with a busy highway, and noise have number of additional negative economic, social and ecological consequences of movement of people and the goods on roads» [9].

Considerable growth of intensity of movement in city streets involves deterioration of traffic conditions, leads to growth of number of road and transport incidents (road accident) and victims in people, and also to sharp deterioration of level of transport service of a city as a whole. As researches show, ecological and social costs (the expenses connected with local air pollution, road and transport incidents and stoppers) can reach 10 and more percent of gross national product of region or the country and considerably to exceed the sums necessary for initiation of transition to “green” economy [10].

The sustainability of transport systems in large cities and megapolises is determined by the stability of their constituent subsystems, as well as the stability of relationships between them. This stability is ensured, to a considerable extent, the quality of governance. Now for the management of large systems, which also include transport, special instruments are created, such as decision support systems, expert systems and management information systems. Such systems are designed for the purposes of strategic management, as well as for solutions for local tactical tasks. Rational control allows not only to improve economic performance, but also to solve social tasks on improvement of transport service of the population and reduce the negative impact of the transport complex on the environment.

Intelligent transport systems are increasingly seen as one of the components of solutions to current and future problems in the field of transport. Recognizing ITS as an effective tool for achieving safe and inclusive sustainable mobility, their important role in promoting the growth of life quality is celebrated. In 2003 the Inland Transport Committee (ITC) of the UNECE has identified the use of telematics and intelligent transport systems (vehicles, infrastructure) as priority areas. For development of this direction in 2004 under the auspices of the world forum for harmonization of rules in the field of transport vehicles a round table on the ITS was organized, which has contributed to the preparation of the UNECE strategy on the development of a framework and practical implementation of the ETS.

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In world practice Intelligent transport systems are considered as service system of service to users—drivers, pedestrians and cyclists, passengers of public transport, carriers, transport operators, services of transport infrastructure operation,

emergency services. At the same time, in society there is no uniform understanding of this term, it leads to that at regional levels commercial projects of the ITS local components ideologically and technologically not interconnected are realized. Lack of system approach to implementation of the ITS national projects blocks development of their market, stopping it at the level of rendering commercial services with use of the ITS local components.

Assessing the value of ITS for better functioning of the transport system, the authors of scientific developments note that ITS enhance its effectiveness [11] provide sustainable development of the territories [12], are used to reduce the negative impact of the transport sector on the environment and to reduce energy consumption [13]. At present, ITS becomes a tool of transport planning and is used for surveys [14], to decrease congestion [15] and planning joint travel [16].

For coordination of actions on introduction of ITS and development of policy in global research ITS in 2008 for the purpose of awareness increase and informing of politicians and the high-ranking politicians on technical and political aspects of ITS advance the International road federation committee on policy of ITS was founded. The committee studies advantages of the international cooperation and promotes removal of ITS problems for the general public, helping to develop effective strategy and, finally, successfully to introduce Intelligent transport systems. Directions of work of Committee:

- practical realization of ITS and corresponding political tasks;
- ITS financing;
- researches in the field of ITS, and also educational and social problems;
- standard and legal base for ITS;
- development of ITS of strategy and comparative analysis.

Mission of ITS International road committee on policy Representation and Committee is increase of ITS role awareness and understanding level, support of the bodies making decisions in advance of ITS as the effective instrument of transport policy in the field of safety objectives achievement, stability and efficiency, an exchange of experience between experts in the field of ITS from all over the world.

ITS development methodologically is based on system approach, forming ITS as systems, instead of separate modules (services). The uniform open architecture of system, protocols of information exchange, form of transportation documents, standardization of communication used technical means parameters, control and management, management procedures, etc. is formed.

National concepts of ITS development, national architecture of ITS and the development program form an organizational and methodical basis of ITS development, however, in most cases ITS is considered as service system, with all that it implies. So, for example, considering the conceptual scheme of ITS creation, by the general purpose determine the organization of transport all means interaction system form, the most effective use of a transport resource at the expense of joint transport operations with the most rational versions of structural and line schemes of movement of passengers and freight traffics, providing quality of transport

services. Such approach is directed not on elimination of the above described problems, and on elimination of current situation consequences that in itself is incorrect.

2.2 Directions of Transport System Safety Increase

In the rationale of the “road map” of the UNECE of ITS in 2012–2020 [17] 20 directions for global action to promote use of ITS were allocated. These areas include steps towards a common terminology and a common understanding of the essence as well as tasks of the ITS and development implementation in its field. This applies both to the technical component (the development of technologies of communication vehicle–infrastructure, vehicle–vehicle; integration of different modes of transport) as well as to the activities in the field of management and improvement in the security of transport systems, including the environmental, analytical work and development of various techniques.

The importance of this direction is shown due to the numerous activities and analytical reports that are dedicated to improvement of transport system in general and the issues of transport security in particular. This security is understood in the broadest sense—from reducing the number of accidents and negative impact on the environment to the creation of “green” jobs in the transport sector.

Considering sharpness of the problems existing in a transport and road complex, and also need of their immediate decision, on a past on June 7–8, 2012 at Research institute of the motor transport in Moscow the International seminar “A sustainable development of city transport systems: calls and opportunities” were discussed such questions, as:

- Transport problems in the largest cities of Eastern Europe and the CIS countries;
- Principles of city transport systems providing a sustainable development: best practices and practice of the states of the CIS;
- Role of the national governments in ensuring city mobility steady and favorable for health;
- Infrastructure development, the organization of public and passenger transport services quality work and improvement—the only real alternative to use of cars and preservation of an urban environment;
- Parking policy: experience and decisions in the largest cities;
- Introduction of ITS as instrument of transport streams and traffic safety increases effective management increase;
- The analysis of public transport and cycle movement for land granting priorities the allocated strips and other methods organization experience: positive effects and possible problems;
- Use expansion ecologically “purer” vehicles and fuels in the cities.

Considering the situation which has developed both in Russia, and in other countries, it is possible to note unity of the purposes as producers of automobile

equipment, and enterprises for creation and service of road infrastructure most important of which is increase of safety and comfort of movement, satisfaction of freights and passengers requirements for movement and decrease in negative impact on environment.

Experience shows that good results are yielded by only system approach to the solution of such complex problem, as ensuring steady functioning of transport system. Along with the artificial intelligence systems this field of research is one of the most dynamically developing and unites different classes of tasks.

Since the sustainability of the transport system in many ways is a guarantor of sustainable and economic development, ensuring quality control is a priority during the solution of the problems connected with the intellectualization of its sub-systems and objects.

In addition, numerous objects of the transport system are sources of increased danger for road users and the environment. This applies to vehicles, the objects of the road network, infrastructure, providing the transportation process. The greatest problems are road traffic accidents, especially those connected with human victims. Numerous state programs illustrate the urgency of this problem. In different countries use various approaches to safety on roads. Striking example—Sweden which, after acceptance in 1995 of the law on traffic safety builds strategy of traffic safety reforms on the basis of Zero mortality Concept approach [16]. The vision zero regards road transport system as a whole, the components of which (roads, cars and pedestrians) guarantee the safety of each other. In the official publication of the Swedish road administration it is stated that the concept is in the responsibility for safety rests with all of the creators of the transport system: the road services, manufacturers, carriers, politicians, government officials, legislators, and the police.

Measures to provide road safety can be divided into two big groups of measures to prevent accidents and measures aimed at reducing the severity of their consequences (Fig. 1). Since a large portion of accidents associated with the «human factor», numerous developments of manufacturers of automobile electronics are designed to alert traffic participants and specialists in traffic management. First of all, this system alerts the driver of the parameters of traffic flow on the route [18]. The works of a great number of researchers are dedicated to the analysis of trends and development prospects of ITS [19–22]. ITS means are used to ensure the safety of road users—in intelligent vehicle systems (systems of active safety) [23] and systems of pedestrian recognition [24]. The development of warning systems is associated with the development of technology and communications infrastructure [25], which are used for traffic control and traffic management [26].

ITS helps to reduce accidents and the safety of transport systems [27]. Because of the fact that ITS technologies are creating applications and systems for traffic management and accident prevention, they reduce the workload on the driver, preventing his overloading [28].

If to analyze documents and development in the field of ITS, it is possible to find distinctions in understanding of the term. As a rule, one group of authors considers ITS as a way of administrative measures for traffic streamlining

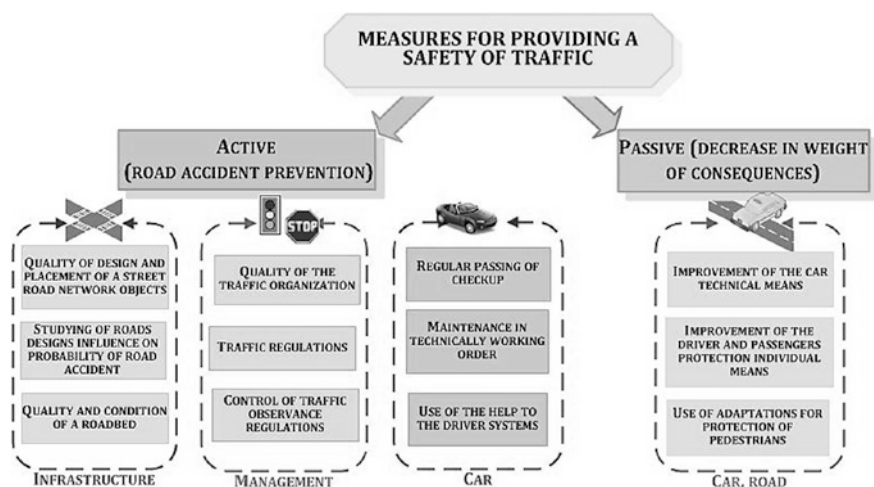


Fig. 1 The classification of measures for providing safety of road traffic

intellectualization. And in most cases measures are directed not on realization of “feedback” principle, and on the notification of movement participants, at the best—control of violations and reaction in the form of fiscal character taking measures. The second group of authors considers ITS as the way “intellectualizations” of the car. Though, there is also other term—IOS (intellectual onboard systems).

In world practice five main groups of ITS users are defined: drivers, pedestrians and cyclists, passengers of public transport, carriers, transport operators and services of transport infrastructure operation. Apparently from the specified list, neither about the car, nor about infrastructure (road) there is at all no speech while these two components just create problems.

3 Prospects and Risks upon Transition to “Green” Transport

The UNEP report [4] states that in order to reduce transport emissions of greenhouse gases it is required to increase the efficiency of energy use and to refuse energy-consuming vehicles both passenger and freight transport. To achieve economic goals and objectives of sustainable transport development and integrated planning of its development and regulation system load, you need to switch to fuels with lower carbon content and to implement a more extensive electrification of transport. As one of the ways of moving towards more sustainable transport it is proposed to include “green” conditions to the assistance plans to the car manufacturers, providing targeted investments aimed at increasing saving motor fuel, as well as for research in the development of more affordable on-board energy storage devices.

Part of measures to ensure the sustainability of transport can be planning for urban and suburban centers in accordance with development, providing for a mixed fleet of vehicles and reasonable growth. Such principles of urban development will help to reduce dependence on private vehicles and to ensure widespread use of public and non-motorized transport for short trips and for regular commuting into the city from the suburbs.

Taking into account that transport is an important economic sector in which only the European Union has over 16 million people, and its direct contribution to GDP of the EU reaches 11 %, it can play an important role in meeting new global challenges, “green economy”, developing new directions in the field of job creation and economic development. Moreover, having a high level of socio-economic significance, clean transport can play a positive role in improving the health of the population, ensuring a cleaner environment, improved the quality of life and achieving higher rates of economic growth. And thanks to the innovative transport policy it is possible to achieve the maximum positive effect for the environment and human health. Providing access to goods, jobs, services, education and entertainment through environmentally friendly, healthy, economically and socially sustainable transport system is a key factor in improving the environment and quality of life, economic and social growth.

Starting from the 80s, the United States, Europe and the Asia-Pacific region purposefully and systematically promote the ITS as a central theme in the implementation of transport policy, but the implementation of ITS on a global scale has become possible only in conditions of saturated communication space, when there are no serious technical problems with the transfer of large volumes of digital information in real time at any point in the transport network. Development of ITS is methodologically based on a systematic approach, forming the ITS as a system and not as a separate modules (services). Approaches to the creation of ITS is based on the principle of modernization, reengineering of the existing transportation systems.

Today in the world's leading countries was formulated legal and regulatory framework was debugged process of strategic and ongoing planning of ITS development. Special organizational structure was created. Process of budget financing development and implementation of pilot projects of ITS deployment worked out at the national level. Experience of EU countries, the USA, Japan, China and other countries in the promotion of ITS projects, shows that in a market economy only a single state policy allows you to combine the efforts of the state and its subjects, business at all levels and sectors of the economy in addressing national goals in the transport sector. An important role in the dissemination of knowledge and experience in the development of ITS, establishing contacts in the global community of ITS play annual global and European Congresses of ITS accompanied by exhibitions and educational programs.

One of the main directions of ITS, which is actively promoted by the last 15 years—the realization of the concept of intelligent vehicle. International program “Vehicles with Advanced Security” operates. Even the first experiments of using the airborne intelligence systems have shown that they are able to reduce

the number of accidents by 40 %, while the number of fatal accidents—50 %. In December 2008, the European Commission formally adopted an action plan on introduction the ITS in Europe and presented the draft directive, which creates a legislative basis for its implementation [2]. Due to the fact that the ITS can significantly contribute to the formation of a more environmentally clean, safe and efficient transportation system, was set the goal to accelerate the penetration in the European market that need to deploy the ITS software and hardware, which degree of development has been assessed as sufficiently mature. This initiative was supported by five general directorates, working closely with each other: for Energy and Transport, Information Society and Media, Research, Enterprise and Industry, as well as the environment. Action Plan for the introduction the ITS is based on a number which is in the process implementation of the initiatives of the European Commission, including the Action Plan on Freight Transport Logistics; Action Plan for the development of intra-urban mobility (Action Plan on Urban Mobility); introduction of the navigation system Galileo; Complex of measures to increase the environmental performance of transport (Greening Transport Package); 2010 initiative on intelligent vehicles, the program of implementation of the system eSafety; The 7th Framework Program for Research and Technology Development; program of introduction of the system eCall; program “European Technology Platforms”.

Intelligent Car initiative which was launched in October 2008, aims to prevent road accidents involving two or more cars with the use of communications systems car-to-car, allowing to continuously monitor the vehicular traffic from special centers that can provide early warning about the dangers of collision [29]. For this control system, which can also warn of traffic jams, the potentially adverse road conditions, sudden changes in the weather, in most EU countries have already begun to reserve frequency range. In addition, these frequency bands for future vehicle communication systems have already been reserved in the United States and Japan.

According to the experts, the development of this system in the near future is likely to lead to the emergence of a standard system, in which each vehicle on the road will be connected with the rest of cars. Technology has the potential to create a world without real driving with on-board computers and system GPS, controlled from a single center of movement control.

Within the project e-Merge, which ran from April 2002 to March 2004 was developed specification of electronic system emergency service eCall, which in the case of an accident provides the ability to automatically notify a special public service and send a voice message. In December 2008 the European Commission instructed the organizations involved in the activities of the Forum eSafety to develop a plan of implementation of eCall.

Action Plan implemented within the framework of initiatives to reduce the adverse impact of transport on the environment (Greening Transport Initiative), aims to accelerate deployment of these systems in road transport, as well as their development of its interaction with other modes of transport. All road users, from passengers to freight carriers, need the reliable traffic information provided in real time for more effective planning routes and to avoid delays caused by traffic jams.

The introduction of the ITS plays an important role in the “greening” of transport. As one of the ways to influence on transport demand can be applied differentiation of charges levied by electronic payment systems for the passage of vehicles on certain routes. Furthermore, application of ITS for travel planning, dynamic navigation and support for the regime economically and eco-driving helps eliminate congestion, providing mobility with less harmful impact on the environment and reduce energy costs.

Relying on advanced technology ITS has a large value and to achieve the objectives which are placed in the framework of the EU to create a “Green transport corridors.” This initiative involved promoting the concept of integrated freight transport, where different modes of transport complement each other in order to provide a more ecologically safe alternatives to long-distance transport between logistics centers.

ITS, according to the European Union, can create clear benefits in terms of efficiency of the transport system, its stability and security, while at the same time, contributing to the development of the EU internal market and competitiveness.

As noted in the documents of the European Commission, since the 80s the last century in Europe implemented a number of activities in this area. However, these measures are often have uncoordinated and fragmented nature. In addition, they have traditionally been aimed at solving specific problems, such as ensuring the ecological compatibility and energy efficiency of transport, congestion on the roads, traffic management, road safety, and safety of commercial vehicles and also the mobility of the urban population. At the current stage of development of these systems in Europe are considering the most urgent tasks: geographical continuity, interoperability of systems and services and standardization.

Currently, service that provides real-time information about traffic conditions and optimal routes trip (Real-time Traffic and Travel Information (RTTI)) contributes significantly to the growth of population mobility. This information (increasingly combined with the services of satellite navigation) is now offering both public and private sources.

In many parts of Europe ITS have become the foundation of effective management of traffic on intercity and urban routes facilitating the development of a flexible system to switch from one to another mode of transport in major transportation hubs. In the longer term is expected to reveal the full potential of the system arranged on the principle of cooperation between members of the movement, and infrastructure elements, which include systems that provide communication and information exchange between vehicles V2V (vehicle-to-vehicle), between the transport facilities and infrastructure V2I (vehicle-to-infrastructure) and between the different elements of infrastructure I2I (infrastructure-to-infrastructure). If necessary, these systems will be complemented by system of location determination and time Global Navigation Satellite System (GNSS).

Vice-President of the European Commission, Antonio Tajani, responsible for transport commented the decision of 16 December 2008: “Ensuring of ecological compatibility of transport, reducing congestion and saving lives on European roads are priority for the Commission. Intelligent transport systems will help us to

make progress towards achieving these goals. Today's initiative will contribute to a more efficient, safer and more sustainable mobility in Europe".

Viviane Reding, EU Commissioner for Information Society and Media, in turn, said: "The proposed by the Commission Action Plan for the introduction ITS will provide much-needed policy instruments in addition to the work carried out in the framework of the "Intelligent Car" and the eSafety Forum to make cars safer, cleaner and more "intelligent".

As noted in the documents of the European Commission, the potential of ITS can be fully revealed only when it will be implemented in Europe not occasionally and locally, as it is today but on a European scale. In this regard, the removal of existing obstacles to the deployment of the system acquires key value.

Structure of the European Union called upon to play a significant role in creating an enabling environment for accelerating coordinated deployment of ITS: the definition of political priorities, the selection of nonproprietary components for sharing or reuse and harmonization of clear timetable.

The European Commission believes that the complex of measures implemented across Europe will contribute directly to:

- solving the problem of the complexity of the deployment of ITS, arising from large number of stakeholders and the need for synchronization, both geographically and among the various partners;
- the market penetration of the most modern means of ensuring the mobility of the population and the development of public transport as an alternative to private transport;
- creating conditions for reducing costs and risks, as well as reducing the time of implementation of ITS;
- accelerating the pace of deployment of ITS in road transport, as well as ensuring ubiquitous availability of services throughout the EU;
- strengthening of leading role of European companies involved in the deployment of ITS in the world markets by stimulation of supply of innovative products and services for vehicle manufacturers, transport operators, logistics providers and users.

To achieve these objectives, the European Commission plans to use the financial support, standardization initiatives, legislative and other measures.

The Action Plan also contains a draft directive of the European Parliament and the Council, which lays down the general scheme of the introduction of ITS. Six priority areas were identified; each of them has a specific list of activities and a clear timetable for their implementation:

- optimal use of road, and data on travel and nature of traffic;
- continuity of traffic management and freight transportation. ITS services on European transport corridors and in conurbations;
- traffic safety and transportation security;
- integration of the vehicle into the transport infrastructure;
- security and data protection and also liability issues;
- European cooperation and coordination of activities in the field of ITS.

First direction: you have to know, where you ride

Measures provided in framework of the first lines of action were developing taking into account that many of the relevant modern level of development in the field of ITS are based on accurate information as to the characteristics of the road network, and the applicable regulations (For example, mode of one-way traffic and speed limits). In those cases, when it comes to road safety, it is extremely important that this information has been confirmed and available to all participants on a fair and equitable basis for the safe and orderly management of the movement.

This applies in particular to creation of electronic terrain maps, including the necessary processes of collecting, testing and timely update of data.

Second direction: ITS for everyone and everywhere

In keeping with the second direction of the Action Plan for the implementation of ITS in Europe is planned to ensure the continuity of traffic management and freight traffic and availability of ITS on European transport corridors and in urban areas.

Imposition of restrictions on the use of certain routes or transit through the certain areas are increasingly based on a number of different parameters such as vehicle dimensions, emission levels, distance and time of day. Solutions incorporated in the ITS and providing for the use of satellite positioning and mobile communications offer new opportunities for such regulation of access to infrastructure.

Third direction: the security of people, vehicles and cargoes

The third direction of the Action Plan for the implementation of ITS covers the measures to ensure road safety and transport security.

The aim is more efficient use of the newest active safety and driver assistance systems which have great opportunities in terms of safety features for passengers and other road users (including vulnerable road users).

Navigation systems and detection systems can help in providing remote monitoring of vehicles and cargoes in process of transportation, for example, the transport of hazardous cargoes or animals. They can show drivers safe parking space, will help to implement existing rules under the regime of work and rest, and will support the next generation of digital tachographs.

Among the planned activities are invited to facilitate the deployment of advanced driver assistance systems and related road safety and traffic safety of ITS systems, including their installation in new vehicles and, if necessary, in the previously released cars. These measures are planned for the 2009–2014 period. It is planned to develop legal and regulatory framework for safe human-machine interface included in the design of the car and the integration of moved devices based on the “European Declaration of Principles for safe and effective information and communication systems in the vehicle”.

Until 2014 it is planned to develop a number of activities including guidelines of the best practices, which relates to the impact of software and hardware of ITS on safety and comfort of vulnerable road users.

Development of appropriate measures was provided, including guidelines of the best practices on the safe organization of parking areas for trucks and commercial vehicles and on telematics-controlled parking spaces and reservation systems.

Fourth direction: general interconnection

In the fourth direction were planned actions for the integration of the vehicle into the transport infrastructure.

The ordering and integration of ITS software within a harmonious architecture peculiar to an open system can improve the efficiency and convenience of their use. In addition, according to the documents of the European Commission, it will reduce expenses and increase the ability of system expansion, it will provide an opportunity to use the plug&play function for the integration of future new or upgraded software tools such as used in the moved devices or use of GNSS services (Global Navigation Satellite System) for determining the position and time.

In accordance with the plans of this direction will be created architecture of open embedded software platform for software and hardware tools of the ITS, including standard interfaces. The results of this activity is planned to submit for consideration of relevant standardization bodies.

Fifth direction: the security of information

The fifth group of actions of the implementation of ITS in Europe is aimed at providing security and data protection, as well as to address issues of responsibility allocation. Integrity, confidentiality and availability of data must be provided in the interests of all road users, especially citizens.

Sixth direction: overcoming of national barriers

The sixth group of actions aimed at strengthening European cooperation and coordination of activity in the field of ITS.

As pointed out by the European Commission, coordinated activity of the implementation of ITS in the EU requires an active and effective cooperation between all stakeholders at European level. It is expected that such cooperation should lead to the convergence of requirements regarding the introduction of ITS, more efficient synchronization of the implementation process and overcoming barriers on the European integration. To support investment decisions by public authorities all over Europe it is necessary to extend information on the costs and benefits of ITS. Exceptional importance are agreements on common assessment methods and uniform tools for decision support in order to implementation of ITS in the EU. Coordination of efforts on introduction of ITS throughout Europe also requires greater participation of city and regional authorities. Finally, the implementation of the Action Plan for the introduction of ITS in Europe requires the formation of an adequate governance structure. States which are part of the EU should strive to reach agreement on key issues of introduction and functioning of ITS, as well as concerning transition methods from drawing up plans to coordinated action on their implementation, for example by collective investment or harmonization initiatives.

According to results of Meeting in the framework of the pan-European program on transport, environment and health (the PEP) held in 2009 in Amsterdam, as well as on the Symposium of the PEP 2010, dedicated to environmentally friendly, health preserving investment and jobs in the transport sector, Partnership to coordinate efforts of the countries-participants and development of joint projects on the transition to “green” transport was established [30].

It also states that the transition to a low-carbon transport system can be implemented through a combination of the following directions:

- system of transition to a low-carbon modes of transport, including renewable energy and alternative vehicles and fuels;
- reduction of emissions from this type of movement, including mobility management, promoting less polluting and more cost-effective transport;
- changing patterns of mobility in the direction of reducing the number of trips and shrinking distances.

During the debate on sustainable development by the participants of the United Nations on sustainable development (Conference “Rio+20” [4]) it was noted that the transport and mobility are essential for sustainable development as one of the factors increasing the level of social justice, improving human health, ensuring the sustainability of cities, establishment of relations between urban and rural areas and improvement of the productivity in rural areas. They emphasized the need to promote an integrated approach to development of the policy in respect of transport services and systems to promote sustainable development at the national, regional and local levels.

4 Safety Increase Through System of the Car Technical Operation

4.1 Cars Intelligent Onboard Systems

Tendencies of IOS improvement modern cars are characterized by emergence of nonconventional systems for the car of automatic control, such, as the electronic control system of the engine (ECSE), systems of malfunctions collecting and processing and some others. All of them are intended for increase of the consumer safety and convenience of driving.

As producers of Nissan though intellectual systems of cars have information bias declared, after all first of all are developed for safety of drivers and passengers therefore the various options, allowing to make driving the car safer are built in them. The main highlight of on-board computers for cars of Suzuki is opportunity to carry out car diagnostics, and thus not to be connected to the diagnostic socket. The Verona 4.2 computer can be installed on any injector car working at petrol fuel which keeps data on 80 last trips which are grouped in dates, thus full information is output to the screen of the computer in days. It allows the driver to define the most economic daily route. The device includes the function similar to actions of a

tachometer, and displays exact information on engine turns, can be completed with the sensor of temperatures and tension of an onboard network [31].

On the CES 2012 exhibition technologies which will define our lives in the future were presented. One of them—an intellectual control system of the DICE car from Mercedes-Benz, the phrase “onboard computer” seeming ten years ago in relation to cars progress top, now means the standard from which car makers in further development make a start. Example of such searches the control system of the DICE car developed by request of Mercedes-Benz can couple.

DICE (Dynamic and Intuitive Control Experience) represents the interactive panel which will appear instead of the car modern dashboard, possessing function gesture control. The main functions which will be assigned to this panel, this obtaining road and technical information, and also data on interesting places on route. Through it will be possible to operate navigation, and also to get Internet access that will allow to adjust communication with the mobile phone, a tablet and the laptop of the driver, and also with other cars going nearby for coordination of joint actions and prevention of road accidents. The DICE system will be self-trained.

One more example—EMIRAI control system developed by Mitsubishi which cars in 10 years will possess. At the heart of this system management lies transformation of the car dashboard into the uniform screen of a back projection on which all information on the car, necessary for the driver will be broadcasted. And, the person himself will be able to program, which parameters he would like to see. Sideways from this screen one more display, smaller by the sizes, but touch will be placed. It can be used for input of information, direct driving and as the menu of the mobile phone. During car movement on this screen there will be the buttons necessary to control. The wheel in EMIRAI is made not round, but curved. On it also there will be a touch screen, and eighteen more buttons for driving and check of its condition. The special system which has been built in EMIRAI, will watch the physical condition of the person. It won't allow him or her to drive while drunk or has serious problems with health which can affect driving process. Moreover, it will trace all changes happening in an organism during driving, and to report about any critical processes to the driver when his condition threatens with danger to it and passengers. EMIRAI provides also driving transfer to other person if the driver wanted would be tired or feeling bad. In backs of forward chairs of the car, according to founders of EMIRAI, have to be built-in 3D—the screens allowing people, going behind, to watch film in high quality. As consider in Mitsubishi, the EMIRAI system will allow to establish the new principles of intellectual interaction between the driver and his car. In mass use similar control systems of a car, according to Mitsubishi plans, have to appear only in ten years. And, all technologies necessary for this purpose, exist already now [32].

For integration of IOS all components activity and also accumulation and information output the electronic block serves in its structure [33]. Some given examples about the direction of design thought on the way of improvement of one of the car main consumer properties: comforts in management, testify that seeking to create “the perfect car”, producers don't reflect that complication of a design and

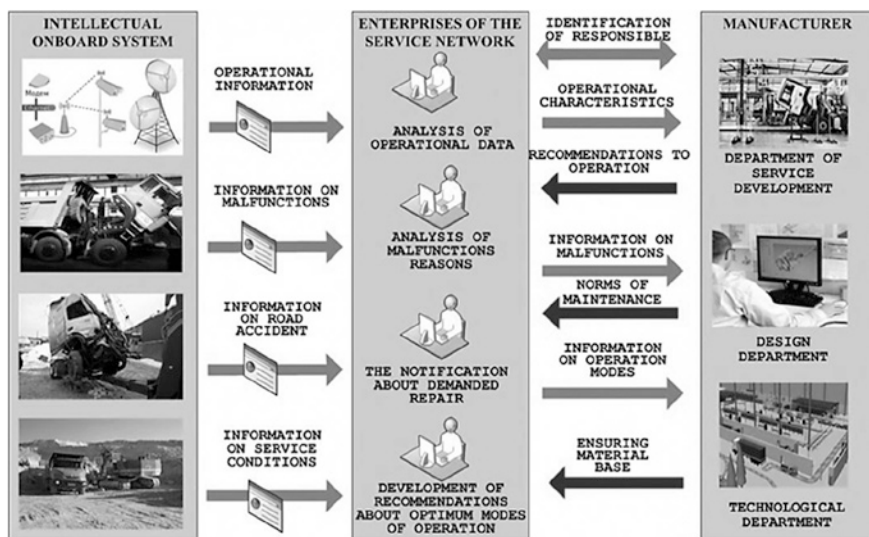


Fig. 2 The scheme of information streams organization with use of intellectual on-board systems

increase of technical characteristics repeatedly increases probability of problems emergence at its operation and service. IOS which has to provide feedback realization between the driver, service station and plant the manufacturer can reduce risk of emergence of emergencies.

Thus the following problems have to be solved:

- the notification of the nearest stations of service or services of emergency reaction about malfunction and the related road accident [34];
- accumulation of statistical data on the most frequent reasons of premature refusals emergence in certain service conditions—that will help to plan activity of the service centers;
- accumulation of analytical data from the dealers allowing the producer purposefully to improve a design of the car, increasing its reliability and safety.

Modern cars are impossible to imagine without the embedded electronic systems, the most advanced of which combine the functions of automotive onboard computer, solve the navigation and entertainment tasks (Fig. 2). Automobile concerns collaborate with developers of compact and productive processors that can be used in their models. NVIDIA exists on this market for a long time and NVIDIA Tegra in automotive computers is used not only in electric Tesla Motors, but also in the production of Volkswagen, the famous brands Volkswagen, Audi, Skoda and others.

To have their success on the market of automotive systems NVIDIA offers modern modular development platform NVIDIA Jetson, which will build and test a variety of automotive applications. Modern driver assistance systems have an important place (Fig. 3). Examples of such systems on the GTC-2013 GTU Technology Conference—(GPU—graphics processing unit)—showed Victor Ng-Thow-Hing—representative of Honda company. Research department of this

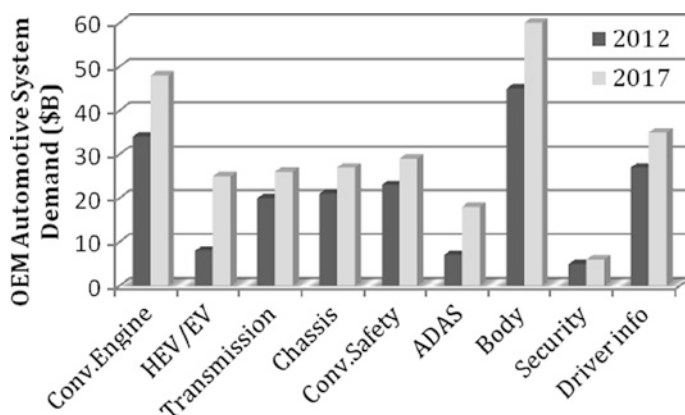


Fig. 3 The analysis of the current situation on development of modern onboard computer systems

company for a long time has been developing systems of augmented reality which draws the auxiliary images directly on the windshield of the car. Augmented reality systems are useful in navigation and they are capable to assist in identifying hazardous maneuvers and reduce accidents.

For example, the system can estimate the position and speed of oncoming vehicles and provides information to the driver about the safety of the left turn at the crossroads at the moment, in this case, the system draws on the windshield the arrow of planned rotation and paints it depending on the driving situation: green—if maneuver is safe, and red—if there is a risk of collision with the oncoming vehicle.

In addition, Strategy Analytics analysts also analyzed key factors which will be the engine of development onboard computers: the revolutionary options like parking and lighting systems will be habitual in the future, taking the place of night vision function, control of sleepiness, warnings about the difficulties of road traffic and the “blind spots” etc.

One of the most impressive examples of this intelligent system was introduced in the presentation Mario Toppelhofer, a research engineer from the laboratory of automotive electronics in Audi of America. Initiative of Audi Urban Intelligent Assist, developed in collaboration with leading American universities, is aimed primarily at the prediction of traffic events, possibility of deep settings of embedded system to user needs, intuitive interface and advanced interaction of onboard computer with the driver.

The main functions of onboard intelligent system Audi Urban Intelligent Assist:

- Smart Parking with provision detailed information about street and stationary parking with the issuance of parking options to choose from.
- Intelligent prediction of road traffic (Predictive Traffic) based on analysis of the current traffic situation, the preferences of the driver and the prediction of possible variants of behavior on the road by the results of emulating the traffic situation.

- Monitoring of the driver's attention (Driver Attention Guard) with intelligent interface with two-way interaction between man and machine which allows to return the driver attention to the road on the analysis of indications of the inner chambers, taking into account gained experience and models of predicting the behavior of the driver.
- Intelligent prediction of merging/separation traffic lanes (Merge/Lane Change Assist) with an intuitive interface to help in a timely and safe maneuvers on rebuilding the desired lane on the basis of advanced technology with 360° review and learning algorithm of recommendations taking into account driver's preferences.
- Realistic Navigation Assistant (Naturalistic Guidance) with normal voice prompts and intuitive maps with marks of iconic roadside objects and sights.
- Mobile application Time-2-Start, which allows to plan a trip in advance and arrive at the destination on time, taking into account the current data of traffic situation, prediction algorithms and emulating of road traffic.
- Single navigation system (Seamless Navigation) with a wireless interface between the mobile phone and onboard computer that provides uninterrupted tracking route driver, even when you leave the vehicle.

Besides the traditional options of entertainment and navigation plan, according to Delphi experts, future automotive onboard computers MyFi will inherit many typical functions of mobile Internet devices, which will be combined with external cloud services and opportunities of flexible optimization to requirements of specific user (Fig. 4). Significant attention will also be paid to security issues.

These projects include a plurality of individual algorithms and technologies which development and improvement is conducted in full swing. For example Vladimir Glavtchev an NVIDIA engineer and specialist on computer vision said in

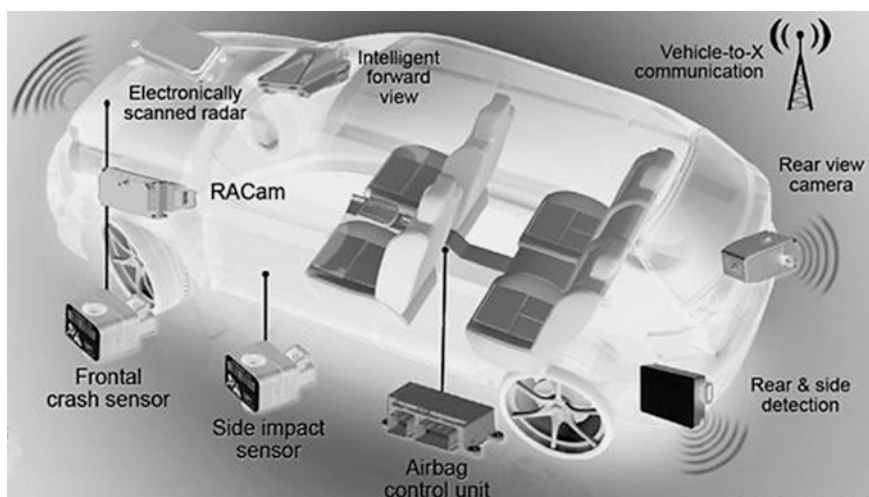


Fig. 4 Equipment arrangement on a car body card

his presentation about the solution of such interesting issues as multi-frame analysis of moving and static objects for the purpose of recognition and identification such as pedestrians, motorcyclists, cyclists, etc.

It is not necessary to emphasize once again how important these features to ensure safe traffic on the road. Now, when such algorithms already exist and have been successfully implemented, the main task is to optimize computational processes in order to minimize hardware requirements of computers which are necessary to identify and classify objects of road traffic. Onboard systems based on the GPU mobile class are turning out very relevant and popular.

4.2 Interaction with Service System for Increase of the Car Reliability

In the itself car as the car—the driver—environment—service “in a context of its interaction with various subsystems which realize actions for its safe operation makes sense to consider technical system as making systems” (Fig. 5).

In this sense purpose of IOS has to be reduced not only to informing of the driver, but also notify other subsystems which are responsible for its safety, in case of unforeseen situations which can lead to problems for other participants of movement.

Complication of the car design, intellectualization is more increasing than it, simplifying operation process, creates problems with service maintenance. To the service centers it is necessary not only to improve constantly processes, to train the personnel, to buy the new equipment, but also for new models to study statistical data on premature refusals to predict probability and time of their approach. Integration of ITS and the car IOS is necessary for the solution of these problems.

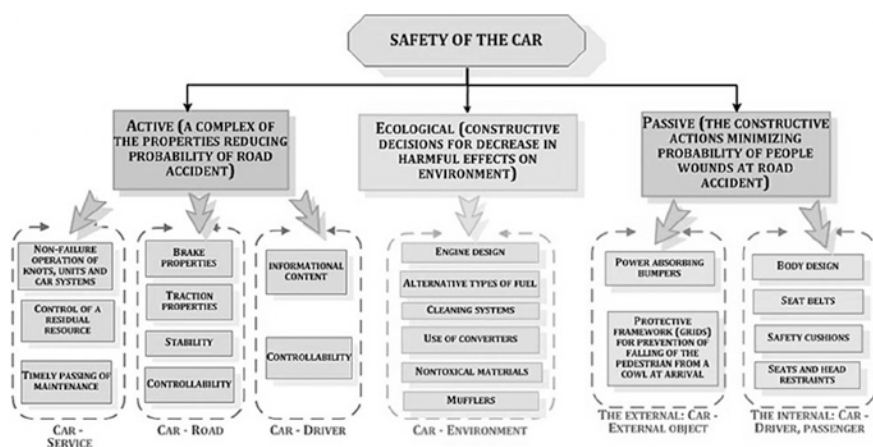


Fig. 5 Measures to provide road safety

The complexity of the design requires the development of a tool for efficient collection, storage and analysis of large amount of information about the condition of the vehicle and its systems. In addition, information should be of high quality. In the analysis of large systems, the optimal tool to quickly react to the changes of both external and internal parameters are decision support system (DSS), which is based on technology that uses an online database, data warehousing, online analytical system of information processing and intellectual analysis of data. The basis of a DSS is a complex of interrelated models with the appropriate information support of research, expert and intelligent systems, including the experience of solving the tasks of controlling and ensuring the participation of experts in the process of making rational decisions.

Since the adoption of decisions based on real data about the control object, analysis and strategic decision-making use aggregated information for the storage of which a data warehouse (DW) is created. The main goal to build DW is the integration, the updating and harmonization of operational data from disparate sources to provide a single, consistent view of the object of management in general. Databases contain the information gathered from multiple online databases OLTP systems (OLTP (On-Line Transaction Processing)—on-line transaction processing in real time).

DSS have the means to provide the user aggregate data for different samples from the original set in an easy to understand and analyze way. Aggregate functions form the multidimensional data make up a set (hypercube or metacube), so users can formulate queries, generate reports, receive data subset. This technology is a complex multidimensional data analysis, OLAP (On-Line Analytical Processing)—analytical processing in real time, which is a key component of data warehousing. Implementation technique involves various patented ideas: varieties architecture «client-server», time series analysis, object orientation, and optimizing data storage, parallel processes, etc. (Fig. 6).

Data on causes of appealing to service centers with details of all options is recorded in the database and serve as a baseline for subsequent analysis. For the formation of every sample one of the factors is considered, and the values of the others remain fixed. The parameters of the distribution laws of failures for each node are determined according to the created array data using Statistica [35].

However, in accordance with the empirical histogram data displays a graph of the distribution law and determined its compliance with sample data for a given level of significance. The results of the analysis are used for the development and correction of instructions designed for the service centers and for car owners, compliance with which allows to ensure reliable operation of the vehicle (Fig. 7).

Since the number of failures with developed dealer and service network is a large amount of data that depend on a significant number of factors, for aggregation abovementioned data OLAP technology is used, enabling the analysis of failure when selected combination of measurements. So, Fig. 8 shows three-dimensional OLAP cube with simple measurements.

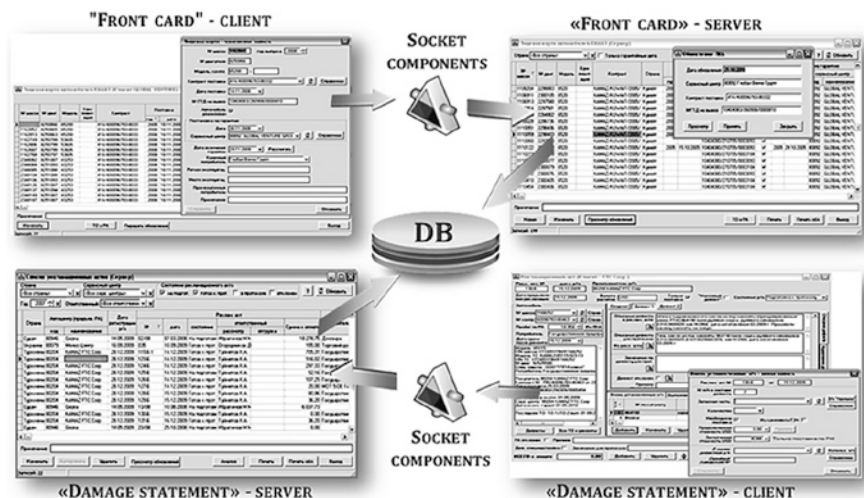


Fig. 6 Collection of information about refusals in firm service system

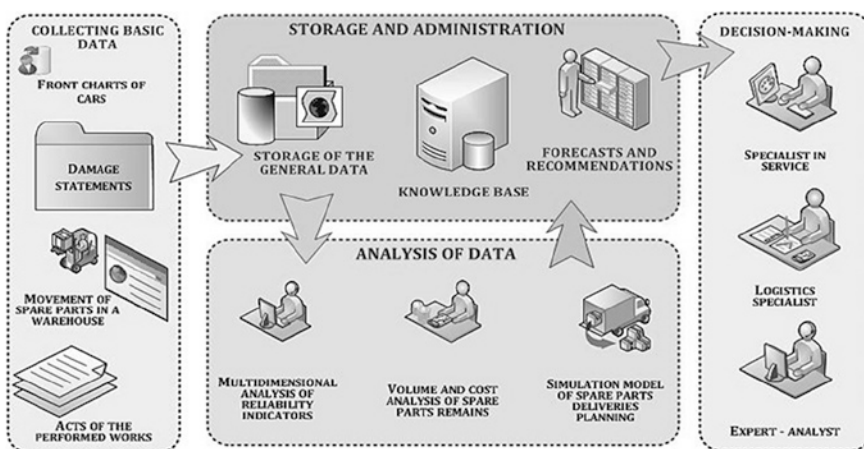


Fig. 7 Conceptual scheme of a dealer-service network DSS

For the rapid exchange of information communication systems are used, which synchrony information from ITBS with information systems of service centers, which, in turn, are linked with the manufacturer (Fig. 9). The transmitted data are the basis for improving the design of the car and increase reliability and safety of its operation.

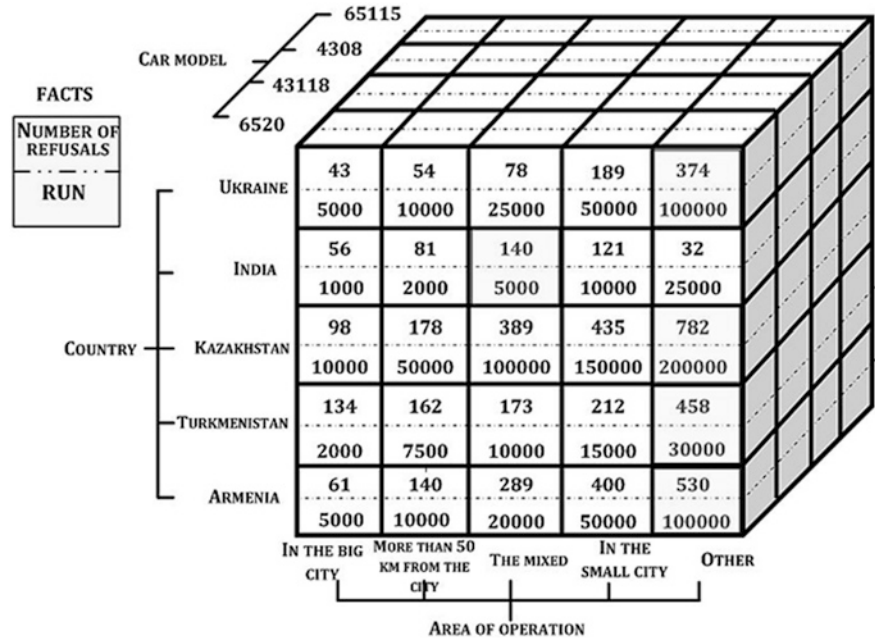


Fig. 8 Three-dimensional OLAP-cube with simple measurements

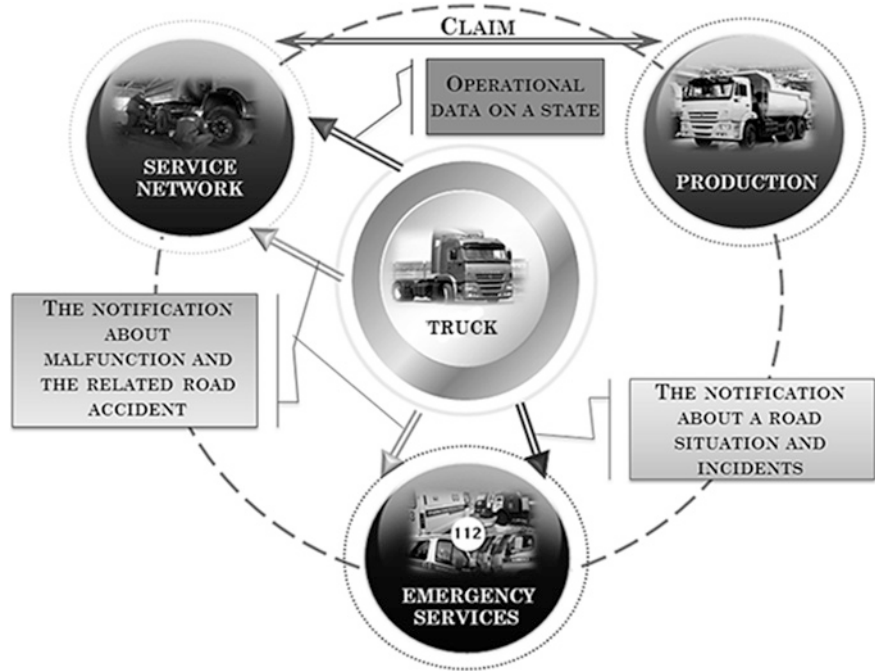


Fig. 9 Organization of feedback between objects of the transport system

5 ITS as Management System

5.1 *Management of Vehicles Fleet*

The larger the city, the more complicated its problems and the greater the likelihood of instability in the absence of effective measures to address these difficult problems. The most serious transport problems are often associated with urban areas and occur when the transport systems on a number of reasons are unable to meet numerous requirements for urban mobility. Efficiency of city functioning largely depends on the efficiency of the movement of labor, consumers and cargoes using the transport system between multiple initial and terminal points.

Experts in the field of urban transport planning are faced with the following problems: they need to effectively use public, land and financial resources for the optimization of the city's transport network by providing optimal mobility, elimination of the negative effects in the maximum extent (traffic jams, fatal accidents, pollution) and the provision in maximum extent of transport service to users.

Achievement of this balance represents the continuing problem for the planners of urban transport since the cities are becoming bigger and bigger and a growing number of people use the urban infrastructure and services of public transport.

The most significant problems of urban transport related to:

- its reliability: citizens will use public transport if they trust it. The credibility to provide services, schedules and the way of message serves the most important to the user;
- its comfortableness: people are in need of services. All types of public transport services should be provided to their users in the form of air conditioning, ensuring cleanliness, ticket machines, stations, protect the interests of passengers and providing the waypoint information in electronic form, etc..;
- the mismatch of public transport needs: many public transport systems or their elements either overloaded or underloaded. During rush hours the tightness creates discomfort for drivers, while the system itself is trying to cope with the increased demand for transportation. Insufficient number of passengers determines the financial instability of many transport services, particularly in the suburbs;
- difficulties of parking: since most of the time vehicles are in the parking lot, automobilization has led to increased demand for space for parking; as a result, there are problems associated with the use of available space, particularly in the central areas of the city. On the parked cars account for a very significant proportion of these spaces. There is also a link between traffic congestion and parking, since the search for parking lots creates additional delays and has a negative impact on local traffic;
- commuter transportation over longer distances, people are spending more time to get to work from the suburbs and back. One of the most important factors causing this trend, related to the availability of housing because housing which are located further away from the central areas of the city (which focuses on the

majority of jobs), is more affordable. Thus, suburban passengers are ready to sacrifice their time for affordable housing;

- traffic congestion: traffic congestion is one of the most common traffic problems in large metropolitan areas with populations, as a rule, exceeding the threshold of one million inhabitants. They associated, in particular, with the motorization and wide dissemination of cars, which leads to increase of demand for transport infrastructure;
- distribution of cargoes: globalization and the materialization of the economy leads to increase of the number of transported cargoes in the cities. Since the freight transportation are usually carried out using the same infrastructure, which are involved in the carriage of passengers, freight mobility in cities is becoming more problematic;
- loss of public space: the majority of roads are in public ownership, and access to them is free. The increase of traffic flows intensity has a negative impact on society; it comes to markets, public meetings, parades, games and social interaction. These activities were gradually supplanted by appearance of cars. In some cases, they were transferred to the shopping malls, in other cases they were abandoned at all. Traffic flows affects life and character of residents interaction and their use of street space;
- IT and intelligent transport systems which improve public transport, because operators are able to improve the quality of their services due to the presence of accurate information about the location and movement of vehicles. In addition, passengers can receive updated information on the respective web sites, stations and other information points;
- using land: transport, especially road transport, affects nature use of the territories. From 30 to 60 % of the territory of any major metropolitan area can be set aside for transportation due to excessive dependence of residents from some types of public transport. In addition, similar nature of the use of land for transportations also confirms the strategic importance of transport in economic and social development of cities.

To solve the above problems a number of projects was developed. Initiators and participants are organizations such as the European Commission, the International Union of Public Transport (UITP), the International Transport Forum (ITF) with OECD, the Pan-European Program on Transport, Environment and Health (PEP), the World Bank, the Working Party on Transport Trends and Economics UNECE Transport Division.

The European Commission has been working to improve the quality of life of citizens and strengthening the economy by stimulating of sustainable mobility in cities and the wider use of environmentally safe and energy efficient vehicles.

Consider the following envisaged measures:

- facilitation of implementation of a comprehensive policy, taking into account the full complexity of urban transport systems, the management and the necessary harmonization of different strategies, for example in the field of urban mobility, interaction, environment and health sectors;

- focusing on the needs of citizens on the basis of assisting in the preparation of reliable trip information and to ensure a high level of protection for passengers;
- facilitating the implementation of environmentally friendly urban transportations by introducing new, environmentally friendly vehicle technologies, alternative fuels, and smart charging to stimulate changes in the behavior of consumers of transport services in the choice of mode of transport;
- settlement of the problem of funding based on a study of available opportunities, innovative schemes of partnership between the public and private sectors and the potential new financial solutions;
- providing support in the exchange of experience and knowledge to provide wider access to this information and assistance to stakeholders in the use of that experience and relevant statistics;
- optimization of urban mobility for stimulation of effective integration, interaction and interconnection of different road networks;
- improving road safety, particularly for vulnerable participants as the young and the elderly.

International Union of Public Transport (UITP)—a global network of authorities, public transport operators, policy-makers, research institutes and enterprises of supplying and servicing of public transport. It is a platform for international cooperation, business development and the sharing of know-how between its 3400 members from 92 countries. UITP is the global advocate of public transport and sustainable mobility, as well as the initiator of innovation in this sector. The International Transport Forum (ITF) with the OECD is an intergovernmental organization with a membership of 54 countries. It acts as a strategic brain center for making transport policy and organizes an annual summit of ministers. Its purpose is to assist in the development of transport policies at the global level and to ensure that this policy will be contributed to economic growth, environmental protection, social inclusion and the preservation of life and wellbeing of people. Pan-European Program on Transport, Environment and Health (PEP), established in 2002, is aimed at equal association of the leading participants in all three sectors. The World Bank supports countries and cities, which are its clients, in their efforts to develop urban transport policies and projects aimed at solving problems. Transport systems of large cities are facing with them due to the continuous growth of the urban population, private ownership of the vehicles, traffic congestion and vulnerability of public transport systems.

According to the Transport Strategy of the Russian Federation for the period until 2020, ensuring, guaranteed by the Constitution of the Russian Federation, freedom of movement for citizens of a single economic space and free movement of goods and services requires a focused outstripping sustainable transport. In this document is formulated the priorities for public transport policy providing achievement of strategic goals, one of which is the harmonization of development of the transport system and improve its security. In addition, in the Transport Strategy of the Russian Federation for the period until 2020 indicated that the transport policy of Russia is built in accordance with the basic principles of

sustainable development [36], which implies a reduction of the negative impacts of transport complex on the environment (Table 1).

Methodical documents PIARC (Permanent International Association of Road Congresses) contain the following important areas of UDM [37]:

- reduction of the intensity of cars motion in city centers;
- priority of public passenger transport and cars, used by several passengers (HOV—high occupancy vehicles);
- regulation of parking;
- the interaction between the street and road network and the urban environment.

Transport solutions that are available today, primarily oriented on the private road transport,—one of the main causes of climate change, environmental pollution and a threat to human health since in cities and outside the transport consumes more than half of the liquid fossil fuel and generates almost a quarter of the world's emissions of CO₂, related to the energy sector.

Table 1 Measures to reduce traffic intensity of road transport

Type of activities	A method of implementation
Coordination of the urban and transport planning	Disposition of urban territories, which reduces the need for transport
Investment to transport systems	Construction of bypasses of urban centers Development of public transport systems
More efficient use of existing transport systems	Decrease of intensity during rush-hours Automated of regulatory system Joint (collective) use of passenger car Priority of bus traffic Restriction on the movement of heavy freight transport
Perfection of public transport systems	Improving the quality of public transport maintenance Stimulation of use of public transport by the owners of individual vehicles
Creating restrictions for movement of road transport	Management of traffic flow movement Zones that are free from road transport Priority of public transport Restrictions of bandwidth
Restrictions of parking	Restrictions on street parking Regulation of parking rules on territories of private possessions Organization of parking on the approaches to urban centers
Economic and administrative methods	The fee for the use of roads The fee for parking The fee for the opportunity to travel on the territories Administrative prohibitions and restrictions

Research shows that the environmental and social costs (costs associated with local air pollution, traffic accidents and traffic jams) can reach more than 10 % of GDP in the region or country, and significantly exceed the amount required to initiate of the transition to a “green” economy [2].

The policy of “greening” the transport is based on three interrelated principles:

- elimination or reduction of unnecessary trips by combining land use planning and transport planning and localization of production and consumption;
- transition to a more environmentally efficient types of transport, such as public and non-motorized transport for passengers, rail and water transport—for the freights;
- perfection of using technologies and fuels to reduce their negative impact on the environment and reduce the social costs.

Some of the necessary measures: land use planning, providing a compact or based on the main transport corridors of urban planning; regulation of fuel types and vehicles; provision of information for making decisions by consumers and companies. Such powerful economic incentives, such as the reform of taxes and subsidies, can also contribute to more “pure” private vehicles and the transition to public and non-motorized transport.

Improving the energy efficiency of the transport sector, the use of clean Fuels and the transition from private to public and non-motorized transport will improve the state of the economy and public health. As the analysis of the European experience shows, the economic returns from investments in public transport at the regional level is almost twice exceed the cost. In African countries, Sub-Saharan reducing the sulfur content in fuel for vehicles would reduce the annual cost of health care and related with their sectors by 980 million dollars [38]. A well-known example in the Brazilian city of Curitiba, where fuel consumption is 30 % lower than in other metropolitan areas of the country, has inspired many other cities to ensure the adoption of similar programs.

Municipal authorities around the world use a variety of tools and strategies to improve the efficiency of their transport systems and the quality of life. The introduction of ‘tax on traffic jams’ in central London has reduced the number of daily trips by car by 70,000 [39], and emissions CO₂—by 20 % [40]. Electronic payment system of road tolls and car quotas in Singapore reduced the growth rates of car use and motorization [41]. Bus rapid transit system (BRT) in Bogota allowed to decrease emissions by 14 % per one passenger [42], and this success was repeated in Lagos, Ahmedabad, Guangzhou and Johannesburg. In Europe, many of the cities follow the example of Zurich, where the main type of public transport is the tram, and not pricy subway [43]. Emission standards allowed to reduce dependence on personal transport [44], and the establishment of zones free from emissions, and the introduction of permits for the delivery cargoes with a time limit solve the problem of traffic jams and reduce pollution of the environment [45], improving productivity and quality of life of citizens.

The rapid growth of motorization and limited bandwidth of street and road network, especially in older cities with dense buildings, forced the authorities of

megacities in different continents to seek new opportunities to combat congestion and vehicle emission to implement new ideas to create a comfortable urban environment, announcing an unconditional priority of high population mobility. In these conditions, only correct and obvious solution is the development of public transport [46].

Analysis of the status and functioning of the transport system of cities in Russia indicates that its stability and security every year reduced because of discrepancies between the growth rates of motorization and level of infrastructure development of street and road network. These trends persist, despite the measures taken to ensure transport safety, as well as the fact that the level of motorization in Russia is far from similar indicators in European countries (Figs. 10 and 11).

According to the chief of the analytical department of PricewaterhouseCoopers in Russia Leonid Kostroma, Russia should catch up with current levels of developed countries such as Japan, France and the United Kingdom in 2025, when by 1000 people in Russia will account for 400 cars. Today Russia by the level of motorization of the population is about the same level as Brazil, ahead of China and India, as well as countries in Eastern Europe such as Slovakia and Ukraine.

At the same time vehicle fleets of developed countries will grow much more slowly because of the high motorization of population and saturation of automotive markets.

Moreover, in European countries, Japan and the United States is now observed a reverse process—demotorization, the level of providing the population by cars in developed countries decreases, in particular, due to the increased costs of

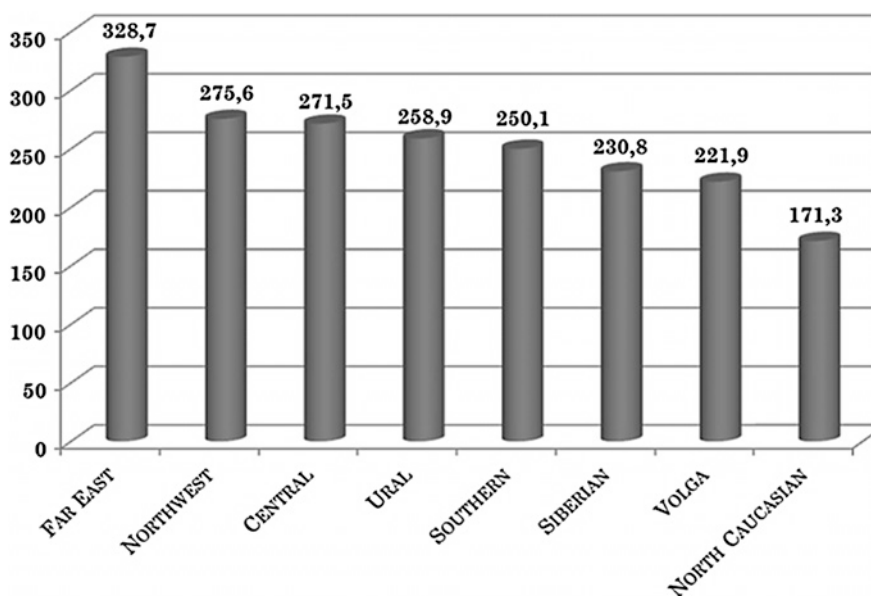


Fig. 10 Rating of federal districts of Russia in terms of providing by cars per 1000 people [45]

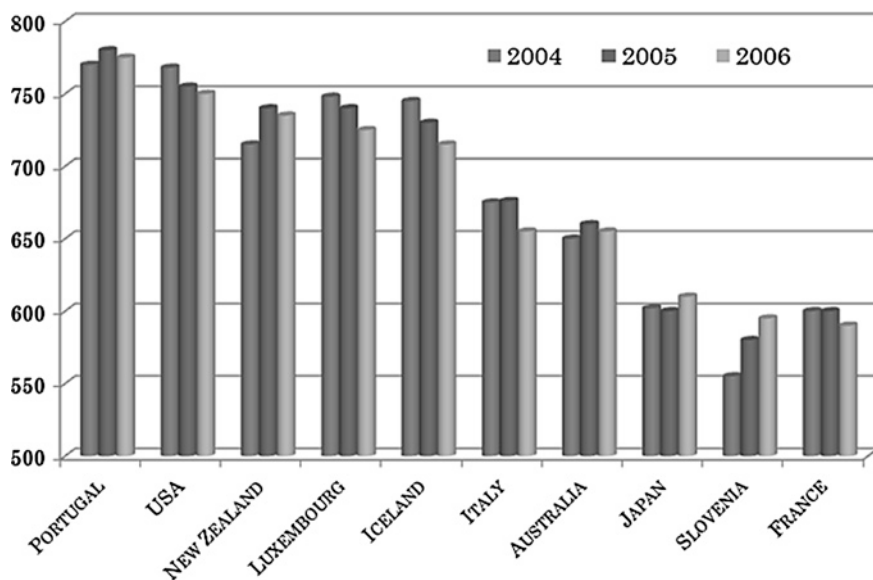


Fig. 11 Top 10 most automotive countries of the world by number of vehicles per 1000 people [49]

ownership and maintenance of vehicles (including the growth of gasoline prices, insurance costs and an increase in paid parking). In addition, the growth of the population of large cities affects this process. In these cities is offered a developed transport infrastructure, which have cheaper price and comparable in quality of movement with a private car [49].

In US motorization is traditionally considerably higher than in Europe, and in the national average is 811, and in the big cities—more than 900. A characteristic feature of motorization in European cities is the slowing down and stabilization its growth. This is explained by the difficulties of using the cars in the city. There are no restrictions on the purchase of a vehicle in any country in Europe, but the number of urban vehicle fleet has remained unchanged for many years. This has been achieved due to the policy of complex solutions of zoning of the city, the development of kinds of public passenger transport and the use of economic mechanism of limits concerning use of private car in the city [50].

Results of research of consumer preferences of the young population of the USA and Europe have confirmed the hypothesis that the youth's interest in cars is reduced. Thus, the share of American consumers who consider that the car is obligatory purchase declined from 93 % in 1996 to 86 % in 2010. According to experts, these trends are still not typical for Russia, but do not exclude that in the big cities after some time we can observe similar changes [49].

However, it is impossible to get rid of the influx of cars in the business centers, trade and administrative centers of the city. In addition, the resettlement of citizens in the suburbs boosts the demand for daily trips to work and back. Fully satisfy the demand for the use of the car in the city cannot be done nowhere in Europe.

The reason—the limitations of bandwidth on the city roads, lack of parking spaces for the organizations. Therefore several directions were produced for reducing the traffic load on the city [50].

- Development, a broad discussion, adoption and implementation of the master plan of the city, oriented on the considerable amount of time (15–20 years).
- Zoning of territory of the city.
- This process is common to all cities. Its main purpose—preservation of the historic part of city from destruction, development of public passenger transport improving the environment.
- The introduction of payment for the use of a personal vehicle in the city.
- This is one of the most unpopular, but very effective measures to reduce the traffic load in the city. The fee is set for the ride on the highway, the entrance in the zone of the city, and parking. Its price increases with approaching the center, and by time—during rush-hours.
- Development of public passenger transport.
- Development of street and road network.
- Dataware of road traffic.

As optimization of the transport system can be done in two ways: regulation density of traffic flow and more environmentally friendly vehicles, for each of these areas methods to achieve their best values have been developed. So, to adjust the density of the transport stream is possible by using fiscal measures (restrictions on entry in busy areas, traffic control, etc.), as well as better use of capacity of the network (the higher occupancy rates of vehicles, replacement of more capacious and so on). Improvement of environmental performance of vehicles can be achieved through fleet renewal and replacement by a more ecological one.

As stated in article [51], according to the statistics, the environmental impact of large parks is higher than personal vehicles because of the large annual mileage. The personal car average mileage is 12,000 miles/year, while the average car in park passes 23,000 miles/year. The share of new cars in the park is significant, because updating is more common than in individual owners. In addition, to stimulate the owners of parks for rational operation is easier than individual owners. Therefore, to analyze the potential benefits from fleet management subsystem of public passenger vehicles was selected (Fig. 12).

5.2 Priority Development of Public Transport

At its twenty-fourth session the Working Party on Transport Trends and Economics endorsed the proposal of the Secretariat about converting of the report with an overview of the transport situation in the countries—members of the UNECE and emerging trends in the development of an annual publication on Transport Trends and Economics in the ECE region and asked the countries answer to the secretariat questionnaire concerning the transport situation in 2011

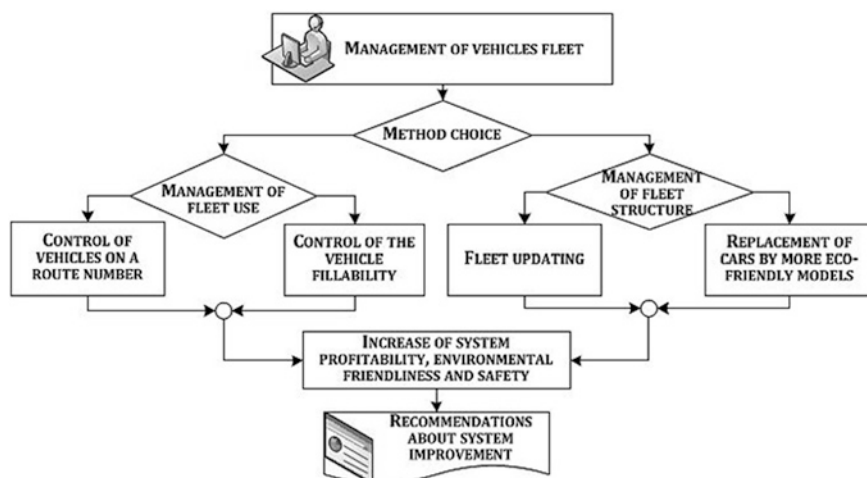


Fig. 12 Management methods of vehicles fleet

and the expected changes in 2012 (ECE/TRANS/WP.5/50, paragraphs 31 and 32). At its seventy-fourth session of the Inland Transport Committee took note of the draft publication and approved the decision of the Working Group about the review of the transformation in the annual publication on Transport Trends and Economics in the ECE region (ECE/TRANS/224, paragraphs 20 and 21) [52].

Considering the status and problems of transportation systems, Working Group on Transport Trends and Economics notes that many of them are associated with urbanization and the status of megacities. Thus, according to one research [53], in 2011 there were an estimated 11 megacities. Apart from Karachi, this select group of cities includes Shanghai, Mumbai, Beijing, Delhi, Buenos Aires, Metro Manila, Seoul, Sao Paulo, Moscow and Jakarta. Istanbul and Bangkok, where the population is more than 9 million people are on the 12th and 13th places in the list of the largest cities in the world. In addition, each of the mayors of the 25 largest cities in the world is responsible for a greater number of people than the prime ministers of most countries. For example, London which occupies 23th place in the world has more inhabitants than in countries such as Denmark, Ireland, New Zealand and Paraguay, and if Karachi—the largest city in the world—was a country, it would occupy a higher place than Hungary, Greece or Portugal. The total population of 11 world megacities—cities which are home to more than 10 million people—equal to the number of inhabitants in Japan.

According to recent statistics, 80 % of EU citizens live in urban areas, and 40 %—in large cities with a population of over 200,000 inhabitants. In their daily lives they use same space, and for the movement—the same infrastructure. Public transport, cars, trucks, cyclists and pedestrians use the same infrastructure. On average, a resident of Europe makes 1000 trips per year, and in half cases at a distance of less than 5 km. Walking and cycling can serve as a real alternative to

many of these movements for a short distance. The urban mobility has 40 % of all CO₂ emissions by road transport and up to 70 % of emissions from transport of other pollutants. One of the three fatal accidents accounted for the city. Problems associated with traffic congestion, are also concentrated in cities and around them. European cities are increasingly facing with problems resulting from transport and traffic [54].

The car is still the dominant means of movement in the cities. So in urban agglomerations of the EU about 75 % run accounts for cars. This leads to the formation of such a number of congestions that in some European cities, the average speed during the rush-hours is lower than in time of horse-drawn carriages. The increasing use of car associated with security problems of the environment, as well as with reduction in the already insufficient investment in public transport.

Transportations of road transport are largely dependent on the availability of petroleum products, and they accounted for most of the transport emissions into the atmosphere. In addition, residents of almost all European cities are experiencing consequences of air pollution; its level exceeds the limits set by the EU for particulate matter. During the last decade there has been significant progress in reducing pollutant emissions, but there are still problems associated with so-called “hot spots” or places with the highest crossing routes, and an alarming increase in traffic flows can reverse the progress made in the improvement of urban air quality and reducing greenhouse gas emissions.

For all major cities in Europe the question of how to increase mobility and at the same time reduce the size of congestion, accidents and pollution is a common problem. City residents like no other experiencing the immediate negative consequences of their own mobility and are probably ready to look for innovative solutions for sustainable mobility.

One of the significant alternatives to the car serves the public transport, which plays an important role in the large cities, where it transports by 2.5–3 times more passengers than private transport. Public transport is very important for approximately 40 % of households in the EU who do not have a car. According to forecasts, without further intervention the public transport in the next decade will retain their market share only in large urban areas, where it has a clear advantage in terms of reputation, reliability and speed of movement (Table 2).

For the improvement of public transport there are different strategies ensuring its benefits:

- provision of higher quality services on public transport, including increasing their diversity, fast and more convenient service;
- the reduction of tariffs and offering the discounts (for example, lower tariffs for not rush-hours or for certain groups of passengers);
- the introduction of more comfortable structures of passenger tariff and payment systems using “smart cards”;
- implementation of programs to reduce the costs of commuter trips, financial incentives of commuter trips, as well as other programs of transport demand management, promoting use of alternative modes of transport;

Table 2 Share of cars in total passenger turnover

Country	Total passenger turnover (train + bus + cars) billion. Pass.km	The share of cars in total passenger turnover (%)
Russian Federation	867	68
France	663.1	84
United Kingdom	707.1	92
Italy	850.9	82
Belgium	142	75
Sweden	119	83
USA	5007.5	90
Japan	1335.5	65
Czech Republic	81	78
Poland	337.4	88
Hungary	76.5	69
Lithuania	32.6	92

- improvement of programs of informing of the passengers and marketing;
- realization of programs of construction of intercepting parking lots and their advertising;
- preparation of guidance on multi-modal access system, including maps, schedules, contact numbers and other information about how to reach the destination by public transport;
- establishment of tariffs for parking and travel on the roads, which would stimulate the use of public transport.

Another alternative to cars is automated passenger routing transport—modern system of transportation, in which an automated self-propelled vehicles operate on specially allocated for them fixed guide ways. Two of the most well-known such species is the Docklands Light Rail railway in London and 14 line of the Paris subway. Automated passenger routing transport is attractive by high intensity work and low operational costs due to a reduction number of staff. Operation of vehicles has more flexible nature because of the lack of the need to ensure proper working conditions and the driver's position about remuneration. Automated passenger routing transport is particularly suitable for situations when you need to provide transportation of small number of people throughout all day. Construction costs of these systems are competitive in the case of new roads, but the unproductive costs are higher with the centralization of the management system and the use of automated technologies. At the same time in terms of bandwidth, they are much more effective in achieving the objectives of sustainable development than any system based on the use of vehicles operated by driver.

Personal rapid transit system—a type of automated passenger routing transport, can effectively overcome the difficulties associated with the adherence to the timetable of public transport, while maintaining the advantages of individual trip. These systems presuppose operation of a small self-propelled vehicle, which

moves along the guide path. Bristol University has developed a system of urban light rail transport. In this case, the vehicle represents 4-seater capsule, which moves on rubber wheels on their own guide way. Management is provided by a computer that responds to magnetic implants of guide way. These vehicles with electric drive provide the place for bicycles, wheelchairs and luggage. Fare payment system is based on the principles of operation of the vehicle, and not individual trip. Thus, the four people who use the vehicle pay the same tariff as the passenger, moving alone, which increases the competitiveness of vehicle in comparison with the transportation on passenger car.

In the documents of the THEPEP (Transport, Health and Environment Pan-European Program) it is noted that positive examples of measures taken to improve the quality of urban environment and support the process of redistribution of means of transportation by increasing the share of walking and cycling in combination with the use of public transport encourage. It includes the improved bicycle infrastructure and urban traffic by using bicycles in Paris and Barcelona, charging for entry in the congested areas of London, Stockholm and other cities and measures adopted in New York in order to “prohibit the movement of vehicles” in heavily congested areas and their transformation into parks [54]. In addition it is noted that electro-mobility is becoming more accessible and widespread. Many corporate car parks and collaboration patterns of using a rental car across the entire pan-European region rely on electric and/or hybrid vehicles, and the introduction of e-bikes are allowed to use the cycle movement not only for rehabilitation and recreation, but also as a viable means of transportation.

Among the factors constraining the development of alternative ways of movement is the fact that only 68 countries have adopted policies at the national and sub-national levels, promoting walking and cycling, and only 79 countries have adopted measures for the protection of pedestrians and cyclists, isolating them from other motorized high-speed means of transport. This indicator is significantly higher in countries with high income level (69 %) than in low- and middle-income countries (34 %) [56].

Safe public transport systems are increasingly viewed as an important tool for safe increase of mobility of the population, especially in urban areas suffering from growing traffic congestion. In many cities with high income the policy of reducing the use of personal motor transport is particularly emphasized through investment in the development of public transport networks. Investments in safe public transport are also seen as a mechanism for stimulating the growth of physical activity and, therefore, strengthening the health of the population.

More than 100 countries adopted policy measures on investments in public transport at the national or subnational levels. In most countries with high-income public transport is regulated properly and therefore significantly more secure than private vehicles: however, in many countries with low and middle income levels, whose economy is growing rapidly, the growth is not regulated, leading to increased road traffic injuries among its users.

For increase of motivation of car owners of transition to public transport in the cities such system of city passenger transport which, on the one hand, will provide comfort and safety of movement of passengers at the smallest both temporary,

and monetary expenses has to be created, and with another—will be formed taking into account street road network capacity, from the point of environment load minimization view, and also from the point of traffic safety view.

For the population the public transport becomes attractive only when will be able to make the worthy competition to the cars which are in private use, first of all, from the point of provided services comfort and quality view [43], that is possible, in turn, only at scientific approach to development of city passenger transport route network. Besides, the structure of the bus fleet functioning on each of routes, qualitatively and quantitatively has to correspond to volumes of passenger traffics and ecological requirements of the modern city.

Thus, one of the purpose achievement ways set within the Global “green” new course, transition from private cars to public, more eco-friendly, to transport is without prejudice to mobility of the population.

5.3 Decision-Making Support Systems as Mode of Transport System Parameters Optimization

As the quality of the decisions on the management of transport systems depends on the quality of information, adequacy of methods of its analysis, as well as on an efficient tool for working with large arrays of data for these purposes decision support systems (DSS) are created. They are automated computer systems that combine the properties and abilities of management information systems and database management systems. For analysis and development of recommendations in the DSS information search, data mining, knowledge retrieval in databases, reasoning based on precedents, simulation modeling, evolutionary computation and genetic algorithms, neural networks, situation analysis, cognitive modeling, etc. are used. If the operations of the DSS are methods of artificial intelligence, we talk about intellectual DSS, or IDSS. The design of the DSS significantly depends on the type of tasks for which it is developed, from the available data, information and knowledge, and also from users of the system. There are three main parts in the DSS:

- Data system for collection and storage of information received from internal and external sources, as a rule, it is a data store.
- The system of dialogue that allows the user to specify what data to choose and how to handle them.
- The system of models—ideas, algorithms and procedures that allow to process data and to analyze them. The user has the experience, knows the situation and follows certain considerations when fetching data. In the processing of data, use different procedures, from simple summing to statistical analysis and nonlinear optimization.

Conceptual scheme DSS for the management of the transport system of the city is shown on Fig. 13.

The simulation model is the intellectual core of the designing DSS. Simulation modeling is the tool that allows you not only to perform a qualitative analysis of the processes but also to explore the effects of any changes in these processes.

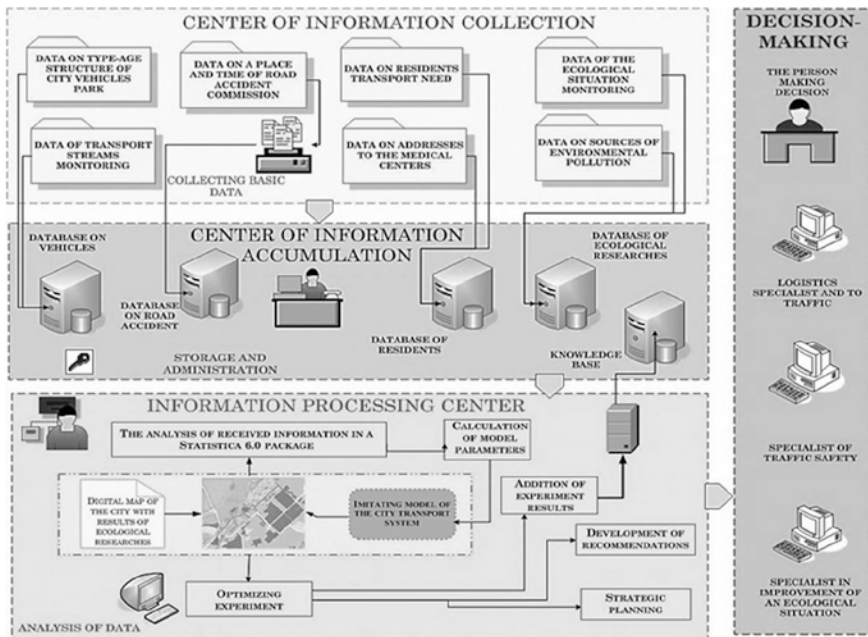


Fig. 13 Conceptual scheme DSS for the management of the transport system of the city

What's more it allows you to choose the variant which satisfies all specified limitations and issues optimal system parameters [57].

The software developed for these purposes allows you to build models that reflect the processes as they were in reality, and then conduct a series of virtual experiments specifying the model time. Thus it is possible to study the process using the single test as well as set of tests that allows you to find the optimal process parameters and the results will be determined by their random nature.

Economic effect of ITS application is determined by the reduction of transportation costs by optimizing routes and increasing efficiency of the vehicle fleet. Environmental effect is to reduce the negative impact on the environment and can be achieved through rational redistribution of traffic flows on the city road network. Social effect will be to reduce the risk of disease due to urban air quality.

The multidimensional intellectual data model is installed in traffic control center and serves for gathering, storage and formalization of road network parameters. The operative information which comes to Control center in a mode of real time from various sources is necessary for correct reproduction in a model of real situations: from servers of the municipal enterprises, from the equipment for operative monitoring of a road situation (GPS/Glonass systems).

Storage of the information in the form of an OLAP-cube and its subsequent processing will allow to estimate street network parameter dynamics with high accuracy on different measurements (quantity of vehicles, a road section, a season, average speed, traffic light availability etc.). Packages of the formalized data are

continuously transferred in a simulation system for changing of model parameters. Information analysis of the city transport system's parameters' changes by the day time, day of the week, month of the year makes it possible to predict possible city roads situation changes in subsequent periods. Furthermore, modeling workarounds with changing system parameters allows you to choose the most optimum of them and to build a knowledge base of the best solutions for fixed traffic and environment parameters. Such databases are used for operational decision-making management in the case of emergencies in the transport system.

5.4 Optimization of Public Transport System Parameters

Road transport is the main source of environmental pollution in Naberezhnye Chelny, because the main stationary sources are outside or on its borders. On spatial-planning organization of the city natural landscape situation has materially affected: the city is focused on water areas of Nizhnekamsk reservoir, Shelninsky Bay, and forests located on their shores. Linear structure open type with the "classic" functional zoning was laid in the basis of planning organization of the city with a parallel location of industrial and residential areas, suburban recreation zones. Longitudinal highways which connect the residential areas of the city compose a transport-planning frame of the city that gives rise to attribute the planning scheme of its road network to rectangular. The main "diameter" of the city is a longitudinal thoroughfare, which includes M. Jalil avenue, Naberezhnochelninsky avenue, and Mira avenue [4].

Charts of dispersion of pollutants, received by results of natural supervision (Fig. 14), allowed to highlight problem areas one of which is a complex junction formed by the intersection of Prospect Mira, Peoples' Friendship and Syuyumbike (Fig. 15). Analysis of statistics on the road traffic accidents showed that this site is a place with a high concentration of road accidents. It creates problems for the normal functioning of the transport system and of the environment because the frequent occurrence of the congestion situations exacerbate the negative impact of transport on the environment.

For a more detailed analysis of the area its simulation model was built using the Russian software developer AnyLogic.

There are several factors that were taken into account:

- geometry portion of the road network;
- traffic density;
- intensity of pedestrian traffic in the area with the distribution lanes;
- emissions of pollutants from motor vehicles and emissions quotas;
- modes of traffic lights on the previous and subsequent sections.

As the limitations of the model the emissions' quota was set that should not be exceeded:

$$Q_{aut} = \frac{M_{Li} + M_{Pi} + M_{pr}}{M_{kv}} \leq 1 \quad (1)$$

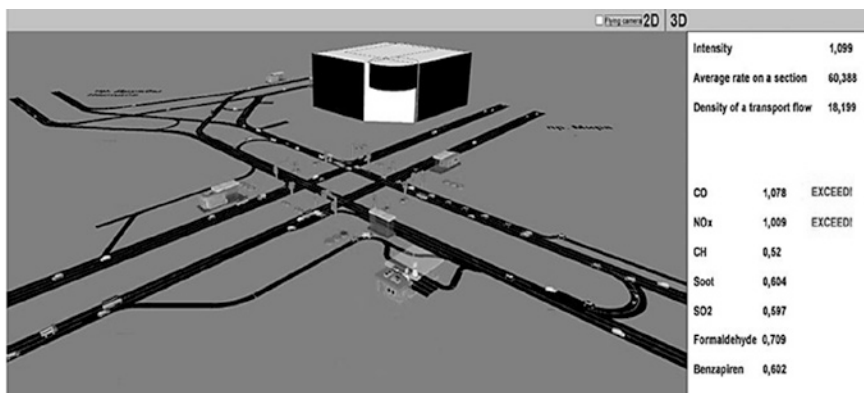


Fig. 16 The view of the simulation model of the considered section of the road network

Model experiment on the flow characteristics, established as a result of field observations showed that there was an excess of carbon monoxide and nitrogen dioxide emissions on the considered section during the congestion situations (Fig. 16). The first stage of optimization experiment allowed us to determine optimal parameters of the traffic flow (the density, the intensity and the speed) that provide not exceeding quota emissions of pollutants.

Since the considered site is the confluence of the two main avenues of the city, it forms a significant number of public transport routes, which connects the new and old parts of the city. One of the methods of optimization of parameters of traffic flow on this site is the improvement of the route network. The second direction is connected with the use of the bus routes greater capacity, which will reduce the density of traffic flow and reduce emissions of harmful substances. Similar methods are described in articles [57].

In the second stage of the optimization experiment the part of the public transport's replacement for the more environmentally friendly was done and the vehicular traffic emissions calculated for the original parameters were determined. Such replacement leads to considerable decrease in volumes of emissions of pollutants (Table 3).

Table 3 Change of substances by public transport polluting emissions volumes when using gas motor fuel

Substance name	The volume of emissions		
	100 % of fleet on diesel fuel	50 % of fleet on gas motor fuel	100 % of fleet on gas motor fuel
CO	1036	0870	0691
NOx	0974	0907	0830
CH	0499	0437	0386
Soot	0581	0102	0043
SO ₂	0578	0422	0361
Formaldehyde	0681	0663	0627
Benzapiren	0579	0514	0489

Acknowledgment This work was funded by the subsidy allocated to Kazan Federal University for the project part of the state assignment in the sphere of scientific activities.

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Intelligent Transportation Systems – Problems and
Perspectives

Śladkowski, A.; Pamuła, W. (Eds.)

2016, IX, 303 p. 113 illus., Hardcover

ISBN: 978-3-319-19149-2