Ways to improve safety and environmental friendliness of the city's transport system

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Abstract. The transport sector is one of the largest environmental polluters and hydrocarbons consumers. The oil prices instability and the need to reduce the negative impact on the environment, cause countries to introduce alternative technologies. In the article, measures to reduce harmful substances emissions with vehicles exhaust gases are divided into three groups: constructive, organizational-technological, and organizational-managerial. The environmental friendliness of urban transport systems is ensured by an increase in the “green” vehicles share in the fleet. This electric transport: trams, trolley buses, electric buses, as well as vehicles with natural gas' engine. Reducing air pollution, noise and vibration make electric vehicles more attractive and competitive, but we must bear in mind that the silent movement of electric vehicles and electric buses may pose a threat to the pedestrian’s safety. Road traffic accidents (RTA) worsen the situation, as they aggravate the difficult traffic situation, causing congestion, traffic jams, and, consequently, increase the negative impact. The study authors selected the intersection Avtozavodsky Avenue - Syuyumbike Avenue (Nabereznye Chelny), as a RTA concentration place in 2015-2019. We investigated emissions and noise pollution by road transport. In the article, we proposed measures aimed at reducing emissions and noise.

1. Introduction

Road transport is a source of chemical and physical pollution. Chemical pollution is caused by vehicles engines emissions. Physical pollution is caused by acoustic and electromagnetic fields arising during operation of vehicle's systems and aggregates, as well as from the interaction of its especial elements (tires, body) with the environment (road, atmosphere) when driving.

One of the transport situation degradation’s factors in cities is the existing disproportion between the road network development and the vehicles fleet growth rate, which leads to traffic conditions degradation, congestion, increased delays, increased fuel consumption. This situation becomes characteristic of many large and medium-sized cities [1]. Along with the progressing atmospheric air quality reduction, the environmental problems associated with the motor vehicles noise impact on the environment are also increased. To solving the approaching environmental crisis humanity places great hopes on alternative energy sources and environmentally friendly transport [2]. The cities' transport complex is becoming more environmentally friendly by an increase in the “green” vehicles share in the fleet. This electric transport: trams, trolley buses, electric buses, as well as vehicles with natural gas'
engine. Reducing air pollution, noise and vibration make electric vehicles more attractive and competitive transport mode. The environmental reasons for the use of vehicles on natural gas also are major [3]. To reduce the motor transport’s negative impact on the environment, it is necessary to update the urban fleet by transiting public transport and municipal vehicles to environmentally friendly fuels (compressed and liquefied natural gas, liquefied petroleum gases), as well as created infrastructure for refueling these vehicles.

2. Existing Solutions in the Sphere of Increasing Safety and Environmental Friendliness of the City’s Transport System

2.1 Methods to Reduce Emissions of Harmful Substances with Vehicle’s Exhaust Gases

Measures to reduce harmful substances emissions with vehicles exhaust gases can be divided into three groups.

The first activities group is related to improving the vehicles and engines design, improving the fuels quality and includes:
1) changes in fuel supply processes to engine cylinders, including the use of electronic fuel injection;
2) provision of exhaust gas recirculation and mounting of microprocessor-based engine control systems;
3) application of gasoline and diesel fuels of high ecological purity, characterized by optimal fractional composition;
4) using of vehicles on alternative energy sources [4, 5].

The second group includes organizational-technical measures:
1) ensuring regular monitoring of the exhaust gases toxicity and smokiness;
2) limitations introduction to the vehicles movement on certain lanes at certain day hours;
3) route drivers’ orientation;
4) fleet formation in accordance with the not exceeding emissions’ conditions (forecast number, fleet structure by age and type of fuel; adjustment of the vehicles fleet numerical composition);
5) equipping the truck fleet with exhaust gas neutralization systems [6].

The third group – organizational-management activities - includes:
1) selection of optimal urban planning solutions, including the transport interchanges construction, underground crossings, the circular motion using;
2) traffic and its structure redevelopment for a long period and separate day hours [7, 8];
3) vehicles-free zones creation, primarily in the Central cities part;
4) introduction of paid travel during peak hours in urban areas with the highest traffic intensity;
5) location of public transport stops optimization;
6) using to traffic organization the automated traffic management systems in combination with the air pollution control system [9];
7) improving the traffic lights efficiency;
8) introduction of one-way traffic schemes.

2.2 Methods which Used to Protect from Transport Noise

Road transport is the noise impact main source on the environment, which intensity increases in dense urban construction conditions. Many researchers note that in the overwhelming majority of cases, it is traffic noise that determines the city's noise background.

Transport noise has a negative impact on the person's basic organs and systems: the hearing aid, the central nervous system, the cardiovascular system, the vision organs, the immune system. The constant impact of noise high levels, adversely affecting human health, reducing his work productivity, creative activity and the rest effectiveness, causes significant damage to society and the state [10]. In the works
by the main methods allowing to reduce the traffic flows noise impact are: architectural-planning solutions; design-technological and organizational-administrative methods.

Architectural-planning solutions include: the buildings location at the maximum possible distance from highways, urban railways, no closer than 100 m to them; the use of new soundproofing building materials, triple windows glazing or double-glazed windows, windows sealing; landscaped areas. An effective measure is the use of noise screens, which are sound-reflecting, sound-absorbing and combined.

Design and technological measures include the improvement of vehicle design and infrastructure solutions.

Organizational-administrative measures provide for the traffic flow differentiation according to place, time and its qualitative composition. Reserve of decrease in traffic noise levels, especially on high-traffic lines, is the flow separation of trucks and cars, with adequate segregated lanes provision.

2.3 Prospects for Market Development and Ways to Solve the Problems With Electric Buses Safety Operation in Russia

Buses are vehicles that create a noise high level in urban areas. The article authors [13] are investigating the possible noise extent reduction in urban areas through electric buses. Taking into account the traffic peculiarities on different bus routes, the authors found that the noise from electric buses is practically not reduced on roads with heavy traffic.

The paper authors [14] analyzed the societal benefits derived from noise reduction through the electric buses using in the Gothenburg city. The results show that the largest benefits from electrical buses are obtained during acceleration, for example, at bus stops, and for maximum levels indoors.

Electric transport can actively develop not in all segments. In freight traffic, where there are no standard routes, the development of charging infrastructure for electric transport will be difficult for a long time. From this point of view, this direction is more promising in the city buses segment.

Electric buses sales will depend primarily not on private customers, but on federal, regional, municipal financing. Thus, the article authors [15] studied the key factors hindering the electric buses use as passenger transport, such as their cost, lack of charging infrastructure. The findings also indicate that the electric buses introduction is more dependent on state support.

The papers authors [16, 17] believe that the main attention in the electric bus market development should be given to a key requirement for the urban automobile transport electrification: the charging infrastructure development for refueling the city buses network.

Traffic noise in urban areas is a key factor for informing road users. The condition of the road surface, the type of vehicle and the age of the pedestrian affect the reactions timeliness to avoid collisions [18].

A high percentage of accidents are caused by electric and hybrid vehicles [19]. In the authors' study [20, 21] the main problem reported by all drivers was related to the electric buses noiselessness for pedestrians.

For preventing impact crashes, the electric vehicles with pedestrians it is necessary to install noise generators [22].

3. Results and discussion

Naberezhnye Chelny city with over half a million people population is largest industrial center of Zakamsky region Tatarstan Republic. The city is characterized by a high level of road transport networks development. During the problem area study, an electronic map of the RTA in the Naberezhnye Chelny city (based on the results of 2015-2019) was studied. As a RTA result, concentration points were identified, as a which result traffic along one or several lanes was blocked for a long time, as led to traffic difficulties and jams on this road network part. Thus, according to the analysis results, the
intersection Avtozavodsky Avenue - Syuyumbike Avenue (24 RTA) was chosen as the object under study. Field measurements were carried out by visual observation. As these observations result, a time was detected, during which at the selected intersection there is the greatest vehicles accumulation. Peak time were divided into: morning high hours - from 6:30 to 7:30; evening high hours - from 16:30 to 18:00.

3.1 Calculation of Motor Transport Emissions

For the road (or its section) in the presence of an adjustable intersection, the total pollutants emission, $M$, g / km, is calculated by the formula:

$$M = \sum_{i}^{n} (M_{P_{i}} + M_{P_{2}}) + \sum_{i}^{n} (M_{I_{3}} + M_{I_{4}}) + \sum_{i}^{n} (M_{P_{3}} + M_{P_{4}}) + \sum_{i}^{n} (M_{I_{11}} + M_{I_{2}})$$

(1)

where, $M_{P_{i}}, M_{P_{2}}, M_{P_{3}}, M_{P_{4}}, M_{I_{11}}, M_{I_{12}}, M_{I_{13}}, M_{I_{14}}$ - is the pollutants emission into the atmosphere by vehicles in the intersection area when the traffic light signal prohibits vehicles from passing, g / km;

$M_{I_{i}}$ - pollutants emission into the atmosphere by vehicles moving along this road during the period under consideration, g / km.

Here indices 1 and 2 correspond to each of the two movement directions on a highway with greater traffic intensity, 3 and 4 - for a highway with a lower traffic intensity.

$n, m$ - is the vehicles flow stops number before the intersection on the roads forming it for a 20-minute period.

$n_{1}, n_{2}$ - the periods number of vehicles flow movement in the intersection area at allowing traffic signal for a 20-minute period of time.

The i-th pollutant emission by particular direction vehicles movement in the intersection area with traffic signals prohibiting traffic for a 20-minute additional inspection period $M_{P_{i}}$, g / km, is calculated by the formula (2):

$$M_{P_{i}} = \frac{P_{c}}{60} \sum_{k}^{N_{c}} \sum_{i}^{n} (M_{I_{i}} * G_{k})$$

(2)

where $P_{c}$ - the duration of the traffic light prohibitory signal (including yellow) within 20 minutes, s;

$N_{c}$ - the action cycles number of traffic light signal prohibiting the movement within 20-minute period of time, s;

$M_{I_{i}}$ - i-th pollutant's specific emission by k-th group's vehicles, which are in the queue at the traffic light prohibiting signal, as show in Table 1, g / min;

$G_{k}$ - the k-th group vehicles amount queuing around the intersection at the each cycle end of the traffic light signal action prohibiting the movement.

| Car group name | Emissions of pollutants, g / min |
|----------------|--------------------------------|
|                | CO    | NO2   | CH   | Soot | SO2       | Formaldehyde | Benzapilene |
| Cars           | 0.5   | 0.015 | 0.1  | 0.015 | 0.1x10^{-2} | 0.4x10^{-3} | 0.15x10^{-6} |
| Trucks and buses total weight up to 3,5 t | 2.0   | 0.04  | 0.3  | 0.08  | 0.9x10^{-2} | 1.4x10^{-3} | 0.4x10^{-6} |
| Trucks from 3,5 to 12 t | 2.5   | 0.12  | 0.66 | 0.9    | 1.7x10^{-2} | 7.2x10^{-3} | 1.1x10^{-6} |
| Trucks over 12 t | 2.7   | 0.14  | 0.83 | 1.1    | 2.4x10^{-2} | 9.5x10^{-3} | 1.3x10^{-6} |
| Buses over 3,5t | 1.9   | 0.1   | 0.57 | 0.67  | 1.5x10^{-2} | 4.8x10^{-3} | 0.9x10^{-6} |

To reduce the negative impact on motor vehicles emissions in the Naberezhnye Chelny city, the following measures are recommended:

1) The optimal town-planning solutions choice which provide for the underpasses and traffic interchanges construction.
2) Control's strengthening on the toxicity and smoke content of vehicles exhaust gases on highways, herewith, special attention should be paid to outdated vehicles models, especially trucks
3) Routing drivers’ orientation, transit transport permits optimization.
4) Improving the traffic lights efficiency.
5) Upgrading the urban fleet by transiting public and municipal transport to environmentally friendly fuels, as well as creating infrastructure for refueling these transport types.

3.2 Calculation of Motor Transport Noise Impact in Cities
To measure the sound pressure at the intersection, a Shl-01 type noise meter-vibrometer was used. The noise levels at the intersection were measured under the following climatic conditions: precipitation lack in the form of rain, snow; atmospheric pressure - 1.013 Pa (760 mmHg), permissible variation ± 5%; ambient air temperature - not lower than -5 and not higher than +30 °C; wind speed - no more than 5 m/s.

The traffic flows noise characteristics at the intersection were measurements in four points. Table 2. shows the noise measurements results in the morning and evening pick hours at the Vakhitov - Suyumbike intersection.

| Time       | Vehicles number | Minimal noise | Average noise | Maximum noise |
|------------|-----------------|---------------|---------------|---------------|
| 6:30-6:50  | 1540            | 69,2          | 79,5          | 84,4          |
| 6:50-7:10  | 1535            | 69,8          | 78,1          | 87,1          |
| 7:10-7:30  | 1508            | 70,0          | 79,9          | 88,6          |
| 7:30-7:50  | 1473            | 70,3          | 78,1          | 86,4          |
| 16:30-16:50| 1734            | 71,6          | 80,1          | 85,2          |
| 16:50-17:10| 1773            | 72,2          | 79,8          | 88,5          |
| 17:10-17:30| 1759            | 71,4          | 79,6          | 88,1          |
| 17:30-17:50| 1719            | 71,7          | 79,7          | 87,6          |

Were also measured noise from a single car. The noise was recorded at different its movement speeds. The experiment results are shown in Table 3, from which it follows that the noise varies in proportional to the vehicle speed.

| Speed, in km per hour | 20  | 40  | 60  | 80  |
|-----------------------|-----|-----|-----|-----|
| Noise, dB-A           | 64,5| 73,8| 84,2| 93,1|

To reduce noise pollution from motor vehicles in the Naberezhnye Chelny city, we can offer the following ways:
1) Introduction of new technologies to road building and pavements repair.
2) Priority public transport development in order to reduce the road network load, negative effect on the environment and improve the citizen’s life quality. Public transport popularization among residents. Urban public transport modernization.
3) Popularization and development of cycling, bicycle lines building, the rental bicycles organization.
4) Installation of acoustic screens along most busy highways.

4. Conclusion
The growth in the vehicles fleet together with a relatively unaltered transfer capacity city streets led to a decrease in the average traffic speed, which resulted in an increase in fuel consumption and time spent on transportation, growth in the RTA likelihood and number, an increase in environmental pollution from vehicles exhaust gases, and a degradation in emotionally-psychological population condition and other negative consequences. Existing methods to reduce vehicle emissions and noise exposure were analyzed.
The use of alternative environmentally friendly motor fuels types is part of the design-technological measures to reduce emissions from road transport. Most automotive companies in the world see the future in the energy-saving technologies application and the vehicles transfer to electrical transmission using environmentally friendly energy systems. However, some studies confirm the increase in the accidents number involving pedestrians due to the low noise level of vehicles on electric propulsion, therefore additional protective measures are necessary.

The electric buses role in the public transport system is important as a counter-measure to climate change and to negative environmental impacts when using non-renewable natural resources as motor fuel. Gas-powered buses and trucks are also a promising transport mode, since they have a high return on investment due to low fuel prices and lower operating costs, while gas is the most environmentally friendly fuel type. Although electric buses and electric cars are an environmentally friendly transport type, it cannot be considered as an alternative to gas because it is about 3 times more expensive, besides, it is necessary to create charging infrastructure for electric transport, while a gas stations network already exists in most Russian regions. Electric buses can only afford large cities.

As a research result conducted in the Naberezhnye Chelny city, proposals were made for organizing events aimed at reducing the road transport negative impact on the environment. Calculated values of pollutants specific emissions for vehicles in the intersection zone. To measure the sound pressure at the intersection, a ShI-01 type noise meter-ribometer was used. Moreover, we measured noise from a single car. The noise was recorded at different vehicle speeds. The results show that the noise varies in directly proportional to the vehicle speed.

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