Increasing the level of automation of dispatch control when regulating at the end stops of public transport routes

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Abstract. The subject of research is automated dispatch control of public transport. Smart systems application on transport started in the second half of the 20th century. Application of such systems aims to improve every aspect of public transportation. However, despite constant development of telematics systems in public transport, this has not been achieved yet. The article discusses the use of telematics in public transport and the existing and actually functioning systems: ASK, NimBus and Navitrans. Authors suggest algorithm for public transport control that should increase the level of automation of dispatch control. The result of such approach is the improved regularity of public transport which is one of the key points to public transport efficiency and comfort to passengers.

1. Introduction
Public transport is an indefeasible part of life and modern society, providing urban mobility to the population. At the same time, it is extremely important to ensure the timely solution of management problems, the availability and quality of transport services, as well as to meet the growing requirements for the operation of urban public transport. All these things are available due to the introduction of telematic systems for public transport.

In recent years, automated dispatch control systems based on satellite navigation have been created in cities across the country, which allow solving the problems of automated control of urban public transport, scheduling and routing of public traffic. The operation of these systems is based on a discrete analysis of the movement of public transport by checkpoints. The effective use of satellite navigation in organizing the work of public transport results in the creation and application of scientific, methodological and technological approaches to improve the quality of information support of the telematic systems.

Enhancing the efficiency of the dispatcher is one of the most important tasks in improving the dispatch management of public transportation. As a result of the efficient operation of dispatching systems, the quality, reliability, availability and comfort of public transport are increased. That is why it is so important to improve the formation of approaches to further automation of dispatch control of public transport, as this is what determines the relevance of the research topic.
2. Review of domestic and foreign experience in the development and use of transport and telematic systems in public transport.

Currently, the concept of transport telematics is constantly expanding [1,2,3]. This is due to scientific and technological progress, which let us solve new practical problems. It is obvious that modern information systems are replacing traditional technologies. Telematics on automobile transport is aimed at developing and improving the transport infrastructure, as well as at ensuring the productive work of participants of the road transport process. The concept of telematics includes the application of information technologies based on the use of stationary and mobile systems, as well as on processing, accumulation and use of information in real time [4].

In the 60s of the last century, Europe, the USA and Japan introduced much more advanced transport systems than the previous traffic management. In the 60s and 70s were formed the basic principles of their functioning. And then in the 80s, the rapid development of electronics began, which made possible to introduce the first telematic systems DRIVE, ROMANSE, PROMETEUS in Europe, UTMS, ASV, ARTS in Japan, MOBILITY 2000 and IVHS systems in the USA [5].

In most of the systems we talk about, the vehicle position on the Earth surface determinating with the global navigation systems GPS (Global Positioning System, USA) and GLONASS (Global Navigation Satellite System, Russia) [6,7,8]. The result of the European Union and The European Space Agency - the Galileo system is also functioning now. The launch of the 5G-based Beidou system made it possible to start development of new innovative transport and infrastructure programs in China in 2020. The Development of the autonomous NavIC system (the system was renamed to IRNSS with the launch) was completed in India. The system is similar to the GLONASS and GPS systems in many ways, but IRNSS is regional. It covers the territory of India and an area up to 1500 kilometers to the Indian border [10].

Dispatch systems with global navigation systems based on collection and processing of operational information about the positioning of vehicles. This information makes it possible to control the transportation process and implementation of transport work, and to manage the transportation process.

Navigation systems consist of several main parts: planning of transportation processes, monitoring the operation of tracking objects, dispatch control, and the formation of various reporting forms.

Automated dispatch system (ADS) based on satellite navigation systems implements the following technological components: obtaining navigation marks, storing them onboard, and transmitting primary information to dispatching points. It also includes software and hardware for processing primary information. The scheme of work of the automated dispatching systems based on satellite navigation is shown on Fig.1.

![Figure 1. Schematic diagram of the operation of an automated control system based on satellite navigation](image)

Below are some automated dispatch systems that applied at public transport earlier:

1) System «ASDU-A». In the late 70s of the last century, SPKB “Promavtomatica” in the city of Omsk developed the first automated dispatch buses control system for large cities. Control point
devices (CPD) are installed on the route network. And these points received marks from vehicles as soon as they entered the checkpoint area using an electromagnetic loop, which was built under the road surface near the stopping point. Each route had to have at least two UCP. For each vehicle of the system, a mobile unit device (MUD) was installed. When the vehicle passed the checkpoint, a signal that contained the vehicle number and the timestamp was generated. After that, this signal was transmitted to the dispatch center using a dedicated telephone line.

2) System «NEZHAN». The principle of the system, developed in the city of Nalchick in the 80s of the 20th century, was to install radio beacons and radio repeaters at the control points of the GPT routes. At the same time, a mobile unit device was installed on each vehicle. Mobile unit, being within a radius of several tens of meters, receives signals from radio beacons, which they send to the radio broadcast at regular intervals. Received signals are stored in the internal memory, they contain the beacon number and the time when the mark was received. The repeaters, in turn, receive the accumulated signals from mobile unit device and, using city telephone communications transmit them to the dispatch center. At the same time, the system made possible the voice communication between the dispatcher and the driver, but only in the zone of the repeater.

3) System «ASU-Reis». Also in the 80s of the last century, the State Unitary Enterprise “MosgortransNIIProekt” was developed a dispatching control system for buses. The main principle of the system was the installation of radio beacons at the control points of the public transport routes, which send information about their own identification number on the air. A receiver that receives these signals, a VHF-radio station and radio modem was installed on the vehicle. Together with the identification number, the current time value is also transmitted to the dispatch center by radio channel. Then, based on the received data, the dispatch center calculates the deviation from the schedule and sends this information back to the vehicle. This system, due to the VHF radio station, made it possible to organize dispatcher-driver radio communication along the entire route of the vehicle.

The main disadvantages of the listed systems, obviously, are the lack of a continuous monitoring mode, as well as the features associated with the need to install and operate the equipment of control points.

3. Review and analysis of existing technologies of dispatch control

1) ASK system – Public transport is a software package for tracking the movement of an object along a route, passing control points by this object in a certain or arbitrary sequence according to a schedule or without it.

Application of this system implements the following features: formation and editing of routes, control over the implementation of specified traffic routes and compliance with the schedule by the driver, control of the driver’s working day schedule.

System consists of the following functional modules: module “Technologist”, module “Dispatcher”, module “Reports”, and module “References”.

A distinctive feature of this system is the service of stop terminals for informing the public. Specifically: informing riders about the arrival of all types of transport, providing background information (weather, news, traffic jams), alerting citizens about emergencies, if they arise, and advertising information.

2) NimBus system is a system for public transport control. The system is the most modern solution in terms of design among those considered in this work. Nimbus app helps public transport dispatchers plan and monitor bus transit. It can control urban, suburban and intercity public traffic [12].

The service combines the main functionality of satellite monitoring systems, as well as special tools for controlling route vehicles: distribution objects (vehicles) by routes, real-time movement tracking, control over adherence to schedules, tracking the location of objects on routes, creating a notification about events on routes, formation of reports on trip performance.

The following modules are declared in the system: stations (creating or import stations for each type of transport, with the ability to search for a specific one, as well as the ability to add and edit a
schedule), routes (formation a route of movement, drawing up a timetable for each route, as well as creating schemes of action), trips (assignment of transport objects to routes with grouping by route and object), tracking (visual interface for controlling schedule execution, with the ability to track deviations from the route, as well as replace vehicles on the route).

3) “Navitrans” system is a modular system for dispatching control and monitoring of the public’s flow. It has been introduced and operated in the enterprises of the State Unitary Enterprise “Mosgortrans” in Moscow, and in more than 80 cities located in 27 regions of Russia. The system allows to organize the management of public transport, control and accounting for implementation of transport work, promptly determine the locations of road accidents and emergencies, increase the speed of response to provide medical and evacuate victims, carry out measures in the line of the Ministry of Emergencies and mobilization [9,13,14,15,16]. A distinctive feature of the system is that the composition of the vehicle’s on-board devices can be different and depends on the specific tasks assigned to the system.

The system also makes it possible to generate various reports, both on the work of the dispatch center, and on the results of the transport work of the vehicle. For instance: reporting data on the drivers, vehicles (schedule execution, total mileage, linear mileage, operating time on the line, downtime), reporting data on the work of system dispatchers (recordings of voice communication between the dispatcher and the driver, recording of control actions).

The sub-system ASM-PP is designed to optimize public traffic for a number of parameters in medium and long-term planning, based on the technology of automatic collection and analysis of information about public flows. The system also obtains characteristics of public traffic in the format of tabular survey data [14].

Basic functionality of the system: operational control of the number of transported persons to set daily plans for collecting revenue, optimization of the route network based on the analysis public flows on stations on each route.

Additional functionality of the system: calculation of profitability for each surveyed route, taking into account zoning of fare payment. Application of geoinformatics tools allows you to create and edit passports of routes, as well as adapt them to specific tasks of public transport, drawing up a timetable taking into account the calculated norms for mileage on any section of the route with a division for periods of the day.

The system uses contactless public count systems, with both domestic and Imported equipment, which is installed on buses, streetcars.

In general, we can say that the “Navitrans” system has the greatest functionality of all systems considered. It is obvious that the basic functions of all three systems are similar; however the “Navitrans” system, as a result of collecting and analyzing data of public flows, provides a much wider functionality.

4. The main problems of providing the quality of service on public transport

It is important to understand that the assessment of the quality of service is carried out according to an integrated indicator – the value of the quality factor. It contains estimates for individual particular indicators, for instance: filling of the bus, the time spent on the trip, the regularity of the public transport movement on the routes, the safety of the public during the ride.

Obviously, it is impossible to accurately assess the current state of transportation, or determine the population’s need for this type of service without providing the management of public transport up-to-date analytical information of the actual capacity and dynamics of public flows on urban routes.

Fig. 2 shows an example of the possible types of supply and demand curves for transport services. It clearly shows that without an assessment of public flows, the curves do not correspond to each other. That means that riders either wait a long time for their transport, or the public transport is almost empty. The red line in the figure indicates the mode of operation that should be achieved at organizing traffic to provide a balanced filling of the cabin, while taking into account the carrying capacity of the
route, efficient use of rolling stock, free entry and exit of people, waiting time at a stopping point, as well as the fastest transportation the public.

Figure 2. Supply and demand curves of transport services on the public transport routes

A similar situation occurs when the dispatcher system does not work correctly, or when an emergency situation occurs and there is no prompt action from the dispatcher. The regularity of the movement of rolling stock is an indicator of the quality of transport work, and it is the activity of dispatch systems that directly affects the regularity. Consequently, enhancing the automation of dispatch systems, and hence their efficiency, also increases the quality of services provided.

It is important to note that automated dispatch systems can improve another aspect of the quality of services provided, namely the safety of publics during transportation. Indeed, in case of an emergency situation, an accident, etc., when using automated dispatching systems, it is possible to take measures both in automated mode, e.g. calling emergency services, and using the driver-dispatcher voice communication. Hence automated systems can reduce the response time to emerging problems in the field of transport security.

One of the most effective ways to reduce traffic congestion in cities is to increase the proportion of citizens using public transport services and reduce the proportion of drivers and publics in private cars. It is necessary to increase the attractiveness of public transport by improving the quality of public flows to do this.

Despite the fact that the quality of public traffic is assessed in a comprehensive manner according to several parameters, one of the most obvious ways to improve the comfort of public traffic is to organize regular traffic of the public transport. This will solve the main problem faced by the public. Namely, the problem of long waiting times for the vehicle, which may be caused by the non-optimal spread of the rolling stock along the routes or non-compliance with the planned intervals of the vehicle. As a result, there is a problem of low ride comfort associated with overcrowding and increased waiting times for vehicles at stopping points.

Unfortunately, feedback from the public is not enough for competent adjustment of schedules and distribution of rolling stock on routes, which is why it is so important to work with operational data from the vehicle. The processing of the initial data on the passing time of the route stops will help to not only determine the most problematic routes, but also the period of the day where the summary schedule on routes is not executed. The analysis of processed navigation data is a tool for improving the organization of transportation on this route by revising the existing timetables. Moreover, the results of the calculation in real time can be the basis for operational dispatching actions. For instance, dispatchers can put additional vehicles on the route to increase the carrying capacity riders at peak times. In turn helping improve the comfort of travel for passengers.

To obtain operational information about the quality of the transportation process on the route, it is necessary to be able to process the primary data coming from the rolling stock in real time.
5. The control algorithm of public transport

This calculation uses a recursive algorithm. When calculating the departure time of the current vehicle, the interval of the vehicle in front is not taken into account, since it is taken into account when calculating the departure time of the vehicle in front, when it was current.

5.1. Real-time simulation, end of the trip event processing.

1) Get the data from the retrospective data array with two requests for each direction.
2) Saving the data in the corresponding entities containing the following variables: stop time, trip number, stop number, vehicle number. The data is saved into an array, which stores the numbers of adjacent stops in the order of their passage. The associative array is used where the “key” is the time of the stop arrival, and the “value” is the duration interval between adjacent stops. At this moment the program can determine the time of the end of the trip.

5.2. Predicted arrival time calculation for the vehicle behind

This calculation is necessary in order to subsequently determine the value of the time interval for which the program needs to “hold” the current vehicle at the end stop to maintain a uniform interval, if the vehicle behind is late. This situation is shown in Fig.3. The program already stores the time of passage of the current vehicle in RAM. The program also receives in real-time simulation the navigation marks from the vehicle behind. So, when the current vehicle arrives at the end stop, the algorithm determines the last stop passed by the vehicle behind. We assume that the vehicle behind has the same time left to go until the end of the trip. That means that the interval between vehicles will remain unchanged. Further, the algorithm compares, according to formula 1, the interval, between the current vehicle and the vehicle behind, at the stop, the navigation mark about passage of which by the vehicle behind was received last, and the time of the specified interval for the vehicle’s release on the trip.

\[
\Delta t = (t_c - t_b) - t_i
\]  

where \(\Delta t\) – the time difference between the interval, between the current vehicle and the vehicle behind, and the interval for the vehicle’s release on the trip;
\(t_c\) – the time the current vehicle passed the stop, the navigation mark, about passage of which by the vehicle behind was received last;
\(t_b\) – the time the vehicle behind passed the stop, the navigation mark about passage of which was received last;
\(t_i\) – the interval for the vehicle’s release on the trip.

So, if \(\Delta t > 0\), the vehicle going behind it is late.

5.3. Departure time calculation of a vehicle on a trip.

\[
\Delta t = (t_c - t_b) - t_i
\]

If \(\Delta t < 0\), in further calculations we take \(\Delta t = 0\). If \(\Delta t > 0\), the left time of the trip is longer than the specified interval for releasing the vehicle on the trip. That means that the interval of release of the current vehicle on the trip must be increased by half of \(\Delta t\). In this case, when calculating the adjusted interval, the value of half of \(\Delta t\) must be saved in the program’s RAM in order to add it when calculating the adjusted interval for the vehicle behind when it becomes current. The adjusted interval is determined by formula 2:
\[ t_{ad} = t_i + \frac{\Delta t}{2} + t_h \]  

(2)

where \( t_{ad} \) – adjusted release interval of the current vehicle on the trip;
\( t_h \) – the half value of half of \( \Delta t \) saved in the program memory when calculating the adjusted interval for the previous vehicle.

6. Conclusions

The calculated departure time can also be used to inform the public. Moreover, the methods of informing can be completely different.

First of all, information can be displayed on the stop information display. Adjusted intervals can be displayed on stop information display, in a mobile application or web interface. If the installation of stop information display is impossible, a QR code can be installed on the stop. When this QR-code is scanned, the currently calculated interval will be displayed, or in case of improving the public information system, on the basis of the developed system, it is possible to display the time of arrival of the vehicle at a particular stop.

When considering the issue of informing passengers about the time of arrival of the vehicle at the stop terminals, it is important to understand that there are people who do not have access to Internet resources or the mobile platform. Therefore, to organize informing these citizens, a free telephone line can be launched. Operators of this line will provide the information of the movement and waiting time of public transport at the indicated passenger stop.

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