Model for effectiveness evaluation of planning measures for protection of areas surrounding main roads from the influence of environmental pressures of the Kyiv main road network

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Summary. Raising the requirements to the ecological state of the urban environment engenders the issue of efficient planning and functioning of protection elements of areas surrounding main roads. Surrounding main roads are areas situated along the main trunk road networks within the space from the main road to the building line. As defined, the building lines are the boundaries of placing houses and buildings relative to frontage lines [1]. They make up about 15 − 30 % of a town or city area [2].

Research of the methodological framework of the sustainable development of urbanized territories should be based on a complex problem-oriented approach of different related scientific researches. This is why the task of examining the environmental pressures of main road network is highly relevant for a city. An analysis of Ukrainian regulatory documents showed that the development and feasibility evaluation of urban development regulations are insufficient for evaluation of planning measures for protection of the areas surrounding main roads.

The mathematical and information models demonstrating the dependence of environmental pressures by factors and attributes in accordance with planning decisions were presented for the evaluation. On-sight surveys of a main road network with different planning criteria were conducted as exemplified by Kyiv, in the course of which data necessary for evaluating the efficiency of planning decisions were collected. On the basis of the obtained data recommendations on planning decisions for respective urban areas have been given.

Key words: trunk road network, environmental pressures, urban area protection.

INTRODUCTION

The impact of automobile transport manifests itself most in an urbanized environment. A city or town is an indicator of sustainable development or adverse interconnection of automobile transport and urbanized environment. This research is based on the evaluation of the impact of the current state of automobile transport on the trunk road network and the area surrounding main roads to demonstrate the feasibility of adopted planning measures for protection and selection of the functional profile of the areas surrounding main roads by environmental pressures arising in the trunk road network. The technology-related atmospheric air pollution sources are mostly represented by emissions from the industrial enterprises and automobile transport.

PURPOSE OF THE RESEARCH

The purpose of this research is to develop a model for evaluating effective protection

measures and determining environmental pressures with due regard of their potential influence for further searches of new ways of solving the problem, scientifically grounded complex solutions and methods of urban area organization.

Such approach will enable to better understand the essence and consistent patterns of the manifestations and forecasting environmental pressures advance on a certain planning area with diverse development properties and their character depending on the relief, built-up density, planning organization of the trunk road network.

ANALYSIS OF THE LATEST RESEARCH AND PUBLICATIONS

Having analyzed the scientific works and effective regulatory documents on urban planning, it is possible to come to the following conclusions: to date, the growth in the number of vehicles together with the development of the trunk road network put environmental pressure on the existing built-up area with relevant engineering and design values of environmental pressures during a certain period of inter-main road areas. The ecological state of urban environment has been the object of the research conducted by such prominent scientists as B.V.Solukha [3], G.B.Fuks [3], O.S.Furmanenko [4], T.O.Shylova [5], I.I.Ustinova [6, 22], I.B.Solukha [7], M.M. Osyetrin [23, 24] and others, where the authors propose the methods for calculating environmental values. However, their works do not fully enough reflect the measures to protect areas from different planning methods influencing statutory indicators and functional areas of the territory.

METHODS FOR EVALUATION OF THE EFFECTIVENESS OF MEASURES FOR PROTECTION OF AREAS SURROUNDING MAIN ROADS

The main task in determining the evaluation of effectiveness of planning decisions on protection or areas surrounding main roads is the right choice of evaluation criteria in accordance with which the effectiveness of decisions will differ. As the trunk road network with all its traffic streams is an integral part of a city or town, its impact on environmental performance of urban area can undoubtedly be called dominating.

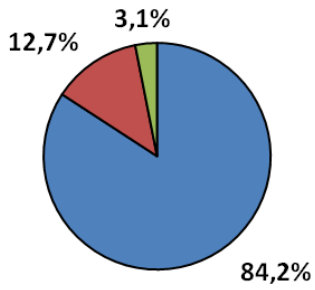
Among the main environmental pressures stemming from the functioning of the trunk road network, noise and atmospheric pollution should be pointed out. As the system of streets and roads is the key means of surface water collection and sewerage, it also directly influences the environmental state of hydrosphere objects, i.e. ground waters, sources, water bodies. Its environmental pressure on the urban environment lithosphere is also obvious – littering of the surface, lubricant and petrol residues pollute the soils when rain and snowmelt sewage waters are drained away. The harmful effect of electromagnetic loads imposed by rail transport functioning should also not be disregarded.

Therefore, the main trunk road network of a city or town may be called the main source of complex environmental pressures on urban area and environment, i.e. urban ecosystem, as a whole.

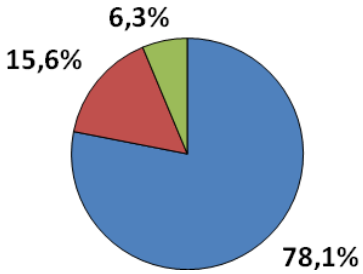
All natural components of urban environment, namely geological, atmospheric, hydrologic and other environments, suffer from harmful anthropogenic impact of the trunk road network. The state of atmospheric air, the degradation of which constitutes a worldwide problem, is considered to be the most critical.

The quality of atmospheric air in a modern developed city depends, in the first place, on the volume of pollutant emissions, with two sources there of – stationary and mobile (Fig.1).

During 2015, according to statistical studies, as much as 171 thousand tons of pollutants from stationary and mobile pollution sources were emitted into the atmosphere of Kyiv city, which is 51,58 % less in comparison with 2012. The dynamics of such drastic change of this index is largely explained by the decrease in the use of private vehicles due to the rapid growth of fuel prices and general



In 2012:
Automotive transport – 84,2 %.
Stationary sources – 12,7 %.
Railway, air and water transport and manufacturing technology – 3,1 %



In 2015:
Automotive transport – 78,1 %.
Stationary sources – 15,6 %.
Railway, air and water transport and manufacturing technology – 6,3 %

Fig. 1. Distribution of pollutants emitted into atmospheric air in 2012 and 2015 by emission sources

recessionary economic state of the country. However, a significant number of the emission sources remains mainly in the automotive transport segment [9, 10]. The density of emissions into the atmosphere per one square kilometer of the city territory amounted to 31,9 tons of pollutants, which exceeded the average value for Ukraine by factor 6,8 and is the highest in the country, the second place held by Donetsk oblast, the last place – by Volyn oblast, where the density of emissions reaches 34,6 and 2,5 tons per square kilometer respectively. The main zones of pollution are focused in the places surrounding main roads and in the areas of concentration of industrial complexes.

The example will be the city of Kyiv, which has a massive complex of enterprises of various industrial branches polluting atmosphere with emissions of contaminating gases and industrial dust.

During 2015 as many as 367 enterprises, institutions and organizations in the city were contaminating the urban air with their emissions. They emitted 26,7 thousand tons of contaminants, which is 4,7 thousand tons or 14,97 % less than in 2014 and 51,2 % less than in 1990 (Fig. 2).

In 2015 the density of contaminant emissions from stationary sources of contamination per 1 square kilometer of Kyiv city amounted to 31,9 tons, which is 6.8 times more than the

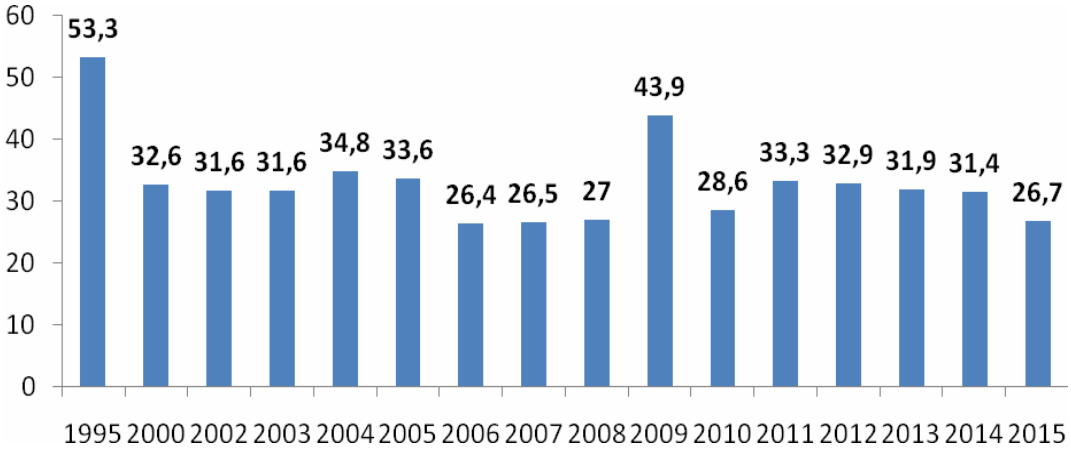


Fig. 2. Emissions of contaminants from stationary contamination sources into the atmosphere, thousand tons

country average (to compare, in some capital cities this density is as follows: 91,4 tons of emissions in Astana, 86,6 tons in Minsk and 65,6 tons in Moscow). Around 12 kg of contaminants per capita in the capital is 8 times less than the country average (to compare, in some capital cities this density is 83 kg of emissions per capita in Astana, 14 kg of emissions in Minsk and 6 kg in Moscow).

Compared with other regions of Ukraine, Kyiv has the lead by the amount of emissions from mobile sources.

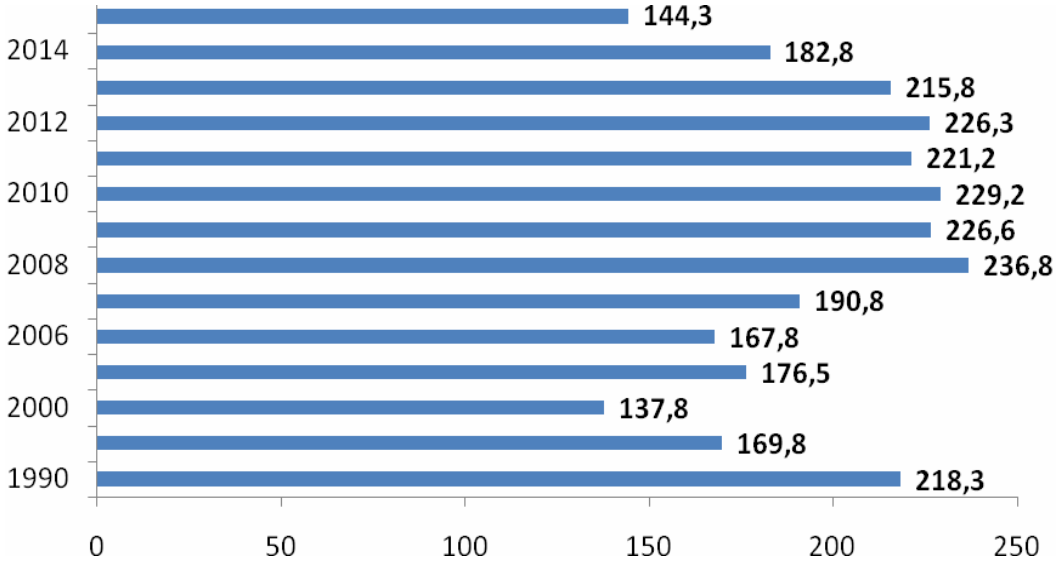


Fig. 3. Emissions of contaminants produced by the road transport into atmosphere, thousand tons

In the total volume of contaminant emissions, emissions of methane and nitrogen oxide amounted to 624,8 tons and 20,5 tons respectively. Beside this, 5648,9 thousand tons of carbon dioxide, also having the greenhouse effect, was released into atmosphere. The main air contamination source in the capital city is mobile sources. In 2015 in Kyiv engines of mobile contamination sources accounted for 144,3 thousand tons of contaminants, which is 36,24% less in comparison to 2012 (Fig. 3).

Since 2012 this figure continues to decrease, which can primarily be explained by the economic crisis in the country. Nevertheless, a vast majority of those emissions – 133,6 thousand tons or 92,6 % − comes from the automotive transport, and 10,7 thousand tons or 7,4 % comes from the air, railway and water transport.

The automotive transport of the capital causes 78,1 % of all emissions into the atmosphere of substances harmful for human health.

For the most part, the automobiles used in our cities and towns, in Kyiv in particular, do not meet to international environmental safety and compliance standards. Most automobilists use the low-quality fuel; it is common that engines are obsolete and worn-out. This leads to the critical state of the urban ecology.

From the general amount of pollutant emissions into atmosphere by automotive transport, about 97.1 thousand tons (72.6 %) were emitted by the automobiles privately owned by general public, and the rest 36.6 thousand tons (27,4 %) are the emissions of the automotive transport of economic entities.

Distribution of pollutant emissions from separate kinds of automotive transport for 2012 and 2015 respectively (Fig.4):

- load carriers – 38,5 % and 43,5 %;
- special-purpose light motor vehicles – 2,7 % and 3.3 %;
- passenger light motor vehicles – 32,4 % and 37,2 %;
- special non-light motor vehicles – 6,7 % and 6,3 %;
- passenger buses – 19,7 % and 9,7 %.

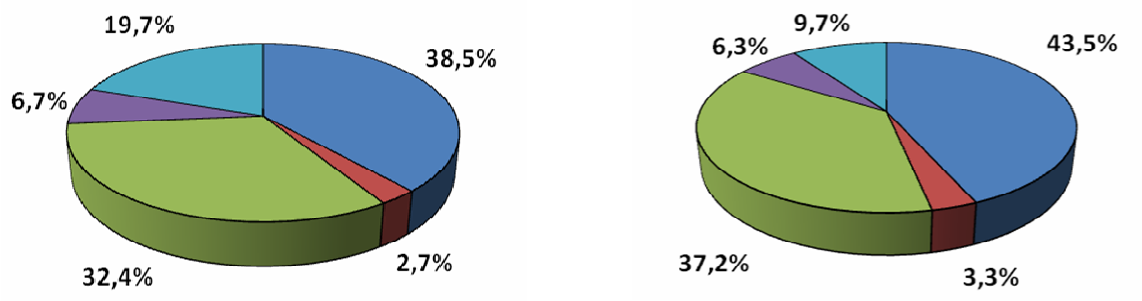


Fig. 4. Distribution of pollutant emissions into atmosphere in 2012 and 2015

Analyzing the above data of statistical observations, it is beyond dispute possible to emphasize the topicality of this issue, the necessity of constant monitoring of urban environment and implementation of planning protective engineering solutions to prevent negative impact on the urban ecology. The reconstruction of crossings of trunk road network with the increase of its traffic capacity as a hub and lineal inter-hub section of the street network increases the potential of environmental pressures on the existing area surrounding the main road. The estimate of the environmental pressure potential is formed by different environmental elements (e.g., noise, gas contamination, dirt accumulation, dust and light pollution) characterized by respective attributes (duration, propagation distance). Thus, it is possible to describe the environmental potential index as an *environmental pressure matrix E* and demonstrate it as follows:

$$\mathbf{E} = \begin{bmatrix} \mathbf{E}_{11} & \mathbf{E}_{12} & \cdots & \mathbf{E}_{1m} \\ \mathbf{E}_{21} & \mathbf{E}_{22} & \cdots & \mathbf{E}_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{E}_{n1} & \mathbf{E}_{n2} & \cdots & \mathbf{E}_{nm} \end{bmatrix},$$

where E_{nm} is the environmental pressure with element *n* and attribute *m*.

Depending on the target of research, attributes have different capacity potential which, in its turn, depends on the planning properties of the urban area, namely on the planning solutions for main streets and areas surrounding main roads. Mathematically, the potential of environmental pressures in space can be presented as the following formula:

$$E_{en.p.} = E_1P_1 + E_2P_2 + E_3P_{3+\ldots.+}E_nP_m,$$

where E_n is the type of environmental pressure on the area, and P_m is the potential of pressure in space and time on the area.

Having studied the current state of the areas surrounding main roads and analyzed the obtained data, it is possible to present the environmental pressure as a model of influence of environmental pressures of the main trunk road network on the urban area (Fig.5).

The modeling of the anthropogenic influence – the curve of environmental pressure on the urban area is an important stage in evaluating the anthropogenic impact.

In the city-planning practice the anthropogenic pressure coefficient is used for calculations of various kinds [11].

In accordance with the proposed model, the level of environmental (anthropogenic) pressure depends largely on the quantity of automobile transport and its stable compliance with the present-day safety regulations, trends of new technological developments in automotive engineering, their interchangeability, on the balance of the environmental pressure with the existing buildings under the conditions of urban densification and new spatially planned building.

The potential (significance) of these parameters is determined, on the one hand, by the engine type, traffic intensity, road traffic

organization, and on the other hand, by the type of road surface, driveway grade, planning solutions for the area between main roads, the green coverage ratio and climatic conditions.

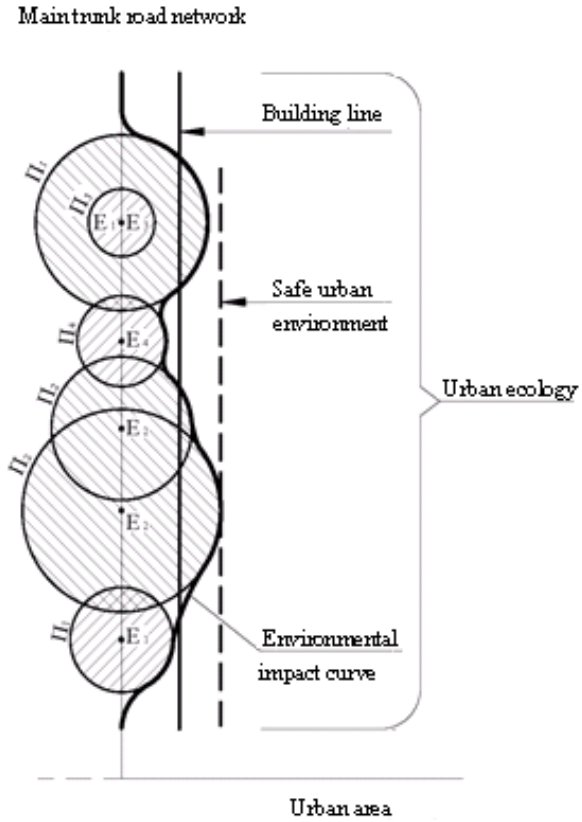


Fig. 5. Model of impact of environmental pressures of the main trunk road network on urban area (where E_n is the environmental pressure/attribute of a respective factor/, P_m is the potential of environmental pressure/effect of a respective factor)

CONCLUSIONS

The presented model serves as a framework for determining the potential of environmental pressures which will enable to evaluate the environmental state of urban environment and make respective planning decisions to afford quality of urban environment and choose of methods of engineering protection of urban areas in order to further study of territories against the backdrop of reconstruction and new development of territories with modeling of the environmental state of the areas surrounding main roads.

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Модель оценки эффективности планировочных мероприятий по защите примагистральных территорий от влияния экологических нагрузок магистральной сети г. Киева

Алексей Приймаченко

Аннотация. Повышение требований к экологическому состоянию городской среды порождает проблему в эффективном планировании и функционировании элементов защиты примагистральных территорий. Магистральными называют такие территории, которые расположены вдоль магистральной улично-дорожной сети в пределах от магистрали до линии застройки. По определению, линия застройки является границей расположения зданий и сооружений относительно красных линий. Они составляют примерно 15 − 30% территории города. Исследование методологических основ устойчивого развития урбанизированных территорий должно основываться на комплексном, проблемно-ориентирован-ном подходе различных смежных научных исследований. Поэтому задача исследования экологических нагрузок от магистральной уличной сети является актуальной для города. Проведя анализ нормативных документов Украины, было установлено, что для разработки и обоснования градостроительных регулирующих норм недостаточно для оценки планировочных мер защиты примагистральных территорий.

Для соответствующей оценки предложены математические и информационные модели, которые показывают зависимость экологических нагрузок по факторам и признакам в соответствии с планировочными решениями. Были проведены натурные обследования магистральной сети с различными планировочными критериями в Киеве, в ходе которых собраны данные, необходимые для оценки эффективности планировочных решений.

На основании полученных данных даны рекомендации по планировочным решениям соответствующих городских территорий.

Ключевые слова: улично-дорожная сеть, экологическая нагрузка, защита городских территорий.