ITS-RELATED ASPECTS OF DEVELOPMENT OF URBAN TRANSPORT SYSTEMS

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ABSTRACT: *This article provides an overview of an ITS-related application developed for Urban transport systems in Russia.*
In today's society, where the public relies increasingly on the transport network, Russian Federation, as the many other countries, faces tough challenges ahead. From congestion, safety to environmental impact, technology provides a rich variety of options to address existing and future concerns, and Intelligent Transport Systems are at the forefront.

Deregulation of public transport in Russian market places new challenges for national transport companies. There is an increasing need of new service models and operational schemes allowing improved transport offer and competitive advantages. Investments are necessary to optimize the use of transport resources and increase the quality of service for the customers.

Information and communications technologies play a fundamental role to achieve these objectives. This is the case with both flexible transport, where telematics allows to optimize resources and improve mobility services for the customers, and with optimization of regular, line based transport services.

*Thereupon, **coordinate (position data), time and the navigation support (CTNS)** together with telecommunications became a main informational background for automation basic technologies for the Urban transport systems.*

KEYWORDS: *Automatic Vehicle Location (AVL), Coordinate (position data), time and the navigation support (CTNS), Dispatch control system, Information, Intelligent Transport Systems (ITS), Monitoring system, Satellite navigation, Telecommunications systems, Transport telematics, Urban transport systems.*

INTRODUCTION

The exponential growth of satellite navigation devices since the last 10 years supports the opinion expressed then that the use of factory-fitted, PDA or 'stand-alone' devices demonstrates the public's interest in minimizing journey times and avoiding travel delay and inconvenience and there are great expectations from the delivery of accurate location based, road user and tolling services.

The importance of secure asset-tracking is self-evident, however, it is essential that minimum standard data concerning security on connectivity and communication are invoked particularly with increased reliance on collecting vast amounts of data over Wireline, WI-Fi, GPRS, Bluetooth and Ethernet connections.

This article provides an overview of a the main Moscow State Automobile and Road Technical University's scientific and educational activities towards the ITS-related aspects of development of Urban transport systems. The main purpose is providing the scientific background for the following key themes:

- Improving road network management;
- Improving road safety;
- Better travel and traveler information;
- Better public transport on the roads;
- Supporting the efficiency of the road freight industry;
- Reducing negative environmental impacts.

The main aspects, which involved these themes into the Urban transport systems (as the main integrate multiplier) are Video image processing systems, Automatic Vehicle Location (AVL) technology and telecommunications systems and Public transportation Priority Systems.

Video image processing systems for real time traffic data collection processing of images from a video camera for real time estimation of traffic characteristics and data transmission to the control unit, especially in the case of Web interface (which allows provision of online public information for quick inspection of road traffic situation).

Automatic Vehicle Location (AVL) technology and telecommunications systems is a powerful tool for managing fleets of vehicles, from service vehicles, emergency vehicles, and construction equipment, to public transport vehicles (buses and trains). It also is used to track mobile remote assets, such as construction equipment, trailers, and portable power generators. Using an AVL system allows dispatch personnel to evaluate the locations of all vehicles in a fleet.

And, the Public transportation Priority Systems give priority to public transportation such as buses by means of bus lanes, warning vehicles which are illegally running in the bus lane and traffic signal preemption. For the latter, a fleet monitoring and management system, including automated vehicle location

capabilities, will be a fundamental element for effective service operation.

The main benefits of such combination of these ITS-related applications are: improve convenience for users, encourage the use of public transportation, ensure on-time bus operation, reduce bus waiting time at intersection, reduce the number of traffic violators driving in a bus lane, ensure bus safety (when making a right turn or merging into traffic out of the bus bay).

CTNS AS THE MAIN PLATFORM FOR ITS-RELATED TRANSPORT TECHNOLOGIES

At the present stage, development of the automated systems in Urban transport in Russia (for example - systems of dispatching management by transport on the basis of satellite navigation) became the real tool for control and the account of performance of transport work, for the full provides definition of places of road accident and emergencies, increase of efficiency at rendering medical aid and evacuation of victims, carrying out of actions of the Ministry of Emergency Measures and mobilization readiness.

In Russia practical use of a wide spectrum of opportunities of satellite navigation for the decision of organizational-technological problems of transport is realized within the Federal target program (FTP) "Global Navigating System".

In this connection, coordinate (position data), time and the navigation support (CTNS) together with telecommunications became a necessary informational background for automation basic technologies for the transporting passengers and goods by road, including (See fig.1):

a) Automation of dispatching management by passenger transportations (automation dispatching control movement), including Automation of gathering and the account of incomes of passenger carriers (automate data collection, the proceeds);

b) Automation of research and monitoring of volumes of passenger traffic (on passenger route);

c) Automation of informing of passengers (automation inform the transport process).

A global strategy for urban mobility management consists in wide usage of Intelligent Transport System (ITS) and technologies (See fig.2) and it is not less than infrastructure, vehicles and demand management.

To address the solutions of the organization, technological and technical tasks of CTNS in road transport corporate systems, on-board unit's hardware and software applications should be built on the principles of modular architecture and the need to provide an opportunity to modernize its based on the needs and objectives of carriers.
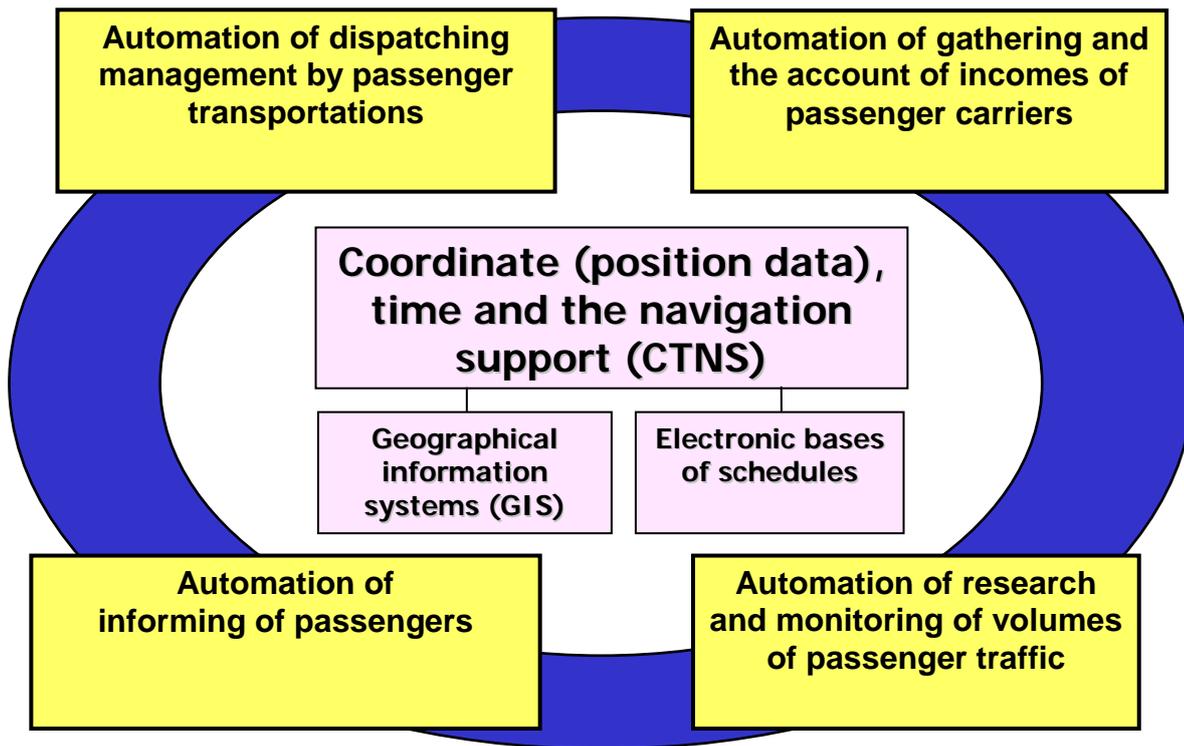
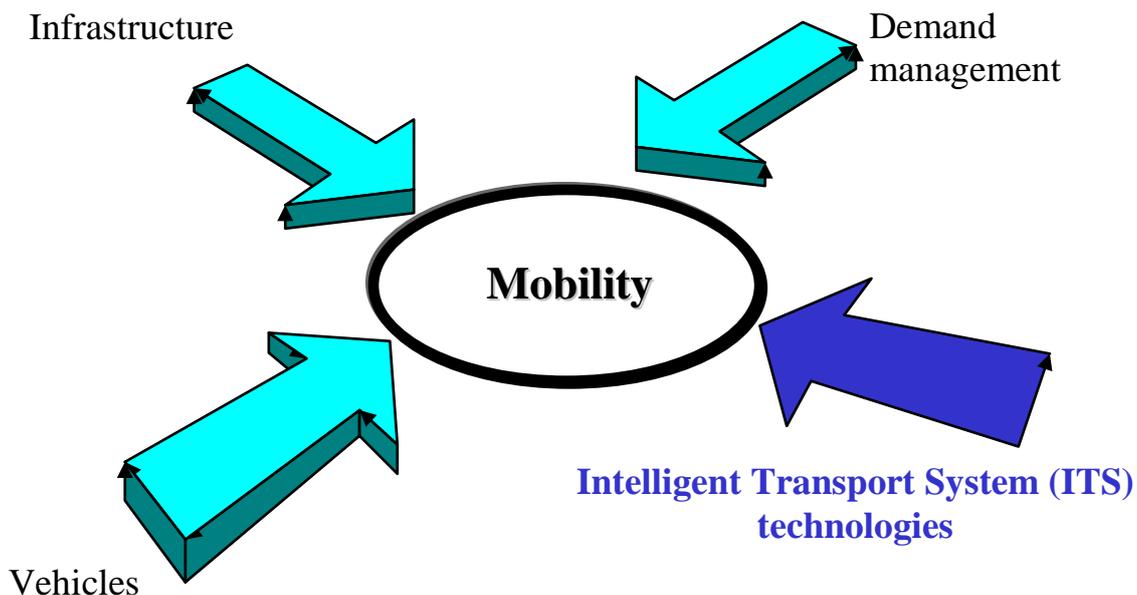**Fig.1** *Interaction with base technologies*

Fig. 2 *A global strategy for urban mobility management*

Intelligent Transport Systems - is a generic term for the integrated application of communications, control and information processing technologies to the transportation system.

ITS covers all modes of transport and considers all elements of the transportation system - the vehicle, the infrastructure, and the driver or user, interacting together dynamically. The overall function of ITS is to improve decision making, often in real time, by transport network controllers and other users, thereby improving the operation of the entire transport system. The definition encompasses a broad array of techniques and approaches that may be achieved through stand-alone technological applications or as enhancements to other transportation strategies.

ITS deployment has much to offer to all of the main groups of stakeholders: National, regional and municipal governments and public authorities; Owners and operators of transport networks (public- and private-sector); Automotive manufacturers; Fleet operators (commercial and public transport); Industry and commerce; Individual travelers.

Governments have a political priority to deliver sustainable and efficient transport. They need to evaluate the benefits of ITS (both nationally and globally) as the basis for long-term investments. ITS methods are policy-neutral, and can be adapted to a range of needs. At national level, governments can pave the way with enabling legislation (e.g. regulations for road user charging) and create frameworks for private-sector involvement, (e.g. via public-private partnerships). At regional and municipal levels, they can implement demand management and

integrated information (inter-modal and multimodal) and payment systems, to encourage intermodal travel.

Operators of road, rail, tram and waterway networks and the associated transport interchanges (from road to rail and transit, and the airports, ports and ferry terminals) can manage their operations with better information and can provide users with safer or more reliable travel conditions. Automotive manufacturers can achieve significant product differentiation and customer loyalty by developing appropriate in-vehicle telematics products.

Vehicle fleet owners can run more cost-effective services and save on energy costs. Businesses can move goods and services more efficiently. Individuals can plan journeys better, enjoy safer travel, avoid delays, and make informed choices between modes. All transport providers and users can enjoy greater security.

Ultimately, many ITS benefits are likely to be invisible to the end user - ITS will simply improve safety, security, efficiency and comfort of the transport system and the environment without the general public being aware that ITS is at work. Therefore there is an important role for public awareness programmes to show transport users how they can enjoy increased safety and security, better information, greater convenience and reduced journey times; and how populations as a whole can enjoy the healthier environments produced by sustainable mobility.

The use of navigation and communications resources to the cargo and special transport may be on the following tasks: information and control processes escort cargo; ensuring vehicle alarm; monitoring the status and safety (especially in the transport of dangerous goods).

Thus, effective automation of the basic technologies in transporting systems is to be based on the use of a specialized on-board unit's hardware and software to achieve the objectives of CTNS through the use of satellite navigation and the transmission of digital data of the board-control center, and voice communications between the driver and dispatcher (controller).

Relevant ITS services include: Intelligent speed adaptation; Assistance for vulnerable road users; Weather and road condition monitoring and information; Incident detection and warning systems; Collision warning systems; Emergency vehicle priority; Driver monitoring systems; Speed and traffic signal enforcement; Hazardous load monitoring; Cargo screening; Driver vision enhancement systems; Evacuation route signing and priority.

For all transport networks the major problem is congestion, and increasing the efficiency of existing transport systems is a major goal of ITS programs. Congestion can be reduced by instrumenting networks to improve their real-time operation; introducing control systems; managing demand; and encouraging off-peak travel or the use of alternative modes. Relevant ITS services include:

1) Network efficiency: Area-wide traffic control; Long-distance traffic management; Rerouteing guidance; Variable speed controls; Ramp metering; Incident detection and management; Driver information.

2) Demand management: Access control; Road user charging; Congestion charging.

3) Encouragement of modal shift: Journey planning; Real-time passenger information systems; Bus/tram traffic priority.

Users of urban transportation system need to feel comfortable, confident and secure. Route confirmation, journey time estimates and clear advice on approaching interchanges and connections all play their part. Speed controls, ramp metering, advance incident and congestion warnings, journeys easier and less stressful. Facilities such as multimedia systems that provide both entertainment and navigation can do this too.

ITS relies on a wide range of enabling technologies and functions.

1) Communications: Microwave, short-range radio and infrared-based dedicated short-range communications (DSRC) - used for EFC; commercial vehicle operations (CVO) pre-clearance; Mobile communications - used for real-time travel information; fleet management; emergency response; The Internet - used for real-time travel information; trip planning; traffic images; payment.

2) Geographical Location: Global navigation technology: global navigation satellite systems (GNSS) – GPS (Usa), GLONASS (Russia), Galileo (Europe) - used for satellite-based position finding for automatic vehicle location (AVL); tracking and tracing; distance-based EFC.

3) Geographical Information Systems: Used for location-based databases of transportation networks, location-based services and other features.

4) Data Acquisition and Exchange: Used for real-time traffic management and information.

5) Camera Systems and Artificial Vision: Used for enforcement and security.

6) Detection and Classification: Used for traffic management, incident management; compliance; safety; security.

7) In-vehicle Systems: Used for travel information, vehicle control systems, accident avoidance.

8) Digital Mapping: Databases of road and transportation networks stored on digital media using agreed data dictionaries and standardised location referencing. Digital maps are a key building block for ITS; Used for traffic management, traffic information, route guidance, car park management and routing, lorry route monitoring; recreational facilities direction.

AVL-BASED AUTOMATION OF DISPATCHING MANAGEMENT BY PASSENGER TRANSPORTATIONS FOR URBAN TRANSPORT SYSTEMS

Public transport users also expect high standards of comfort, convenience and service. ITS can provide the realtime passenger information, automated scheduling and priority systems needed to improve public transport. Relevant ITS services include: Real-time traffic and public transport information; Dynamic route guidance; Automatic vehicle location (AVL); Smarteard payment systems for toll highway and public transport use.

Examples for passenger transport, grading passenger buses for the movement of more possible on the following tasks: management of the electronic bus route signs in operational switching its traffic to another route; obtaining control centre video into a compartment of a bus driver's signal, or at the request of control system;

Advanced Public Transport Systems (APTS) applications aim to improve the efficiency and user-friendliness of public (collective) transport. They include real-time information systems; fare advice, pre-booking and journey-planning; demand-responsive transport and ride-sharing; and automated scheduling for better fleet management and increased security. All help to position public transport within integrated, multimodal systems that will encourage people to rely less on cars, and so help reduce traffic congestion and environmental pollution.

One way of promoting greater use of public transport is by providing reliable and easily-accessible real-time passenger information (RTPI) - See fig.3-4. Automatic vehicle location (AVL) can drive real-time information systems giving service running and connection times and route advice in-vehicle, at-stop, at home or work, on the street or using other transport modes. Information can be provided via various media including the Internet, interactive information kiosks, text messages to cell phones, voice phone inquiry services and personal digital assistants (PDAs). Enhancements include journey planning, fare options, booking services and 'on-arrival' location and tourist information.

ITS support efficient operation and management of public transport vehicle fleets. On-board AVL continuously transmits data that enables the operator's control centre to monitor individual vehicle's schedule keeping and adjust service intervals to compensate for early or late running. Using GIS-aided Regional multi-screen monitoring, automatic fleet monitoring can also give early warning of maintenance needs and anticipate the risk of vehicle breakdown (See fig. 5).

Door opening/closing detection systems and automated fare collection (AFC) provide operators with valuable passenger data - including loading, journey length, and time of travel - which they can use to evaluate route usage and refine services to meet

passenger demands and roster vehicles and drivers more effectively, and improve financial management.

ITS-based shared and demand responsive transport systems are bridging the gap between private and public transport.

Potential users contact a control centre to specify their destination, preferred time of travel, and any special needs.
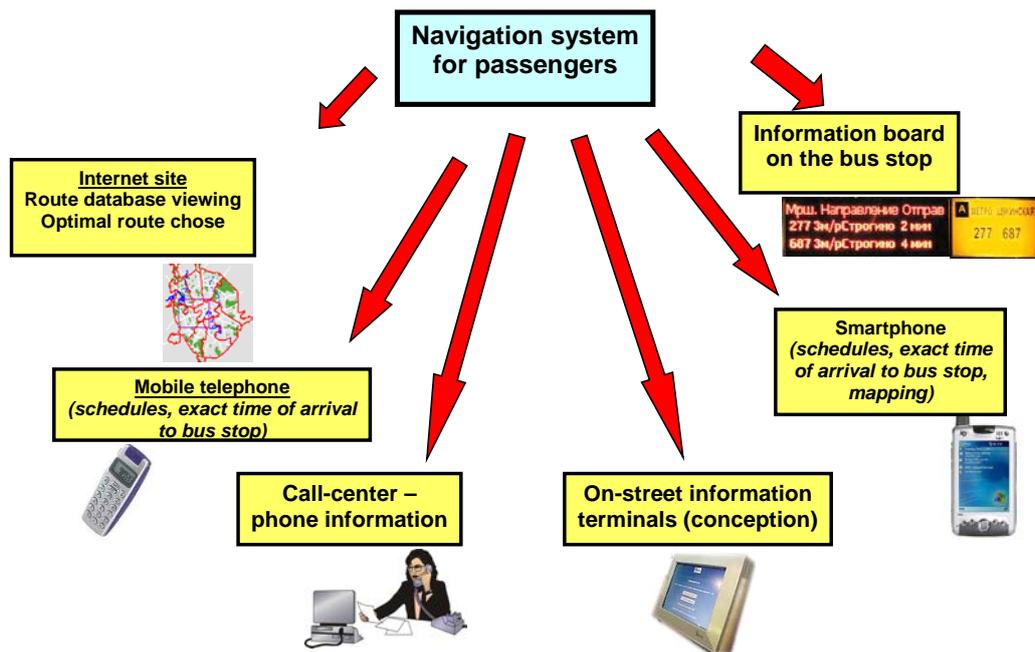

Fig.3 Navigation system for passengers

The centre uses AVL to identify and dispatch the most conveniently-located vehicle, which also carries other passengers on compatible routes. Charges can be billed automatically to accounts. Fleets can consist of public transport vehicles or taxis. Car-pooling, which is being introduced in a number of Russian cities, is a similar concept, with intending users pre-booking vehicles to suit their individual travel needs. It also has urban planning benefits, in that building developers can be required (or choose) to provide fewer parking spaces, so saving land and costs.

Also ITS-related modern EP systems offer major advantages over cash payment for transport and highway operators,

their passengers and customers. ETC/EFC is now well developed on expressways, bridges and tunnels across the world.

Smartcards in AFC systems offer public transport operators more flexible ticketing, lower administrative costs, and better management and marketing information; while passengers save time and appreciate the convenience and security of cash-free travel. EPS also offer prospects of interoperability within and across transport modes and systems, using a single, intelligent payment medium.
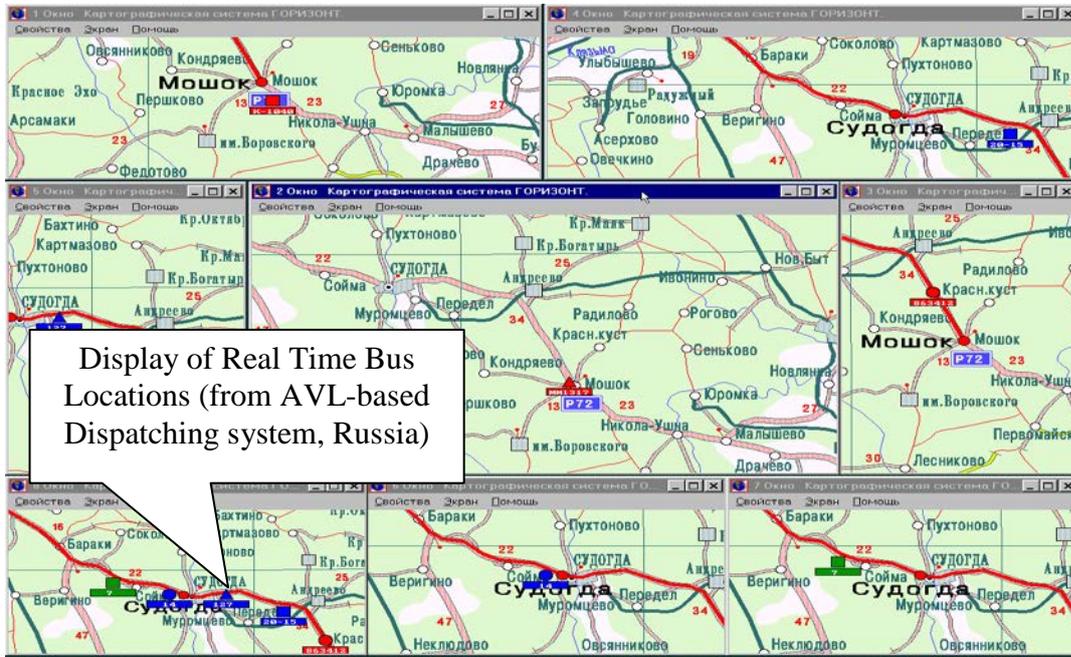
Fig. 4 Information board for passengers (variants from AVL-based Dispatching system).

Fig. 5 Regional multi-screen monitoring (for bus operator) - example

Public transport vehicles can be given priority over general traffic by integrating their operation into urban traffic control (UTC) systems. AVL enables buses and trams to be identified on the approaches to signalised intersections, where they 'request' the traffic light controller to extend or recall the green phase for long enough to let them through. Detection can be via inductive loops under the road' surface, roadside beacons, or satellite-based positioning systems (see fig. 6).

This supplements conventional bus lanes with specially-designed track sections that deter general traffic and speed buses past known congestion points. In mechanical systems, lateral wheels on front wheel mountings guide the bus along raised curbs (relieving the driver of the need to steer). The electronic system is based on an electric cable embedded in the centre of the bus way, with onboard inductive detection that continuously steers the wheels to keep the vehicle centred over the cable. At the end of a bus way section, traffic signal priority gives access to general lanes.
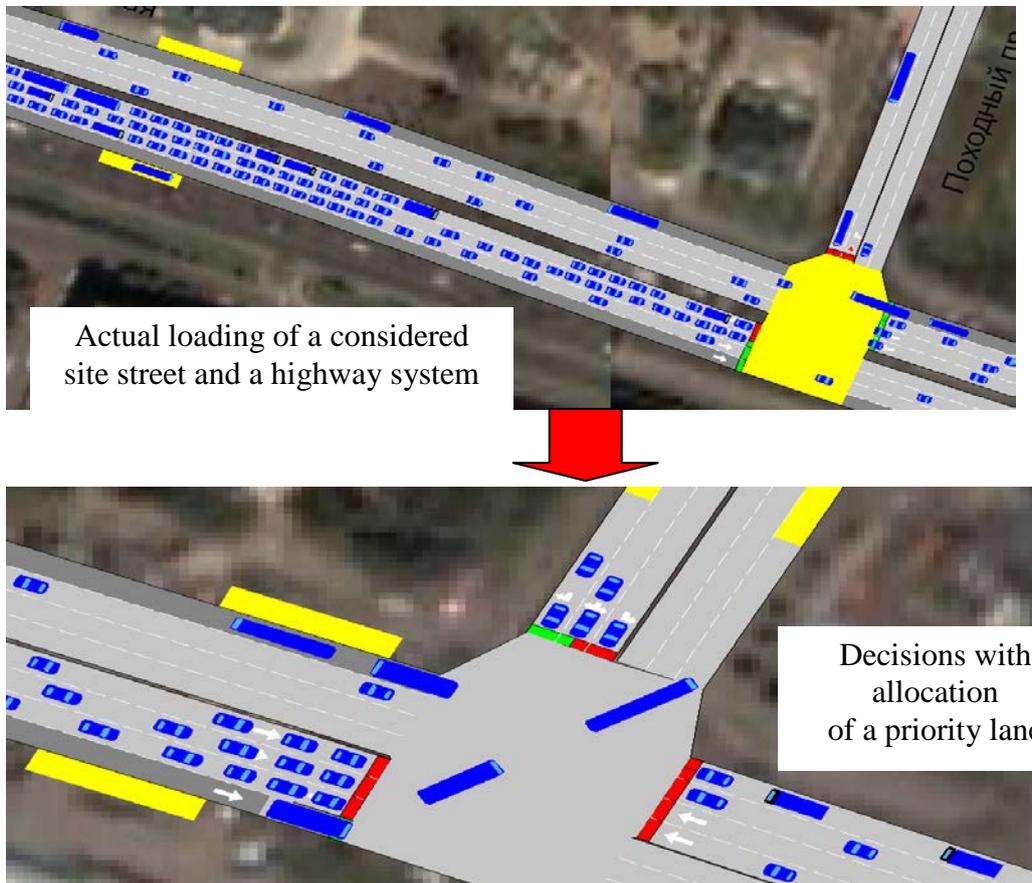

Fig.6 The pilot project of the organization of priority travel of public transport (Moscow Routing network of passenger transport - example)

AUTOMATION OF RESEARCH AND MONITORING OF VOLUMES OF PASSENGER TRAFFIC - REAL ITS-RELATED SOLUTION FOR URBAN TRANSPORT SYSTEMS

The development and demand of the AVL-systems of public transport control initiated the further research and development of new telematic systems for public transport such as "Automated System for Monitoring of volumes of passenger traffic (Passenger's Flows)". The demand of such system was based on the following factors:

- 50-80% of the inhabitants use the public transport every day.

- Average load of public transport is 20-50% of rated capacity, while the load at rush-hour is 90-150% of rated capacity.

The hardware-software complex of automatic system of research and monitoring of volumes of passenger traffic is intended for replacement of existing manual methods of inspections of volumes of passenger traffic. There are modern means and technologies in the basis of it. Tool means allow to carry out stage-by-stage creation of constantly operating (working) automated system of monitoring of actually executed services on transportation of passengers (See fig.7).
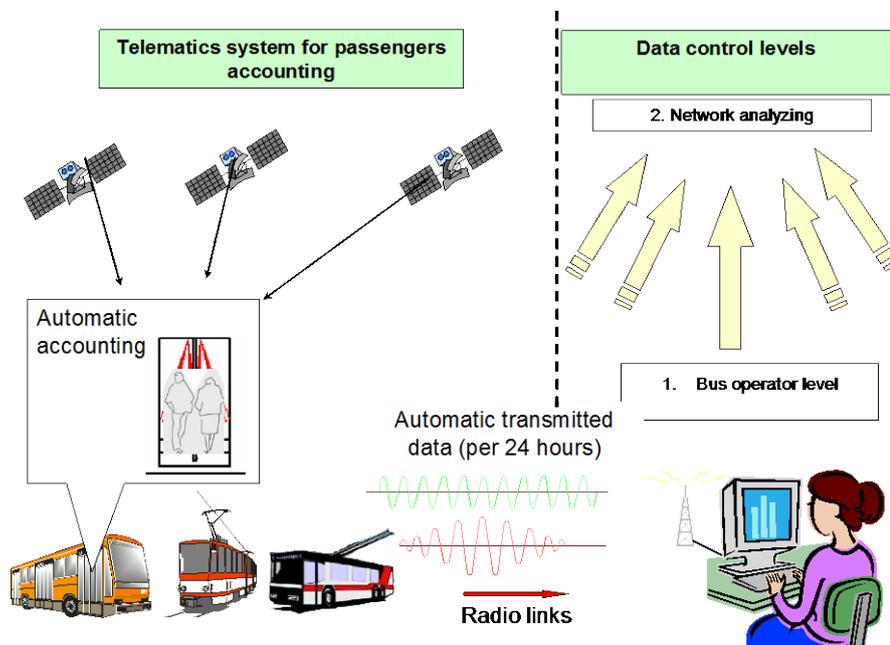

Fig.7 Automatic system of research and monitoring of volumes of passenger traffic – main levels.

The method which is used at calculation of number of entering and leaving passengers through a door of a vehicle is based on use of tiny gauges of thermal radiation which are mounted above doors of a vehicle (See fig.8).

Gauges register impulses of thermal radiation which each time arises at crossing by the passenger of a zone of measurement of the gauge of the analyzer. The gauge includes passive and active

elements. The active component in the gauge consists of the transmitter.

Data obtained from routes collect in constant databases of volumes of passenger traffic, in the further are processed by applied software in the cuts necessary for motor-vehicle pools and city administration (See fig.9-10).
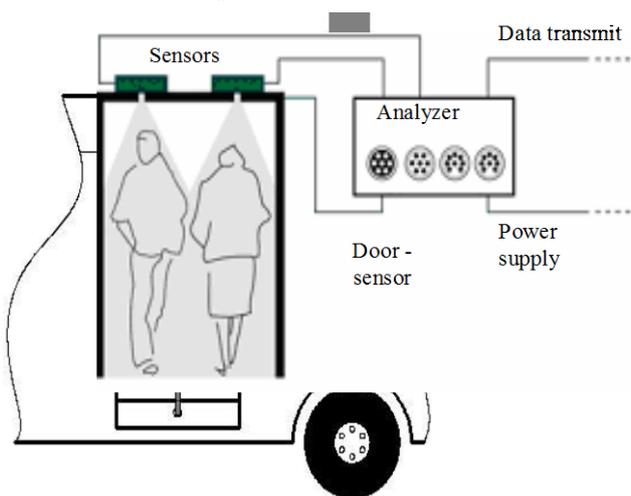

Fig.8 Technical Principles of automated sum of entering and exiting passengers at each door

The automated analysis of volumes of passenger traffic on lines of routes, on concrete stopping items, on hours of day, days of week, seasons is provided. Following primary goals are solved: Calculation trip and stopping and passenger traffic on surveyed

routes; Calculation of characteristics of a volume of passenger traffic on a route; Calculations of a standard set of parameters of the analysis of volumes of passenger traffic (methodology of a "tabulared" method); Formation of data about distribution of

interstopping correspondence of trips of passengers; An estimation of quality of transportations and efficiency of use of a rolling stock.

Each of the data sets which is collected on the route are processed identifying the stations of the public transport and concrete trip. Collected arrays of statistic provide to get the values of a big variety of activities related to a trip, passenger turnover on the stations, the dynamic of the passenger's flows during a day, an average distance of the trip and passenger turnover during the trip. In particular one of the most urgent activities of transportation is the number of carried passengers per hour. Inconsistency between the plan and fact values gives ground to change the schedule of the public transport and for definition of the required vehicle number per hours during a day (See fig.9).
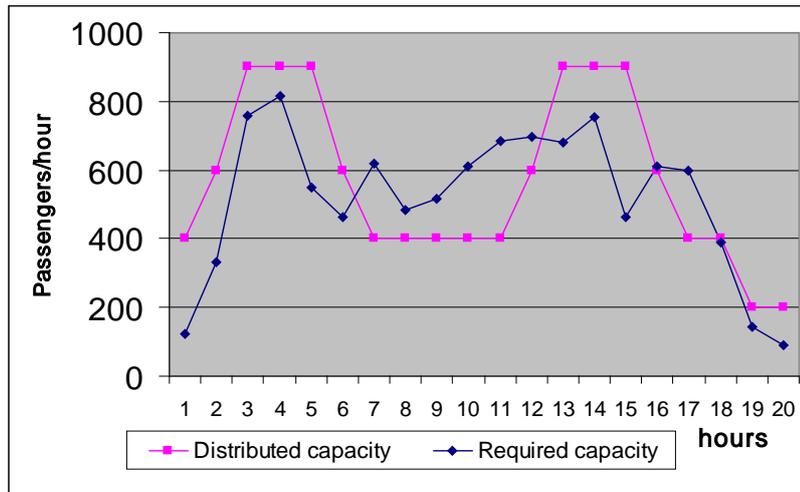

Fig. 9 Schedule perfection on the base of comparing of transport necessity with the plan

A bigger amount of the collected data gives the opportunity to get information of the passengers flows on the roads where several routes of different kinds of public transport are working (See fig.10). The authorities can make macro analysis of the intensity of passenger's flows along the arterial roads and main multi-modal intersections which gives ground to a decision-making for optimization of public transport's route network or its schedules.

Fig.10 Intensity of passenger's flows along the arterial roads and main multi-modal intersections (example of the analysis)

Correctly designed data structure of the system provides the connection with the other information systems, such as, for example, GIS of Moscow, Automated system in the dispatch center for managing public transport traffic, Automated system for collecting fairs and Automated system for designing schedules of public transport.

The main effects from application: It is provided exact enough (mistakes within the limits of 4 - 10 %) the constant automated account of quantity of actually transported passengers on city ground transport. The set of the information for carrying out of various analyses is formed: from an estimation of actual volumes of passenger traffic on routes, highways and directions up to the control of actual proceeds over each vehicle (at 100 % to payment of travel by passengers). There is an objective basis for effective planning routing.

DIRECTIONS OF INTEGRATION OF ITS-RELATED TECHNOLOGIES OF URBAN TRANSPORT SYSTEMS

Summarizing, it is necessary to note, that creation and development of uniform ITS of city of Moscow is planed to be based on the general organizational-technological platform of navigating systems, control systems of traffic flows, etc. - from accounts of uniform coordinate (position data), time and the navigation support - under the conception of creating unified city analytical center (See fig.11).

Efficiency of the given systems provides total efficiency of construction city ITS from the point of view of investment appeal of projects.

Under this conception, ITS architecture is primarily about information exchange and control between systems at various levels of abstraction, as depicted in the multi-level model in Figure 12.
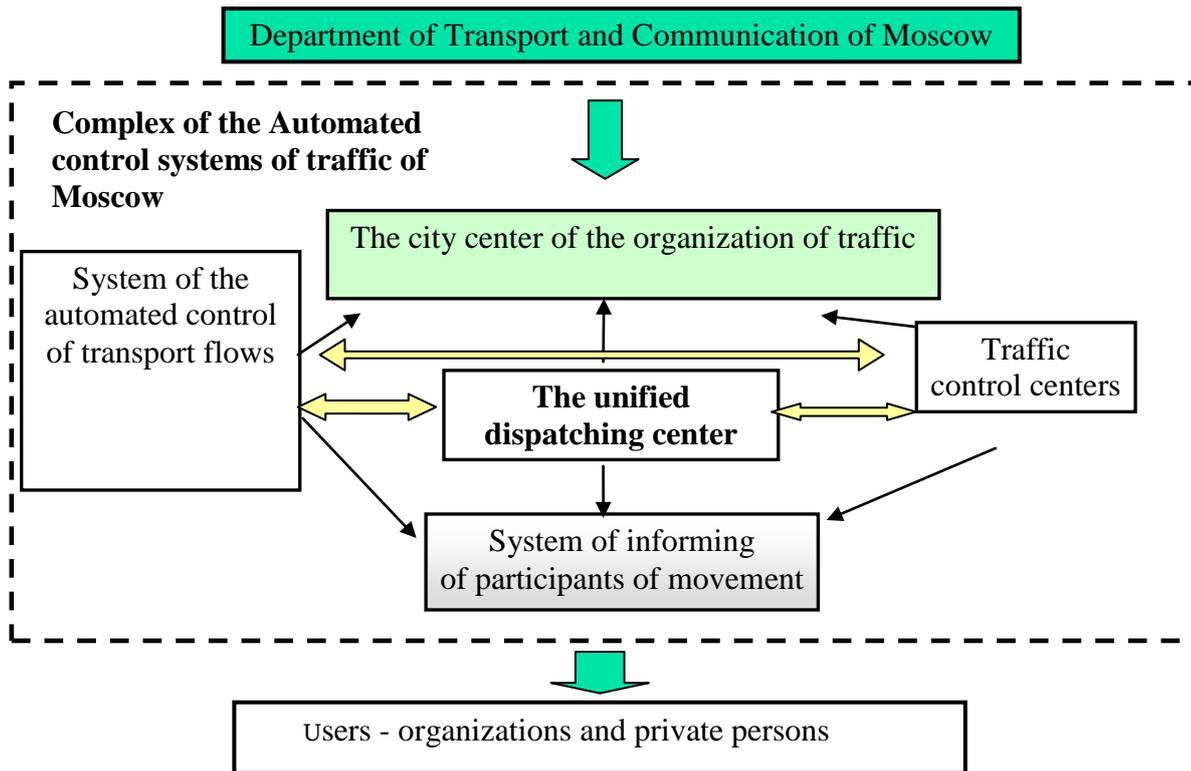

Fig. 11 The scheme of integration of the automated control systems of transport in Moscow (conception)

The concerned project (the scheme of integration of the automated control systems of transport in Moscow (conception) defined these levels as a way of explaining the uses that should be made of the various models and viewpoints that may comprise an architecture.

Level 3	**Multi-Agency Interoperability Properties**
Level 2	**Single Agency System Properties**
Level 1	**System Structure**
Level 0	**Subsystem/ Component Design**

Fig.12 Multi-level Model for Analysis of ITS Architecture for the conception of integration of ITS-related technologies of urban transport systems

Traffic and transport managers lay down high-level properties, or policy, at Levels 3 and 2, and the architectural structure at Level 1 is then devised so that it conforms to these properties. Level 0 is not strictly part of the architecture though it is often referred to as such, and represents the stage at which a supplier designs a system, or component, that conforms to the architecture.

Level 3 architecture needs to reflect the real-world constraints that operate on transport agencies, and to reflect the requirements for such system properties as interoperability between the participating agencies and the retention of information control by the respective agencies.

It may show where existing organisational structures must be modified and changed - perhaps quite radically - in order to deliver ITS services. As an example, a traffic control centre (TCC) may need to exchange data with another TCC or a traveller information centre (TIC), possibly across national or language boundaries. Defining the nature and minimum performance specification for this transaction matters a great deal.

CONCLUSIONS

ITS offers immense scope for integration, and some argue that it is only through integration of ITS components that ITS will achieve its full impact. Key ingredients are thorough planning, good communications and effective coordination of partners and stakeholder interests.

Currently, many ITS deployments are stand-alone applications since it is often more cost-effective in the short run to deploy an individual application without worrying about all the data exchange interfaces, communication links and different hardware platforms required for an integrated system. However, for ITS to take the next steps forward, it will be important both for efficiency and effectiveness reasons to think in terms of system integration. While this integration certainly adds complexity, it is also expected to provide Russian economies of scale in system deployment and improvements in overall system effectiveness, for example by integrating advanced transportation management systems (ATMS) with advanced traveller information systems (ATIS) in Moscow. For the most part, these two groups of services, while conceptually interlinked, have developed independently.

Another aspect of system integration is interoperability - ensuring that ITS components can function together. ITS services can make transport safer and more secure. They can maximise its capability to contain and reduce the impact of disasters, natural and man-made, e.g. by forward planning, cutting emergency service response times, and securing and prioritising disaster evacuation routes.

Current technology trends are enhancing the promises of increased safety and productivity for tomorrow's intelligent highways. The increasing availability of more powerful, yet less expensive software-driven GNSS receivers, integrated with other positioning technologies and wireless communications, will provide the knowledge of traffic flow and status that is the essential element of any intelligent highway system

The benefits of ITS are plentiful and reach in to every sector of the transport realm. It is possible to examine which coordinate (position data), time and the navigation support for ITS-related technology and applications have been the most successful, which have been less successful and what are the underlying factors that determine success or failure.

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