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# Measures to optimize traffic and the environment. Calculations of environmental safety on a given section of the Rostov-on-Don road network

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*Introduction*. One of the most pressing socio-economic problems is the state of the environment, which affects the living conditions of many people. The article deals with the problem areas of the intersection of 20-ya Liniya street – Sholokhov Avenue in Rostov-on-Don.

*Problem Statement*. The purpose of this paper is to improve environmental safety at the intersection of 20-ya Liniya street – Sholokhov Avenue in Rostov-on-Don by reducing emissions from road transport through the proposed measures to reorganize traffic on this section of the road network.

*Theoretical Part*. The article provides an assessment of environmental and road safety on the road network section before applying the proposed measures. The measures are listed and justified that would help improve the conditions for road transport at the selected intersection and reduce emissions from road transport, which would improve environmental safety. The calculation of environmental indicators was made after the proposed measures to reduce NOx emissions by cars.

*Conclusion*. The article analyzes the environmental indicators before and after the events, and then compares them. Based on the analysis and calculations, it is determined how much the proposed measures to optimize traffic will help reduce NOx emissions by cars.

***Keywords***: environment, measures to optimize traffic, environmental safety, mass consumption of NOx, ecology, section of the road network, engine, traffic flow.

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**Introduction.** One of the most pressing socio-economic problems is the state of the environment, which affects the living conditions of many people. The growth of technological progress is associated with an increase in the number of vehicles on the roads. Cars, in turn, are one of the main mass pollutants of the atmosphere. They pose a threat to human health associated with emissions and waste, as well as the impact of noise from traffic flows [1].

In recent years, Russia has been experiencing serious environmental pollution, which is a critical threat to public health and sustainable development. Energy activities are the dominant source of air pollution. The amount of carbon dioxide ($CO_2$) emitted by power plants into the atmosphere is approximately 40% of the total $CO_2$ emissions. The same indicator for power plant pollutants is 30 %. In addition, it has been found that vehicles are making an increasing contribution to air pollution due to the rapid growth of traffic. Transport accounts for 20-67 % of carbon monoxide ($CO$) emissions, 12-36% of $NO_x$ oxynitride emissions, and 12-39% of hydrocarbon compound (HC) emissions. The scale of emissions in most regions of Russia exceeds the possibilities of self-purification and diffusion of pollutants from the atmosphere. At present, there is an acute conflict between the growing demand for energy, the excessive number of vehicles and the "high coal content" in the energy balance, on the one hand, and the imperative to mitigate air pollution, on the other [2, 3].

**Problem Statement.** The aim of the work is to improve the environmental situation at the intersection of 20-ya Liniya street and Sholokhov Avenue in Rostov-on-Don by reducing emissions from road transport through measures to reorganize traffic on this section of the road network. It is also necessary to assess the environmental safety and road safety on the section of the road network (RN) before applying the proposed measures.

After studying the situation at the above-mentioned intersection, it can be concluded that there is a possibility of improving the conditions for road transport at this interchange. The problem factors in the surveyed area are:

— irrationally selected cycle of operation of two traffic lights;

— no traffic lay-by for municipal transport.

It is assumed that the key problem of this intersection is the wrong cycle of traffic lights. This problem is particularly felt in peak hours when the traffic intensity increases significantly. It is recorded that the duration of the permissive signal for pedestrians crossing Sholokhov Avenue is only 24 seconds. The width of the road on this section is 13 meters. For an ordinary person, this time is more than enough. However, for people with limited mobility, given the absence of various types of descents from curbs or ramps, the situation becomes critical [4].

Buses and minibuses moving from the suburban bus station towards Karl Marx square can turn left on 20-ya Liniya street during the operation of the traffic light permissive signal. However, during peak hours, the number of moving vehicles on routes increases, which means that the traffic intensity of municipal transport increases. Buses and minibuses gather at this intersection, and 20 seconds is clearly not enough for them. Everything could be corrected by adding only 10 seconds to the time of the traffic light's permissive signal.

Also, an important condition for increasing the passability of this section is the organization of a traffic lay-by at the bus stop, before reaching the 9th Dormitory of the Don State Technical University. By extending the stop by three meters towards the sidewalk, it would be possible to get a wide traffic lay-by, which would allow buses not to block the flow moving towards the ring at the suburban bus station. The implementation of a traffic lay-by at the stop would increase the passability of this section without violating the relevant standards [4, 5].

**Theoretical Part.** According to the environmental monitoring data, on the section of the road transport network along Sholokhov Avenue near 20-ya Liniya there is an increased content of nitrogen oxides $NO_x$. According to preliminary calculations, NOx emission is 11.2 g/s. As a result of the environmental actions, the speed of traffic increased from 6.8 m/s to 8.2 m/s. Let us calculate the mass of NOx emissions from the transport stream afterwards. The length of a section of the street road network is $L$ = 111.6 m, and the number of lanes in each direction is $z$ = 3 [6].

The speed of passenger cars $v$ is determined by the formula (1):

$$v = 1.8665 v_{m.n.}, \tag{1}$$

where $v_{m.n.}$ — the speed of the traffic flow

Using formula (1), we determine the speeds of groups of cars.

Speed of passenger vehicles (PV):

$$v_{j1} = 1.8665 \cdot 8.2 \approx 15.31 \text{ m/s.}$$

Minibus speed:

$$v_{j2} = 0.575 \cdot 15.31 \approx 8.8 \text{ m/s.}$$

Speed of cargo vehicles and buses:

$$v_{j3} = v_{j4} = 0.4465 \cdot 15.3 \approx 6.84 \text{ m/s.}$$

The product $\delta_{вр} a$ for passenger vehicles can be represented by the expression:

$$\pm \delta_{вр} a = g(2{,}023 v^{-1{,}0678} - \psi), \tag{2}$$

where $\delta_{вр}$ — the coefficient accounting for rotating mass; $a$ — vehicle acceleration, m/s$^2$; $g$ — gravity acceleration, m/s$^2$; $\psi$ — the coefficient of reduced road resistance, it can be calculated by the formula:

$$\psi = (f \pm tg\gamma)\cos\gamma\,,$$

whre $f$ — coefficient of rolling resistance, taken as $f$ = 0,02; $\gamma$ — the angle between the surface of the roadway and the horizontal plane.

Let us determine the product for passenger vehicles groups using the formula.

Passenger vehicles:

$$\delta_{вр}a = 9{,}87[2{,}023 \cdot 15{,}31^{-1{,}0678} - (0{,}02 - tg4)] = -6{,}257 \text{ m/s}^2.$$

Minibuses:

$$\delta_{вр}a = 9{,}87[1{,}6851 \cdot 8{,}8^{-1{,}3825} - (0{,}02 - tg4)] = -6{,}518 \text{ m/s}^2.$$

Cargo vehicles and buses:

$$\delta_{вр}a = 9{,}87[0{,}5502 \cdot 6{,}84^{-1{,}11} - (0{,}02 - tg4)] = -6{,}698 \text{ m/s}^2.$$

The equation for determining the relative power of car engines, depending on their purpose and the type of fuel used, has the form [7, 8]:

$$\overline{N}N_{ном} = \frac{[k_{ф}\rho_{в}F_s v_j^2 + mg\cos\gamma(f \pm tg\gamma) \pm \delta_{вр}am]v_j}{\eta_{тр}}\,, \tag{3}$$

where $\overline{N}N_{ном}$ — the product, representing the effective power of the engine, W, where $N_{ном}$ — rated engine power, W; $k_{ф}$ — coefficient of streamlining; $\rho_{в}$ — air density, $\rho_{в}$=1.293 kg/n$^3$; $F_s$ — frontal area of the vehicle, m$^2$; $m$ — mass of the vehicle, kg $\eta_{тр}$ — transmission efficiency.

The minus signs in equation (3) are placed before the complexes of values $tg\gamma$ and $\delta_{вр}am$, respectively, when moving downhill and when the acceleration of translational motion is negative (movement with deceleration). Let us substitute the values of the mass, power, and aerodynamic characteristics of the passenger vehicle in equation (3) and get the values of the relative power of car engines.

Relative power of passenger cars with carburetor-type petrol engines:

$$\overline{N} = \frac{\left[0{,}15 \cdot 1{,}293 \cdot 1{,}5 \cdot 15{,}31^2 + 1750 \cdot 9{,}87 \cdot \cos 4 \cdot \left(0{,}02 - tg4\right) - 6{,}257 \cdot 1750\right] \cdot 15{,}31}{60000 \cdot \left(-2{,}9224\overline{N}^3 + 3{,}4211\overline{N}^2 - 1{,}0995\overline{N} + 1{,}0299\right)}\,.$$

It follows:

$$-2{,}9224\overline{N}^4 + 3{,}4211\overline{N}^3 - 1{,}0995\overline{N}^2 + 1{,}0299\overline{N} - 0{,}5013 = 0\,.$$

$\overline{N}_1 = 0{,}969$ and $\overline{N}_2 = 0{,}516$. Let us take $\overline{N} = \overline{N}_2 = 0{,}516$. This equation has 2 real roots $\overline{N}_1 = 0{,}959$ and $\overline{N}_2 = 0{,}536$, one of which ($\overline{N}_1$)is approximately equal to one. Based on the physical meaning, we can assume that at these speeds it is impossible to get such a relative power of the first root as a result. Therefore, the most likely option is a real root ($\overline{N}_2$). Thus $\overline{N} = \overline{N}_2 = 0{,}536$.

Relative power of passenger cars with injection-type petrol engines:

$$\overline{N} = \frac{\left[0{,}15 \cdot 1{,}293 \cdot 1{,}5 \cdot 15{,}31^2 + 1750 \cdot 9{,}87 \cdot \cos 4 \cdot \left(0{,}02 - tg4\right) - 6{,}257 \cdot 1500\right] \cdot 15{,}31}{60000 \cdot \left(-3{,}2715\overline{N}^3 + 3{,}8372\overline{N}^2 - 1{,}2194\overline{N} + 1{,}0006\right)}\,.$$

It follows:

$$-3{,}2715\overline{N}^4 + 3{,}8372\overline{N}^3 - 1{,}2194\overline{N}^2 + 1{,}0006\overline{N} - 0{,}5013 = 0\,.$$

$\overline{N}_1 = 0{,}937$ and $\overline{N}_2 = 0{,}53$, let us take $\overline{N} = \overline{N}_2 = 0{,}53$.

Relative power of passenger cars with diesel engines:

$$\overline{N} = \frac{\left[0{,}15 \cdot 1{,}293 \cdot 1{,}5 \cdot 15{,}31^2 + 1750 \cdot 9{,}87 \cdot \cos 4 \cdot \left(0{,}02 - tg4\right) - 6{,}257 \cdot 1750\right] \cdot 15{,}31}{70000 \cdot \left(-1{,}3238\overline{N}^3 + 1{,}118\overline{N}^2 - 0{,}031\overline{N} + 0{,}8755\right)}\,.$$

It follows:

$$-1{,}3238\overline{N}^4 + 1{,}118\overline{N}^3 - 0{,}031\overline{N}^2 + 0{,}8755\overline{N} - 0{,}4297 = 0\,.$$

$\overline{N}_1 = 1{,}12$ and $\overline{N}_2 = 0{,}445$, let us take $\overline{N} = \overline{N}_2 = 0{,}445$.

Relative power of passenger cars with gas engines:

$$\overline{N}=\frac{\left[0,15\cdot 1,293\cdot 1,5\cdot 15,31^{2}+1750\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,257\cdot 1750\right]\cdot 15,31}{55000\cdot \left(-2,9224\overline{N}^{3}+3,4211\overline{N}^{2}-1,0995\overline{N}+1,0299\right)}.$$

It follows:

$$-2,9224\overline{N}^{4}+3,4211\overline{N}^{3}-1,0995\overline{N}^{2}+1,0299\overline{N}-0,5468=0.$$

$\overline{N}_1=0,946$ and $\overline{N}_2=0,562$, let us take $\overline{N}=\overline{N}_2=0,562$.

Relative power of minibuses with carburetor-type petrol engines:

$$\overline{N}=\frac{\left[0,45\cdot 1,293\cdot 3\cdot 8,8^{2}+2750\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,518\cdot 2750\right]\cdot 8,8}{90000\cdot \left(-2,9224\overline{N}^{3}+3,4211\overline{N}^{2}-1,0995\overline{N}+1,0299\right)}.$$

It follows:

$$-2,9224\overline{N}^{4}+3,4211\overline{N}^{3}-1,0995\overline{N}^{2}+1,0299\overline{N}-0,2344=0.$$

$\overline{N}_1=1,06$ and $\overline{N}_2=0,254$, let us take $\overline{N}=\overline{N}_2=0,254$.

Relative power of minibuses with injection-type petrol engines:

$$\overline{N}=\frac{\left[0,45\cdot 1,293\cdot 3\cdot 8,8^{2}+2750\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,518\cdot 2750\right]\cdot 8,8}{90000\cdot \left(-3,2715\overline{N}^{3}+3,8372\overline{N}^{2}-1,2194\overline{N}+1,0006\right)}.$$

It follows:

$$-3,2715\overline{N}^{4}+3,8372\overline{N}^{3}-1,2194\overline{N}^{2}+1,0006\overline{N}-0,2344=0.$$

$\overline{N}_1=1,03$ and $\overline{N}_2=0,265$, let us take $\overline{N}=\overline{N}_2=0,265$.

Relative power of minibuses with diesel engines:

$$\overline{N}=\frac{\left[0,45\cdot 1,293\cdot 3\cdot 8,8^{2}+2750\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,518\cdot 2750\right]\cdot 8,8}{90000\cdot \left(-1,3238\overline{N}^{3}+1,118\overline{N}^{2}-0,031\overline{N}+0,8755\right)}.$$

It follows:

$$-1,3238\overline{N}^{4}+1,118\overline{N}^{3}-0,031\overline{N}^{2}+0,8755\overline{N}-0,2344=0.$$

$\overline{N}_1=1,18$ and $\overline{N}_2=0,263$, let us take $\overline{N}=\overline{N}_2=0,263$.

Relative power of minibuses with gas engines:

$$\overline{N}=\frac{\left[0,45\cdot 1,293\cdot 3\cdot 8,8^{2}+2750\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,518\cdot 2750\right]\cdot 8,8}{65000\cdot \left(-2,9224\overline{N}^{3}+3,4211\overline{N}^{2}-1,0995\overline{N}+1,0299\right)}$$

It follows:

$$-2,9224\overline{N}^{4}+3,4211\overline{N}^{3}-1,0995\overline{N}^{2}+1,0299\overline{N}-0,3246=0.$$

$\overline{N}_1=1,036$ and $\overline{N}_2=0,346$, let us take $\overline{N}=\overline{N}_2=0,346$.

Relative power of cargo vehicles with carburetor-type petrol engines:

$$\overline{N}=\frac{\left[0,45\cdot 1,293\cdot 3,5\cdot 6,84^{2}+4000\cdot 9,87\cdot \cos 4\cdot \left(0,02-tg4\right)-6,698\cdot 4000\right]\cdot 6,84}{72000\cdot \left(-2,9224\overline{N}^{3}+3,4211\overline{N}^{2}-1,0995\overline{N}+1,0299\right)}.$$

It follows:

$$-2,9224\overline{N}^{4}+3,4211\overline{N}^{3}-1,0995\overline{N}^{2}+1,0299\overline{N}-0,2532=0.$$

$\overline{N}_1=1,06$ and $\overline{N}_2=0,274$, let us take $\overline{N}=\overline{N}_2=0,274$.

Relative power of cargo vehicles with injection-type petrol engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 3,5\cdot 6,84^2 + 4000\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 4000\right]\cdot 6,84}{72000\cdot\left(-3,2715\overline{N}^3 + 3,8372\overline{N}^2 - 1,2194\overline{N} + 1,0006\right)}$$

It follows:

$$-3,2715\overline{N}^4 + 3,8372\overline{N}^3 - 1,2194\overline{N}^2 + 1,0006\overline{N} - 0,2532 = 0.$$

$\overline{N}_1 = 1,03$ and $\overline{N}_2 = 0,285$, let us take $\overline{N} = \overline{N}_2 = 0,285$.

Relative power of cargo vehicles with diesel engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 3,5\cdot 6,84^2 + 10250\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 10250\right]\cdot 6,84}{125000\cdot\left(-1,3238\overline{N}^3 + 1,118\overline{N}^2 - 0,031\overline{N} + 0,8755\right)}.$$

It follows:

$$-1,3238\overline{N}^4 + 1,118\overline{N}^3 - 0,031\overline{N}^2 + 0,8755\overline{N} - 0,3656 = 0.$$

$\overline{N}_1 = 1,13$ and $\overline{N}_2 = 0,395$, let us take $\overline{N} = \overline{N}_2 = 0,395$.

Relative power of cargo vehicles with gas engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 3,5\cdot 6,84^2 + 10250\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 10250\right]\cdot 6,84}{80000\cdot\left(-1,3238\overline{N}^3 + 1,118\overline{N}^2 - 0,031\overline{N} + 0,8755\right)}.$$

It follows:

$$-1,3238\overline{N}^4 + 1,118\overline{N}^3 - 0,031\overline{N}^2 + 0,8755\overline{N} - 0,5713 = 0.$$

$\overline{N}_1 = 1,03$ and $\overline{N}_2 = 0,606$, let us take $\overline{N} = \overline{N}_2 = 0,606$.

Relative power of buses with carburetor-type petrol engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 7,5\cdot 6,84^2 + 5000\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 5000\right]\cdot 6,84}{100000\cdot\left(-2,9224\overline{N}^3 + 3,4211\overline{N}^2 - 1,0995\overline{N} + 1,0299\right)}.$$

It follows:

$$-2,9224\overline{N}^4 + 3,4211\overline{N}^3 - 1,0995\overline{N}^2 + 1,0299\overline{N} - 0,2337 = 0.$$

$\overline{N}_1 = 1,06$ and $\overline{N}_2 = 0,253$, let us take $\overline{N} = \overline{N}_2 = 0,253$.

Relative power of buses with injection-type petrol engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 7,5\cdot 6,84^2 + 5000\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 5000\right]\cdot 6,84}{100000\cdot\left(-3,2715\overline{N}^3 + 3,8372\overline{N}^2 - 1,2194\overline{N} + 1,0006\right)}.$$

It follows:

$$-3,2715\overline{N}^4 + 3,8372\overline{N}^3 - 1,2194\overline{N}^2 + 1,0006\overline{N} - 0,2337 = 0.$$

$\overline{N}_1 = 1,03$ and $\overline{N}_2 = 0,264$, let us take $\overline{N} = \overline{N}_2 = 0,264$.

Relative power of buses with diesel engines:

$$\overline{N} = \frac{\left[0,45\cdot 1,293\cdot 7,5\cdot 6,84^2 + 10500\cdot 9,87\cdot \cos 4\cdot \left(0,02 - tg4\right) - 6,698\cdot 10500\right]\cdot 6,84}{150000\cdot\left(-1,3238\overline{N}^3 + 1,118\overline{N}^2 - 0,031\overline{N} + 0,8755\right)}.$$

It follows:

$$-1,3238\overline{N}^4 + 1,118\overline{N}^3 - 0,031\overline{N}^2 + 0,8755\overline{N} - 0,317 = 0.$$

$\overline{N}_1 = 1,15$ and $\overline{N}_2 = 0,347$, let us take $\overline{N} = \overline{N}_2 = 0,347$.

Let us calculate the relative coefficient of excess air (table 1) using the method [9, 10].

Table 1

Relative coefficient of excess air of motor vehicles

| Motor vehicle | Engine type and type of fuel used | $\bar{N}$ | $\bar{\alpha}$ |
|---|---|---|---|
| Passenger vehicles | carburetor-type petrol engines | 0.516 | $\bar{\alpha}=0,8775\cdot 0,516^3-2,1263\cdot 0,516^2+2,0224\cdot 0,516+$ $+0,2387=0,837$ |
| | injection-type petrol engines | 0.53 | $\bar{\alpha}=1,4577\cdot 0,53^3-3,3985\cdot 0,53^2+2,8352\cdot 0,53+$ $+0,1276=0,893$ |
| | diesel engines | 0.445 | – |
| | gas engines | 0.562 | $\bar{\alpha}=0,8775\cdot 0,562^3-2,1263\cdot 0,562^2+2,0224\cdot 0,562+$ $+0,2387=0,859$ |
| Minibuses | carburetor-type petrol engines | 0.254 | $\bar{\alpha}=0,8775\cdot 0,254^3-2,1263\cdot 0,254^2+2,0224\cdot 0,254+$ $+0,2387=0,63$ |
| | injection-type petrol engines | 0.265 | $\bar{\alpha}=1,4577\cdot 0,265^3-3,3985\cdot 0,265^2+2,8352\cdot 0,265+$ $+0,1276=0,667$ |
| | diesel engines | 0.263 | – |
| | gas engines | 0.346 | $\bar{\alpha}=0,8775\cdot 0,346^3-2,1263\cdot 0,346^2+2,0224\cdot 0,346+$ $+0,2387=0,72$ |
| Cargo vehicles | carburetor-type petrol engines | 0.274 | $\bar{\alpha}=0,8775\cdot 0,274^3-2,1263\cdot 0,274^2+2,0224\cdot 0,274+$ $+0,2387=0,651$ |
| | injection-type petrol engines | 0.285 | $\bar{\alpha}=1,4577\cdot 0,285^3-3,3985\cdot 0,285^2+2,8352\cdot 0,285+$ $+0,1276=0,693$ |
| | diesel engines | 0.395 | – |
| | gas engines | 0.606 | – |
| Buses | carburetor-type petrol engines | 0.253 | $\bar{\alpha}=0,8775\cdot 0,253^3-2,1263\cdot 0,253^2+2,0224\cdot 0,253+$ $+0,2387=0,628$ |
| | injection-type petrol engines | 0.264 | $\bar{\alpha}=1,4577\cdot 0,264^3-3,3985\cdot 0,264^2+2,8352\cdot 0,264+$ $+0,1276=0,666$ |
| | diesel engines | 0.347 | – |

Depending on the relative power of the motor vehicle, we calculate the $NO_x$ concentration in the exhaust gases (ED) of the motor vehicle using formulas [10].

Passenger vehicles with carburetor-type petrol engines:

$$c=35,536\cdot 0,837^2-73,553\cdot 0,837+39,411=2,743 \text{ g/m}^3.$$

Passenger vehicles with injection-type petrol engines:

$$c=18,667\cdot 0,893^2-41,8\cdot 0,893+24,043=1,602 \text{ g/m}^3.$$

Passenger vehicles with diesel engines:

$$c=4,2667\cdot 0,445^4-19,2\cdot 0,445^3+18,933\cdot 0,445^2-1,2\cdot 0,445+0,7=2,391 \text{ g/m}^3.$$

Passenger vehicles with gas engines:

$$c = 18,667 \cdot 0,859^2 - 41,8 \cdot 0,859 + 24,043 = 1,911 \text{ g/m}^3.$$

Minibuses with carburetor-type petrol engines:

$$c = -58,578 \cdot 0,63^2 + 62,586 \cdot 0,63 - 9,5996 = 6,58 \text{ g/m}^3.$$

Minibuses with injection-type petrol engines:

$$c = -50,5 \cdot 0,667^2 + 51,98 \cdot 0,667 - 7,1382 = 5,066 \text{ g/m}^3.$$

Minibuses with diesel engines:

$$c = 4,2667 \cdot 0,263^4 - 19,2 \cdot 0,263^3 + 18,933 \cdot 0,263^2 - 1,2 \cdot 0,263 + 0,7 = 1,365 \text{ g/m}^3.$$

Minibuses with gas engines:

$$c = -50,5 \cdot 0,72^2 + 51,98 \cdot 0,72 - 7,1382 = 4,108 \text{ g/m}^3.$$

Cargo vehicles with carburetor-type petrol engines:

$$c = -58,578 \cdot 0,651^2 + 62,586 \cdot 0,651 - 9,5996 = 6,318 \text{ g/m}^3.$$

Cargo vehicles with injection-type petrol engines:

$$c = -50,5 \cdot 0,693^2 + 51,98 \cdot 0,693 - 7,1382 = 4,631 \text{ g/m}^3.$$

Cargo vehicles with diesel engines:

$$c = 4,2667 \cdot 0,395^4 - 19,2 \cdot 0,395^3 + 18,933 \cdot 0,395^2 - 1,2 \cdot 0,395 + 0,7 = 2,101 \text{ g/m}^3.$$

Cargo vehicles with gas engines:

$$c = 0,3987 \cdot 0,606^2 - 0,0327 \cdot 0,606 + 0,0474 = 0,174 \text{ g/m}^3.$$

Buses with carburetor-type petrol engines:

$$c = -58,578 \cdot 0,628^2 + 62,586 \cdot 0,628 - 9,5996 = 6,602 \text{ g/m}^3.$$

Buses with injection-type petrol engines:

$$c = -50,5 \cdot 0,666^2 + 51,98 \cdot 0,666 - 7,1382 = 5,081 \text{ g/m}^3.$$

Buses with diesel engines:

$$c = 4,2667 \cdot 0,347^4 - 19,2 \cdot 0,347^3 + 18,933 \cdot 0,347^2 - 1,2 \cdot 0,347 + 0,7 = 1,823 \text{ g/m}^3.$$

Let us calculate the volume flow of exhaust gases using the formula:

$$Q_{OГj} = 0,0007v^2 - 0,256v + 0,3184 .$$

Volume flow of exhaust gases of passenger cars:

$$Q_{OГj1} = 0,0007 \cdot 15,31^2 - 0,0256 \cdot 15,31 + 0,3184 = 0,091 \text{ m}^3\text{/s}.$$

Volume flow of exhaust gases of minibuses:

$$Q_{OГj2} = 0,0007 \cdot 8,8^2 - 0,0256 \cdot 8,8 + 0,3184 = 0,147 \text{ m}^3\text{/s}.$$

Volume flow of exhaust gases of cargo vehicles and buses:

$$Q_{OГj3,4} = 0,0007 \cdot 6,84^2 - 0,0256 \cdot 6,84 + 0,3184 = 0,176 \text{ m}^3\text{/s}.$$

Let us calculate the mass flow of $NO_x$ for cars by purpose and type of fuel using the formula:

$$M_{jk} = c \cdot Q_{OГj} .$$

Table 2 provides the calculation results.

Table 2

Mass flow of $NO_x$ of engines of vehicles [11]

| Engines by type of fuel used | Engines by type of fuel used Mass emission of pollutants by vehicles by purpose $M_{jk}$, g/s | | | |
|---|---|---|---|---|
| | Passenger cars | Minibuses | Cargo vehicles | Buses |
| carburetor-type petrol engines | 0.2488 | 0.9673 | 1.112 | 1.162 |
| injection-type petrol engines | 0.1458 | 0.7447 | 0.8151 | 0.8943 |
| diesel engines | 0.2176 | 0.2007 | 0.3698 | 0.3208 |
| gas engines | 0.1739 | 0.6039 | 0.0306 | - |

The average spatial interval between cars on a section of the road network is calculated using the formula:

$$h(v_{m.n.}) = 0,285^{2}_{m.n.} + 0,504v_{m.n.} + 5,7 .$$

As a result of substituting parameter values, we get:

$$h(v_{m.n.}) = 0,285 \cdot 8,2^{2} + 0,5048,2 + 5,7 = 11,75 \text{ m.}$$

The volume of traffic on a section of the road network is found by the formula:

$$K = z \cdot \left[ \frac{L - d_{cp}}{h(v_{m.n.})} + 1 \right],$$

where $d_{cp}$ — the average length of the vehicle, m. The parameter $d_{cp}$ is taken from the condition that the length of the passenger car is 3 m, minibus — 5 m, cargo vehicle — 6 m and bus — 8.0 m.

As a result of substituting the parameter values, we get:

$$K = \left[ \frac{111,6 - 5,5}{11,75} + 1 \right] \cdot 3 = 30,1 \text{ pcs.}$$

Let us calculate the mass flow of $NO_x$ for vehicle types by purpose and type of fuel used using the formula:

$$\sum M_{jk} = M_{jk} K \lambda_{jk} ,$$

where $\lambda_{jk}$ — the share of vehicles by purpose and type of fuel in the traffic flow.

Table 3 provides the calculation results 3.

Table 3

Mass flow of $NO_x$ for vehicle types

| Vehicle | Engine type and type of fuel used | Mass flow of $NO_x$ for vehicles types $\Sigma M_{jk}$, g/s |
|---|---|---|
| Passenger cars | carburetor-type petrol engines | 2.705 |
| | injection-type petrol engines | 1.580 |
| | diesel engines | 0.0917 |
| | gas engines | 0.250 |
| Minibuses | carburetor-type petrol engines | 0.670 |
| | injection-type petrol engines | 0.524 |
| | diesel engines | 0.375 |
| | gas engines | 0.727 |
| Cargo vehicles | carburetor-type petrol engines | 0.1088 |
| | injection-type petrol engines | 0.0798 |
| | diesel engines | 0.050 |
| | gas engines | 0.00046 |
| Buses | carburetor-type petrol engines | 0.736 |
| | injection-type petrol engines | 0.597 |
| | diesel engines | 0.156 |

Let's determine the mass flow rate of $NO_x$ by the transport flow in a given section by adding the mass flow rate values for all vehicle types from table 3:

$$\sum M = \sum \sum M_{jk} .$$

As a result, we get:

$$\sum M = 2,705 + 1,58 + 0,0917 + 0,25 + 0,67 + 0,514 + 0,375 + 0,727 + 0,1088 + 0,0798 +$$

$$+0,05+0,00046+0,736+0,597+0,156=8,64 \text{ g/s.}$$

Thus, the speed of the transport flow will increase by 17.1%, and the mass flow of $NO_x$ in a given section will decrease by 23.2% (from 11.2 to 8.64 g/s).

**Conclusion.** Based on the results of the calculation, it can be concluded that these measures are necessary to significantly reduce the negative consequences that road transport creates on a given section of the road network. The less traffic congestion, the higher the capacity of the section. Cars will not wait, and that will reduce emissions into the atmosphere, increase environmental safety, and improve the organization of traffic at the selected intersection.

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