Reduction of the negative environmental impact of motor transport through the use of intelligent transport systems

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Abstract. The work investigates the anthropogenic impact of motor transport on the environment of urbanized areas, including emissions of pollutants into the air, noise and vibration effects. The efficiency of using intelligent transport systems (ITS) to solve various problems of the motor transport complex, including reduction of its negative environmental impact, is shown. The authors considered a local project of the intelligent transport system "Smart Road", implemented in the Kursk region. An assessment of the effectiveness of various ITS scenarios in terms of improving environmental performance on road sections and regulated intersections has been carried out. The following indicators of environmental safety have been studied: mass emission of pollutants contained in the exhaust gases of vehicles; noise level from traffic flow. A significant decrease in the emissions of pollutants from trucks at the site of ITS use has been established, as well as a decrease in the overall noise load from vehicles. At the same time, it is shown that there was no reduction in emissions from cars and minibuses. In this regard, it is proposed to develop scenarios for the functioning of ITS, ensuring the optimization of these types of vehicles.

1 Introduction

In recent decades, there has been a significant increase in the negative impact of transport systems on the environment of urbanized territories, both in Russia and in other developed countries [1-2]. Functioning of various types of transport is accompanied with a serious technogenic impact consisting of chemical contamination of environmental components, as well as vibroacoustic, thermal and electromagnetic effects [4].

The problem of transport systems as the main source of anthropogenic air pollution has been considered in the scientific works of a large number of Russian and foreign scientists [5]. Russian researchers have shown that among the transport system branches, motor transport is the leader in terms of the degree of increasing negative impact on the environment and public health [6-7]. Thus, the total volume of emissions of air pollutants in 2018 amounted to 32.3 million tons, about 50% of these emissions is due to the impact of mobile pollution sources. And in many Russian cities, the share of vehicle emissions can be

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up to 80% of the total amount of emissions into the atmosphere [8]. Similar trends are common in other developed countries [9-10].

Thus, motor vehicles pollute the atmospheric environment with toxic components of exhaust gases, fuel vapor, products of tire and brake linings wear, and create noise and vibration. Emissions from motor vehicles affect negatively the physiological state of humans and animals, pollute water, destroy soil, vegetation, building materials, architectural and sculptural monuments, cause corrosion of metals, etc.

2 Materials and methods

In modern research, two main methods of solving various problems of road transport systems including improving its environmental safety, are addressed. The first method is the modernization of the road infrastructure aimed at increasing the capacity and improving the safety of road networks. The second one is the development and implementation of intelligent transport systems that enable more efficient operation of the transport network based on information, communication and management technologies built in vehicles or road infrastructure.

Information safety transport systems have been systematically developed and implemented in many European countries, economically developed countries of the Asia-Pacific region, and the United States since the 1980s.

On the basis of the world experience generalization and analysis, the concept of the Russian intelligent transport system (RITS) able to perform the functions of dispatching situational and operational coordination of the interactions of all road users, special services and departments, has been developed in our country. It is aimed at increasing the level of transport safety, reducing costs and environmental load.

As part of the development of the Russian intelligent transport system, local ITS projects are being implemented in many cities of the Russian Federation. The purpose of this study is to assess the efficiency of the local ITS project being implemented in the city of Kursk in terms of improving environmental performance on road sections and in signalized intersection areas.

Since 2020, the Kursk region has been developing and implementing a local intelligent transport system project. It is planned to install smart traffic lights, 45 video surveillance systems, weather and environmental monitoring stations on the territory of the region. The project is to start with the introduction of an computer-aided traffic management system in Karl Marx Street in Kursk by installing meteorological and environmental monitoring stations, photo-video recording systems for road traffic offences and 10 smart traffic lights in accident blackspots.

Besides, on the section of Leninsky Komsomol Avenue from M2 highway to Kryukov Street in Kursk, a propotype of the Avtodata platform (a GLONASS pilot project – “Smart Road”) has been deployed providing computer-aided traffic management according to three scenarios:

- Minimization of the number of stops of heavy trucks and their groups when passing signalized intersections. If a loaded truck is moving on the road to a signalized intersection it has to brake at the red light and then start at the green. In this case, the following has been observed: increased fuel consumption; increased emissions and noise; increased wear of the road surface; increased wear of vehicle components; reduced traffic capacity of the intersection; increased risk of accidents. The proposed solution minimizes the number of heavy transport stops, thus minimizing the described negative effects due to running a speed recommendation scenario for driving at the green light and non-stop passage of the intersection towards which the truck is moving.

- Providing priority passing for buses being late. The public transport schedule is calculated on the basis of some average traffic parameters, whereas in the actual conditions, there can be some events in the traffic flow that can prevent the timekeeping. In this case, giving priority passing to delayed public transport at a signalized intersection can help the public transport catch up with its schedule.
- Ensuring safe passing of signalized pedestrian crossings for organized columns of pedestrians by intelligently increasing the duration of the red traffic light signal.

This study is focused on assessing the efficiency of the use of the above-mentioned scenarios of the operation of the prototype of the Avtodata platform in the territory of Kursk in terms of improving environmental indicators on road sections and at signalized intersections.

To assess the efficiency of the implementation of local ITS projects, target indicators are used. The content of these indicators is disclosed through certain functional performance indicators. In this study, special attention is paid to environmental safety indicators. Based on the purpose of the study it is necessary to assess the main environmental indicators that are affected by road transport, before and after the ITS introduction. We considered the mass release of pollutants contained in the exhaust gases of vehicles and the noise level from the traffic flow as such indicators. The assessment of the mass emission of pollutants by vehicles was carried out on the basis of the results of field surveys of the composition and intensity of the traffic flow in accordance with the Methodology for Determining Vehicle Emissions for conducting summary calculations of urban air pollution. Measurements of the noise level from motor transport were carried out in accordance with paragraph 4 of GOST 20444-2014 "Noise. Traffic flows. Methods for measuring noise characteristics".

3 Results

To solve the tasks set in the study, full-scale surveys of the composition and intensity of the moving traffic flow along Leninsky Komsomol Avenue were conducted. To analyze the dynamics of changes in the traffic load, it was decided to conduct a survey during morning and evening rush hours, as well as in the interim time intervals on working days and at weekends.

Based on the results of the field surveys, calculations of emissions of moving vehicles and vehicles in the area of signalized intersections were carried out using the software developed by the authors. For a better visual presentation and analysis of the results, the software developed by the authors provides the possibility to plot various dependences diagrams (Figure 1 and 2).

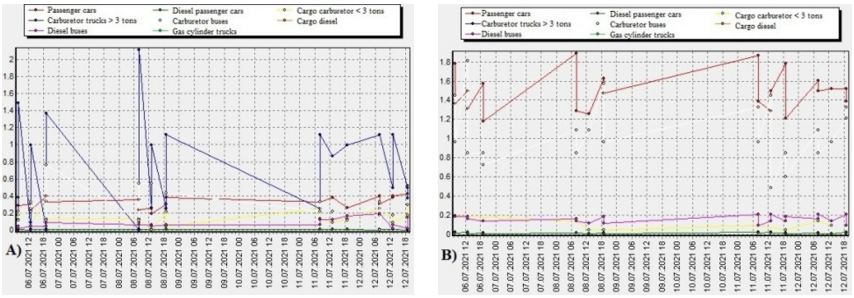

Fig. 1. Carbon monoxide emissions by vehicle groups. A – before ITS; B - after ITS. Source: Compiled by the authors.

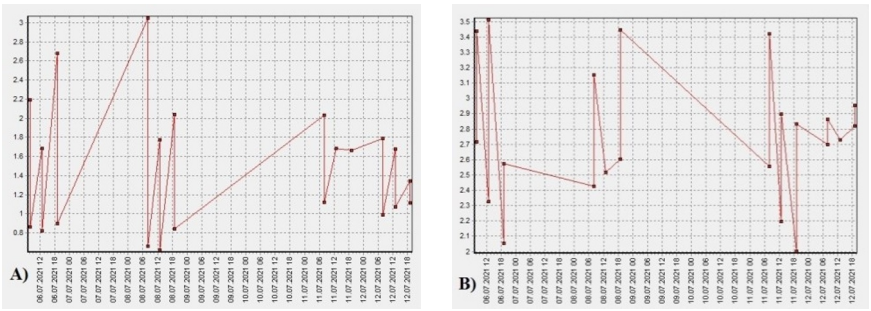

Fig. 2. Total carbon monoxide emissions. A - before ITS; B - after ITS. Source: Compiled by the authors.

The results of measuring the traffic flow noise level are presented in Table 1.

Table 1. The results of measuring the traffic flow noise level.

Noise level measurement points	Place of measurement	Noise level 7-9h., dB	Noise level 9-19h., dB	Noise level 19-23h., dB	Noise level 23-7h., dB
Before the ITS	From the side of the road	79.8	82.3	74.8	59.3
After the ITS	From the side of the road	78.3	81.3	70.3	60.1

Source: Compiled by the authors.

4 Discussion

World practice shows that the introduction of ITS allows reducing fuel consumption by motor vehicles and the total mass emission by 20% [11]. The results of the conducted research indicate that, unfortunately, these indicators concerning the Kursk region have not been achieved.

To the greatest extent, the scenario of ITS functioning, aimed at minimizing the number of stops of heavy trucks and their detachments when passing signalized intersections, contributes to achieving the goals of improving environmental safety, since the bulk of pollutants is released in the greatest amount by trucks. Thus, the most dangerous zone is the highways on which the passage of this type of transport is allowed. The introduction of ITS has contributed to reducing emissions from heavy trucks to almost 0. Moreover, the absence of stops of these vehicles at signalized intersections led to noise reduction.

The released volume of pollutants from passenger cars is somewhat less, but in cities the prevailing kind of transport is passenger cars, as well as minibuses, and therefore the total mass emission of main pollutants from them is not only comparable to the emission of trucks, but often exceeds the latter. In this regard, along with the scenario that minimizes the number of stops of heavy trucks and their groups when passing signalized intersections, it is necessary to develop scenarios aimed at reducing the number of traffic jams and optimizing the movement of passenger cars and minibuses.

The scenario that provides priority passing for delayed buses is more likely to increase the attractiveness of public transport by increasing the accuracy of keeping the schedule. There is no reduction in the negative impact on the environment due to the fact that this scenario does not ensure the elimination of congestion of public transport operating in the idle mode at stops.

Ensuring the safe passage of signalized pedestrian crossings for organized columns of pedestrians by intelligently increasing the duration of the red traffic light signal leads to the increase in the amount of pollutants released into the air. In terms of the ecology, a more rational solution is the construction of pedestrian overpasses or underground walkways.

5 Conclusion

In the Russian Federation, at the legislative level there are no boundary (numerical) values of indicators based on which it is possible to quantify and compare the efficiency of the implementation of various local ITS projects. In this regard, in our opinion, it is advisable to develop an integrated indicator that characterizes the socio-ecological situation on road sections and intersections taking into account the main target indicators of environmental safety. Also, in our opinion, it is necessary to analyze the values of carbon monoxide and nitrogen oxides concentrations as the main components of vehicle exhaust gases, since it is the concentration of pollutants that underlies the sanitary and hygienic regulation applied in the Russian Federation. In addition, the integrated indicator should take into account the distance from road sections and intersections to socially significant facilities where the most vulnerable to the negative impact of adverse environmental factors groups of the population can stay for a long time. Such facilities should include kindergartens, schools, hospitals, medical centres, and nursing homes for the elderly. The weighting factors for each indicator included in the final indicator can be determined on the basis of the analysis of the results of the expert survey which the authors are planning to conduct at the next stage of the study.

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