Ecological and economic aspects of negative impact of transport in large cities

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Abstract. This paper discusses a variety of methodological approaches to economic and environmental assessment of the negative impact of transport in urban areas. The role of the ecological crisis, which is growing in large cities, is noted. There is a trend of a sharp increase in the number of vehicles in the cities. The need for a comprehensive solution of economic and environmental problems based on the systematic collection, analysis and synthesis of environmental information has been formulated. The foundation for economic and environmental assessment of the negative impact of transport in urban areas is the use of a simulation model based on software package AnyLogic PLE. It is noted that the solution of environmental problems of urban transport is a set of program measures of different nature with the aim to minimize the load on the biosphere. The proposed economic mechanisms and criteria were used in economic and mathematical models, which determined the state of urban ecological systems, and made it possible to make necessary assessment of their sustainability.

1. Introduction

Environmental protection is one of the most urgent problems of our time. Scientific and technical progress, which contributes to new technological systems, ultimately leads to the fact that the harm caused by man to nature, acquires dangerous dimensions that threaten the very biological basis of the existence of our society. Globalization processes of the modern world in all aspects are already in the middle of the last century brought to the fore the problem of environmental safety. Moreover, this problem was often vivid at the regional level in a highly urgent context with the effects of cultural, economic, and military opposition to communities.

The social need for qualitative ecological knowledge, practical application of the results of the environmental studies, was formed in the context of the global environmental crisis caused by anthropogenic factors.

The deterioration of the ecological situation undermines social needs and contradicts the interests of the population, causing social and economic tensions at the regional and national levels. Without managing social and ecological processes and lack of tasks to reduce the environmental capacity of the
economy, our society can make the environment unsuitable for human existence, rather than healing the environment. It can bring destructive social processes that can interrupt the onward development of civilization.

For many decades, the economic development of Russia to a certain extent was carried out at the expense of the environment and human health. The environmental crisis, which manifests itself in varying degrees, arose as a result of the neglect of environmental safety of society and coincided with an economic slowdown in development [1].

2. Main sources of pollution
Air emissions from various polluting sources are a powerful factor of the negative impact on humans and the surrounding environment.

Contemporary environmental problems are caused by a lag of economic thoughts, neither the classics nor the theoreticians of the XX century. The expenses of society for the restoration of natural environment are not taken into account in the schemes of public reproduction. The attempts are being made to develop fundamentally new concepts of development.

The modern economic world is built on theoretical schemes of the classics of bourgeois and communist political economy as amended by scientists of the XX century. This type of development is called the technogenic type of economic development. Its characteristic features are the absence of social reproduction of the economic mechanism of reproduction for consumed natural resources and changeable conditions; the use of artificially created means of production without regard to environmental restrictions; the rapid and depleting use of non-renewable natural resources; overexploitation of renewable resources at a rate exceeding their recovery.

Technogenic type of production is characterized as nature-intensive or nature-depleting.

There are many models of a man-made type of development. There are two generalized models:

1. Frontal economy;
2. The concept of environmental protection.

Frontal economy is based on the principle of unlimited natural resources. With the growth of productive forces, population size, deep destabilization of the environment has become apparent; the cost (of resources) of life has sharply increased. Now every 24 hours 35 thousand people die from hunger, 20 thousand of them are children under 5 years old.

The concept of environmental protection. Some developed countries (100 countries) began to create the bodies for nature protection from the negative impact of production. However, the production formula remained the same, focused on expanding reproduction, and the most important the economic component. The environmental component is considered as a factor to reduce economic efficiency of social production.

Negative consequences of the technogenic type of economy are land desertification (aridization), deforestation; lack of natural raw materials; greenhouse effect; depletion of the ozone layer; acid rains; shortage of fresh water, ocean pollution, extinction of many species of flora and fauna. If people do not solve these problems, it will lead to the extinction of man as a species [2].

The main polluters are emissions from industrial enterprises and vehicles. Atmospheric pollution occurs mostly in cities than in the countryside. This is due to the fact that there are much fewer industrial enterprises and vehicles in rural areas.

The main sources of pollutants that enter the air are man-made, namely industry and motor vehicles. Emissions of pollutants into the atmosphere are mainly volatile gaseous chemicals. As the results of environmental studies, air emissions and atmosphere pollution are one of the most powerful and permanent factors of negative impact on humans and the surrounding environment.

In large cities, industry is represented by such fields as non-ferrous metallurgy, mechanical engineering and metalworking, electric power industry, fuel industry, timber and woodworking industries, and the production of building materials. A large and significant contribution to air pollution is also made by vehicles, the number of which is constantly increasing mainly due to large cities.
As a result of industrial activities, the atmosphere is polluted by carbon monoxide, lead, sulfur dioxide, nitrogen oxides, hydrocarbons, including benzo (a) pyrene, photooxidants formed under conditions of intense solar radiation.

At the present stage of overcoming the economic crisis and improving the quality of people’s life, the state of the environment and environmental benefits in the system of social reproduction should be more accurately and specifically evaluated. The preservation and reproduction of environmental goods are perceived as the most important part of the process of economic development, ensuring the growth of well-being, improving the quality of work and life of people to the level of developed countries; maintaining the reproduction of healthy generations; recovery of mining sites and recycling of waste for their recycling. With modern development of urbanized areas, technogenic components (especially motor vehicles) have a very negative impact on the environment and human health [3].

The concentration of a significant part of the population in urban areas has led to the need for the earliest possible solution to the problem of protecting people's health and preventing the occurrence of environmental disasters. Now it is becoming more and more obvious the interrelation of production, natural and social processes in society. There is a merging of objects of human economic activity, its habitat and social and economic factors into the complex interconnected systems, developing according to peculiar, not sufficiently studied laws. The health of the population is 25...50 % dependent on lifestyle, 20...40 % on the environment, 15...20 % on genetic factors, and only 10 % on the activities of health services. If we adhere to the position that a disease is a disturbance in a person’s normal life due to the conditions of its existence in the environment, then it is an environmentally caused phenomenon and, therefore, can be used as an indicator of environmental quality, and various aspects of it. A large group of diseases is directly related to the natural environment. These are pathological conditions caused by local geochemical features, climatic factors, regional biocenological characteristics, variability of pathogens of infectious diseases in a specific host (for example, influenza virus), etc. [2]

Another large group of pathological processes is associated with production activities, with a limited zone of influence and exposure to a small contingent of people directly working in adverse conditions (for example, it has been established that significant concentrations of dioxins in humans have a suppressive effect on endocrine, hematopoietic and immune system functions). The third group occurs under the influence of social causes and intrapopulation interaction (mainly, it is a psychogenic pathology: cardiovascular, endocrine diseases, mental disorders). This pathogenic factor may be ethnic (for example, dietary patterns — the distribution of raw food supply of fish and meat) and genotypic (genetically determined differences in oxidation of alcohol) characteristics of populations.

Finally, an extensive group of diseases, as well as an increase in overall morbidity, often without sufficient factual justification, are associated with intense pollution of water and air (up to 60 % of the Russian population lives under conditions of a constant excess of MAC in air) and soil as a result of human production. The water treatment system is not effective to prevent waterborne diseases (in particular, caused by poliomyelitis viruses, hepatitis, etc.). Each disease is characterized by its own characteristics (spatial distribution, prevalence in the population, spectrum of nosological forms), but all of them are causally related to environmental factors. The primary task in ensuring the health of the population and increasing the duration of active life of people is a deep study of the correlation links between medical-biological and anthropogenic factors.

A powerful complex of harmful and highly toxic environmental factors that have arisen because of the scientific and technological revolution influence on a modern person. At present, 4 million toxic substances are registered in the external environment and their number increases by 6 thousand annually. Over the last decades alone, more than 1 million tons of nickel, about 1 million 1 cobalt, more than 600 thousand tons of zinc were emitted into the atmosphere, 1.5 million tons of arsenic and the same amount of silicon. A particularly large amount of harmful substances enters the environment in industrialized countries, in large cities. The main anthropogenic sources of the increase in carbon dioxide in the atmosphere are energy and transport, running on organic fuel.
The situation in the modern world is that not a single nation, not a single country can single-handedly emerge from an impending ecological catastrophe. It is not even visible to them, except in its local manifestations.

Industrial development has created not only a special world of technology, but also the “urban world”. If in 1800 only 5% of the population lived in the cities (50 million people), then by 2020 the number of citizens should have increased by more than 10 times and reach 53% (3.4 billion people). Although cities with dynamically developing large-scale industrial and energy-intensive production as a whole occupy only 0.5% of the Earth, they have a destructive effect on nature. Explosive urbanization (after 1950 about 2.3 billion new citizens on the planet) enabled not only to concentrate population and technology in cities, but radically transform human activities, change the quality indicators of the whole way of life, people's lifestyle [2].

In recent years, the population has had the opportunity to purchase personal vehicles under affordable credit conditions or to rent it by leasing. Moreover, there are many private business carriers.

A significant growth of vehicles has led to a decrease in the average speed on the carriageway, traffic jams, traffic accidents, increased release of toxic substances into the atmosphere, increased noise and vibration from passing vehicles, increased electromagnetic radiation from radio electronic road systems, and pollution of the urban area and the adjacent aquatic environment with petroleum products, as well as problems with parking for motor vehicles, etc. It is obvious that the growth of motor transport to the city highways created acute economic and environmental problems that require effective comprehensive scientific and practical solutions [3].

There is no mechanism to control emissions of motor vehicles, which would be based on economic instruments of environmental incentives. Such a toolkit could be based on an economic and environmental assessment of the negative impact of transport in urban areas [1].

The relevance of such tools is difficult to overestimate due to the need to implement a systematic and integrated approach to planning and implementation of environmental protection measures, taking into account all the major environmental, economic and social factors in traffic organization in different time and seasonal intervals. Administrations of large cities are taking measures to prevent harmful emissions into the environment; however, their number does not decrease.

Therefore, a complex solution of economic and environmental problems is vital based on systematic collection, analysis and summarization of environmental information. It is necessary to investigate economic aspects that clearly define measures to protect urban areas from dangerous concentrations of harmful substances by transport, optimizing the choice of solution options based on criteria of environmental and economic efficiency, formation of programs and mechanisms that implement the chosen solution. Separate implementation of individual measures of environmental improvement in the processes of functioning of urban transport is contrary to the current environmental situation, determined by the extreme scale of the impact of vehicles on the urban biosphere [3].

Since traffic flows in urban traffic create environmental pollution, it is possible to determine measure effectiveness to protect this environment at a streaming level [7]. Optimization will affect both individual elements of the urban transport system and the measures themselves that limit environmental damage from the scale of the system being optimized.

Within the framework of economic and environmental safety of motor transportation system, it is proposed to model the levels of environmental pollution by motor transport using the theory of traffic flow [5]. The main characteristics of the traffic flow, which can significantly affect the efficiency of vehicles in urbanized areas, include the speed and intensity of movement of vehicles [8].

Therefore, the forecasts on speeds and intensities of urban traffic are very relevant in the process of developing measures to improve the performance of vehicles, improve the road network and the environment in cities.

Fuel consumption by motor transport can be directly used as a criterion for the quality of urban traffic, due to the fact that this indicator is associated with efficiency, speed indicators and indirect release of toxic components along with exhaust gases.
Fuel costs can be translated into value terms, which is a function of changes in the dynamic state of traffic and the level of costs to improve urban traffic [5–6].

Protection against noise and vibrations from urban traffic flows is provided by the construction of anti-noise screens along urban highways, tunnels, bypass racks, equipment, sound-absorbing elements of town houses, etc. When exceeding the permissible noise level by motor transport, health indicators of the population deteriorate and labor productivity drops.

3. Simulation model
The basis for economic and environmental assessment of the negative impact of transport in urban areas is a simulation model based on AnyLogic PLE software package, which will display the movement of vehicles in various traffic conditions [4].

The initial data for simulation:
- a map of urban area with streets defined for the carriageway (Table 1);
- traffic flows with speeds from minimum to maximum and traffic intensity from minimum to maximum;
- dependence of the emissions of harmful substances (carbon monoxide, sulfur oxide, lead oxide, mercuric oxide, etc.) per unit of time on the speed and intensity of movement of vehicles;
- values of maximum permissible norms for emissions of harmful substances per unit of time;
- intensity of natural recovery in certain areas of the environment from emissions of harmful substances that exceed the maximum permissible norms.

As a result of modeling, all possible situations are assessed with the dynamics of exceeding the maximum permissible norms of emissions of harmful substances into the environment of urbanized territories and the dynamics of subsequent natural restoration of the environment from pollution.

Further, it is necessary to determine the implementation cost for various measures of economic, legal, administrative, social and other nature, compensating for the damage from the maximum permissible
pollution by harmful substances or preventing such pollution due to restrictions on the use of motor vehicles in urban areas moving on fuel from oil products [1].

An example of the negative impact of transport on the environment and human health can be the fact that, on average, with mileage of 15 thousand km per year, each car burns 2 tons of fuel and about 26–30 tons of air, including 4.5 tons of oxygen, which is 50 times more people need.

At the same time, a car emits into the atmosphere (kg/year): carbon monoxide – 700, nitrogen dioxide – 40, unburned hydrocarbons – 230 and solids – 2–5. In addition, many lead compounds are emitted due to the use of mostly leaded gasoline. The studies have shown that in houses located near the main road (up to 10 m), residents suffer from cancer 3-4 times more often than in houses remote from the road at a distance of 50 m [7].

The total implementation cost of various measures to compensate for environmental damage can be divided into road users in the form of environmental municipal tax on polluting vehicles.

To reduce the level of air anthropogenic pollution of the urban basin and its negative effects, current environmental protection methods should be improved to implement new organizational and economic policies to protect the urban biosphere and stimulate economic and social development.

Qualitative and quantitative changes in the road transport system of cities will occur when using the economic mechanism to manage this system to reduce the cost to eliminate pollution effects.

The solution for the environmental problem of urban transport could be a set of program measures to minimize the burden on the biosphere. An important part is a program for the effective organization of urban traffic, progressive methods of automatic regulation at intersections to reduce the number and duration of stopping vehicles, eliminating traffic jams and jams, and increasing the average speed of traffic, also requires the transfer of pedestrian crossings or above the roads [3, 5, 6].

With centralized traffic control by means of traffic lights and sign regulation, it is possible to achieve the increase in the average speed of traffic [6]. At the same time, in the future, there is a gradual transition of urban transport to non-petroleum-based fuels: natural gas, electricity, which will eliminate the problem urgency of environmental pollution.

Perspective automation of urban traffic should include full control of each car from the initial to the final point of its movement based on automatic (unmanned) control algorithms, including Internet application for traffic, the formation of an optimal route coordinated with electronic routes of all road users according to the minimum route indicators and limited travel time. Thus, the planned intensity of traffic will be distributed along urban highways, taking into account their throughput capabilities and the required average traffic speed.

The economic component for the regulation of environmental transport safety during its evolutionary development should have a system of economic incentives for environmental activities; the improved system of carriage charges for pollution; prices for goods and services in cities, formed on the basis of environmental requirements; stimulation of processes of centralized traffic control with the growth of environmental vehicles [1].

Each new change in the ecological status of the urban transport system must be tested on a simulation model to achieve the required conditions of economy and environmental safety for road traffic [6].

The proposed environmental and economic approaches and models, by the example of reducing automobile noise, are aimed at optimizing environmental protection measures of the urban biosphere to create acoustic conditions acceptable to the population.

The developed economic mechanisms and criteria were used in economic and mathematical models, which determined the current state of urban ecological systems after which the necessary assessment of their sustainability was made.

The constructed economic and mathematical model to assess the economic efficiency of the developed environmental measures was based on the economic indicators of absolute and relative efficiency, taking into account a discount factor, which determined forecast characteristics for a set of measures to protect the urban air environment from harmful emissions.

In the process of model application of known statistical methods to predict the state of the urban air environment, the interrelations of the main economic factors that caused changes in the city
environmental and economic indicators were identified, evaluated and investigated. A set of environmental protection measures for environmental rehabilitation of the city’s motor transportation system has been developed with minimal additional costs for this system functioning [9].

4. Conclusions

The main emission sources in the atmosphere of large cities are industrial enterprises and road transport. Emissions from stationary sources into the atmosphere of megacities are growing over the last period.

The proposed economic and mathematical model can predict pollution indicators of the urban air basin. Based on the correlation analysis, this model is capable of generating a forecast of the state of the urban air environment on the results of the obtained forecasts in the city’s environmental activities.

It is necessary to combine economic, organizational, legal and educational measures, enhance the role of local authorities and administration in environmental protection, public environmental organizations, and personal initiative of citizens based on general public awareness of the environment, planned design and construction of large economic objects, education to respect nature and improve the ecological culture of the population.

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