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CHARACTERISTICS OF MOTORIZATION'S IMPACT ON THE URBAN POPULATION

Summary. *It is known that the most important thing in maintaining the good health of citizens is to save their lives from possible fatal road accidents, ensure the cleanliness of the air space, isolation from excessive noise pollution, electromagnetic fields. The listed negative impacts generate intensive traffic flows, which are the main component of transport systems. The task of identifying the patterns of changes in motorization over the past five years has become important. Motorization, as it was previously believed, is one of the characteristics of the well-being of the population. Growth is already accompanied in large cities by negative phenomena, such as: road accidents with loss of life; deterioration of air pool quality; excessive traffic noise; excessive electromagnetic fields that cause intense traffic flows. All these negative characteristics of the increase in the level of motorization formed the subject of this study. First of all, on the basis of statistical data, a chronological pattern of growth in the indicator of motorization has been found by year were revealed based of statistical data (they are described by showing filamentous and rectilinear equations): there is a constant increase for the period from 2017 to 2022. Functional dependencies of the influence of motorization levels on each of the hazards were also found: the influence of motorization on fatal road accidents and air pollution is described by exponential equations, and noise and electromagnetic ones are described by straight-line non-decreasing equations.*

Based on the obtained results, conclusions were drawn regarding the reduction of their impact by replacing conventional transport systems with intelligent transport systems with elements of artificial intelligence.

Key words: *motorization level, accident, carbon emissions, traffic noise, electromagnetic radiation, vehicle, traffic accident.*

1. INTRODUCTION

The increase in the fleet of cars in Ukraine has a negative impact on the cleanliness of the air basin and traffic safety (the death rate from road traffic accidents reached 9.1 deaths per 100,000 population by the end of 2021; in Germany, 3–4 people per 100,000 inhabitants).

Every year, more than 1.3 million people worldwide die as a result of road accidents, and the material losses from these accidents are estimated at 500 billion dollars [1]. Road accidents cause significant irreversible damage to the economy of Ukraine, which amounts to 3.6 % of its GDP. It is known, for example, that in Poland, the cost of life of a person who died in a road accident is estimated at 1 million 168 thousand euros and in other EU countries, it is within 1–2 million euros. Human life is considered for budget calculations, for example, in the medical field or the field of traffic safety.

In 2002, the largest package of European legal acts was adopted by the European Conference of Ministers of Transport, which spelt out the defining recommendations on road safety. In Ukraine, at the end of the 1990s, programs (CMU Resolution No. 456 dated 04/06/1998) which were related to

improving the road traffic safety and environmental safety of vehicles were formed and directed to implementation [2].

Subsequently, several systems were developed and protected by state patents. Using these systems makes it possible to increase the safety level of motor vehicles on highways and road networks in cities. These are, in particular, the following individual ones. There is a system for monitoring the functional state of the motor vehicle's driver in the transport process with an information and computing unit, which analyzes the indicators of the functional state of the motor vehicle driver. Another one is the vehicle safety system while driving in groups, which automatically maintains the set distance and speed between vehicles, monitors the state indicators of the drivers and, in the case of increasing critical deviations in the drivers' psychophysiological state or deviations in the movement parameters of the group and each vehicle in the group, or the appearance of obstacles, safely stops the car with light and sound signaling. One more system is the traffic light system alarm, which ensures that the driver receives continuous information about the operation of the traffic light control in advance to increase the awareness of motor vehicle drivers in the traffic flow. The last is a system for maintaining the vehicle's directional stability in the traffic flow for safe emergency stopping in case of an increase in critical deviations in the psychophysiological state of the drivers.

Today, the basic provisions of intelligent transport systems and traffic management based on them have already been formed, and the training of relevant engineering and technical specialists has been developed [3]. The names of scientists who researched traffic safety and environmental risks from traffic are well-known. Mateichyk V. P., Polishchuk V. P., Klinkovshtein G. I., Lobanov E. M., Gavrilov E. V., Klebersberg B., Werner Schnabel and others are among them.

It is known that, in the USA, in the 60s of the last century, a road safety management system was developed, the basis of which is not only the elimination of the consequences of road accidents but also their prevention. Such a system is currently being implemented in Ukraine. In Europe special EuroNCAP evaluation programs for new cars have been developed regarding their safety and impact on road safety. Implementing this program in Ukraine, including Lviv, envisages a "zero vision" (zero mortality, zero emissions of harmful substances, zero barriers to transport infrastructure facilities, and low-floor transport, etc.).

2. PROBLEM STATEMENT

Since February 2010, Ukraine has joined the Geneva Agreement on technical requirements for the construction of vehicles, which are more often called Euro environmental standards. From January 2012, Euro-3 environmental standards came into force, Euro-4 – from January 1, 2014, and Euro-5 – from January 1, 2016. Euro-6 was planned to be implemented by law starting January 1, 2018, but introducing this standard was suspended. Despite existing relevant security services and state standards (for example, SSTU 9030:2020. Roads. Assessment of environmental impacts. Requirements for project documentation), the air basin quality condition in cities is far from normative and is deteriorating over time.

Emissions of pollutants and greenhouse gases from vehicles are calculated considering average specific emissions of substances, type of fuel, fuel consumption per 1 kilometer, coefficients of vehicles' technical conditions, and other impact indicators. However, none of the approaches to calculating a set of indicators considers the peculiarities of the operation of public highways, in particular, traffic volume and composition.

Ecologists in the automotive industry repeatedly raised the problem of studying the calculation of vehicles emissions. An alternative approach in research on the calculating the emissions of pollutants during the movement of vehicles, taking into account their volume, is given in SSTU 9030:2020 "Roads. Environmental impact assessment. Requirements for project documentation".

In many scientific papers [4], fuel consumption is the criterion for assessing the environmental situation created by motor vehicles. The economic loss from atmospheric air pollution from mobile sources exceeding the established standards is determined in this way. It is planned that in 2030, about 3% of the Ukrainian passenger car fleet will be battery-powered electric vehicles. Such a trend will not allow achieving the initial goal of the Transport Strategy of Ukraine – 50 % renewable energy in transport in 2030. However, this is a real first step towards changing the fuel structure in the transport sector.

In urban conditions, a lot of anthropogenic (industrial, traffic noise) is added to the natural noise, which changes the acoustic background significantly. The criterion for the hygienic assessment of unstable noise is the equivalent (in terms of energy) sound level of broadband, stable and non-impulsive noise, which has the same effect on a person as unstable noise [5]. In many cities, the contribution of road transport to the total noise background is up to 80 %. The noise level varies significantly depending on the type and condition of the road surface, the type of engine, the technical condition of the car, the driving mode and speed, car load, traffic volume, etc. The prime sources of noise are also changing. Therefore, if at a speed of 75–80 km/h and fully loaded car, the primary noise source is the engine, then at a speed of 80–100 km/h, the prime noise is created by car tires [6].

It was found that the natural aura of the urban environment is affected not only by pollution of the air basin with exhaust gases and noise pollution but also by electromagnetic radiation from automobiles and other types of urban transport. Today, the share of electromagnetic radiation from urban road traffic is continuously increasing [7]. It is facilitated by the increase in the density of road networks, and in traffic flow, and the appearance of electric and hybrid cars.

The levels of electromagnetic pollution of the environment have acquired such values today that the WHO in 1995 included this problem (especially with the increase in the number of electric cars) among the most relevant for the population of cities. It officially introduced the term “global electromagnetic pollution of the environment”. The level of this pollution increases 10–15 times every ten years. It is known that electromagnetic pollution of the natural environment, for example, in 2022, covered 18–32 % of urban territories because of road traffic [8, 9]. In Ukraine, according to the “State sanitary regulations and rules for the protection of the population from the effects of electromagnetic radiation” [10], maximum permitted intensity level of this radiation is $2.5 \mu\text{W}/\text{cm}^2$. At a radiation intensity of about $20 \mu\text{W}/\text{cm}^2$, the pulse rate and blood pressure decreases, which is precise reaction to radiation.

3. RELEVANCE OF RESEARCH AND FORMULATION OF AIM AND OBJECTIVES

Respectively to the above, the need to investigate changes in the impact on urban residents of each listed hazard over the past five years (2017–2022) has become urgent. The reason for this was the intensive growth of motorization during this period, which was accompanied, most of all, by an increase in the number of people killed under the wheels of vehicles.

The purpose of the study is to determine the functional dependencies (regularities) of changes in each of the hazards (pollution of the city's air basin with vehicle exhaust fumes, its pollution by traffic noise and electromagnetic radiation from traffic flows) from the increase in motorization during the specified period.

Among the tasks is to identify chronological and analytical dependences on the growth of motorization: deaths because of road accidents, atmospheric pollution of cities with exhaust fumes, environmental pollution by traffic noise, and pollution by electromagnetic radiation spread by traffic flows.

4. ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

It has been established that the increase in traffic flow volume and the complication of traffic conditions are reflected in the driver's neuropsychological state instantly, which can lead to road accidents [11, 12]. It is possible to make an appropriate distribution of the relative psychological pressure of various road users on the health of the population in cities (%) [13, 14]:

- drivers of four-wheeled vehicles, motorcycles – 100;
- pedestrians – 50;
- cyclists and other small means of transportation – 25;
- passengers of road public transport – 5.

Motor vehicle drivers carry out the maximum value of this influence on the normal functioning of the life of the urban population; in second place are pedestrians, in third – cyclists, and finally – passengers. This distribution is reflected in the statistics of dangers (road accidents with various consequences) from the use of means of transportation and the reduction of labor productivity of the working urban population, who use vehicles and public transport.

At the beginning of the 20s, publications appeared with the analysis and development of Intelligent Transport Systems in Japan, the USA and the countries of Western Europe, which, among other things, allocated places in their programs to ensure transport safety and environmental safety [15]. In 2020, L. S. Abramova defended her doctoral dissertation: “Theoretical foundations of the formation of distributed traffic management systems in cities” [16], in which, among other things, all the currently possible methods of traffic safety assessment are analyzed – there are 15 of them. Among them are both well-known and rarely used, such as the relative accident rate, the road accident severity factor, the danger of the road network section, the method of conflict points, the method of assessing the quantitative indicator of conflict, the method of conflict situations, the method of testing the driver, and others. In addition, scientists from Kyiv and Kharkiv assessed environmental hazards based on traffic flow monitoring and developed appropriate intelligent management systems to reduce these hazards [17].

5. PRESENTING OF THE MAIN MATERIAL

It was assumed that each of the harms, with the growth of motorization, causes a negative impact on the health of the human population. Based on the processing of statistical data from available and open sources, we found a trend of increasing the level of motorization (Fig. 1), which accompanies, first of all, an increase in the deaths of people under the wheels of cars as a result of road accidents (Fig. 2) [18]. The growth of motorization in Ukraine during 2017–2022 is described by the following equation:

$$y = 1.6607x^2 - 6694.3964x + 6750572.9. \tag{1}$$

The number of deaths (without other categories of victims) in connection with the increase in the level of motorization is also approximated by an exponential dependence:

$$y = 14.7679x^2 - 59581.4893x + 60099355.3. \tag{2}$$

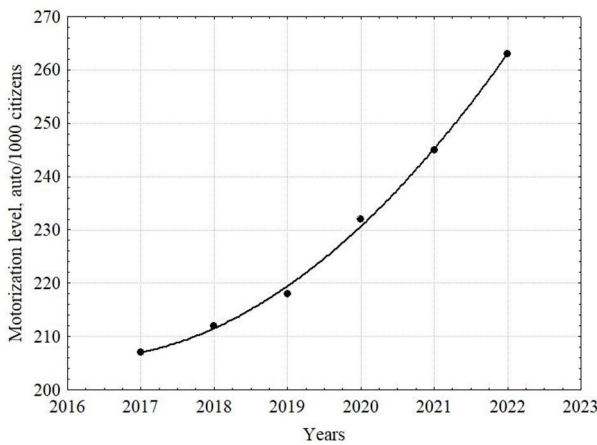


Fig. 1. The trend of motorization growth in Ukraine

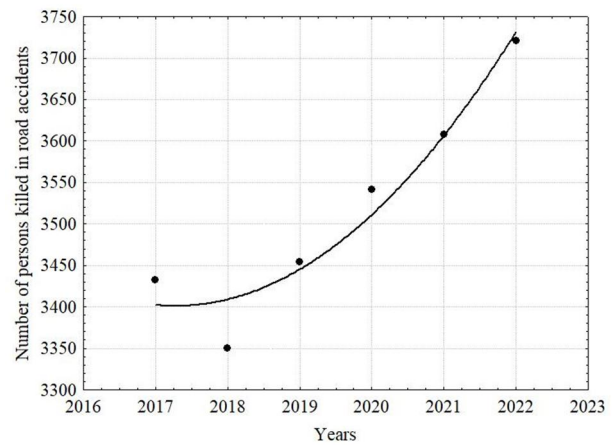


Fig. 2. Characterization of motorization's impact on the increase in fatalities as a result of road accidents

Processed statistics of emissions, for example, of carbon oxides with exhaust fumes of cars into the atmosphere of urban settlements (in thousands of tons), indicate their annual growth (Fig. 3). The trend of increasing pollution of the urban air basin with exhaust fumes from the internal combustion engine of cars is also described by the exponential function:

$$y = 2.2886x^2 - 9233.0471x + 9313722.19. \tag{3}$$

As for noise pollution near road networks in cities (Fig. 4), the nature of their growth is described by the equation of a non-decreasing straight line with a coefficient of determination of 0.9958:

$$y = 3.3714x - 6735.2667. \tag{4}$$

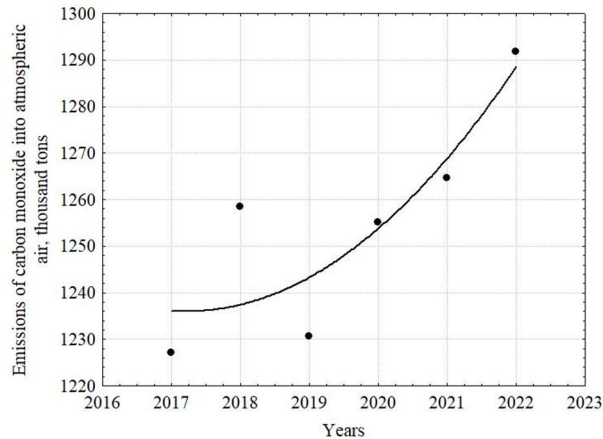


Fig. 3. The trend of increasing pollution of the urban air basin with exhaust fumes from internal combustion engines of cars

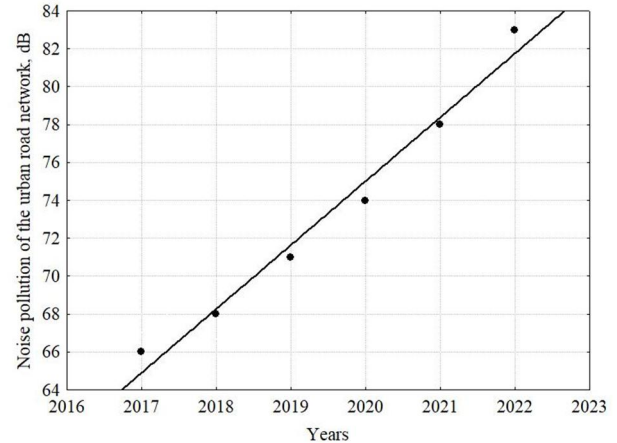


Fig. 4. The trend of increasing noise pollution on the road network of the city

The change by years of electromagnetic fields during peak periods on urban arterials was calculated based on the trends of growth in traffic flow volume, taking into account the intensity of the electromagnetic field of one vehicle (Fig. 5). Traffic flow volume on the road network with two-lane traffic was 1.500 vehicles per hour; the average frequency of the electromagnetic field is 1.5 kHz. The process of changing the intensity of electromagnetic fields over an intense traffic flow can be described by the equation of a non-decreasing straight line (the coefficient of determination is 0.9830):

$$y = 0.028x - 56.3193. \quad (5)$$

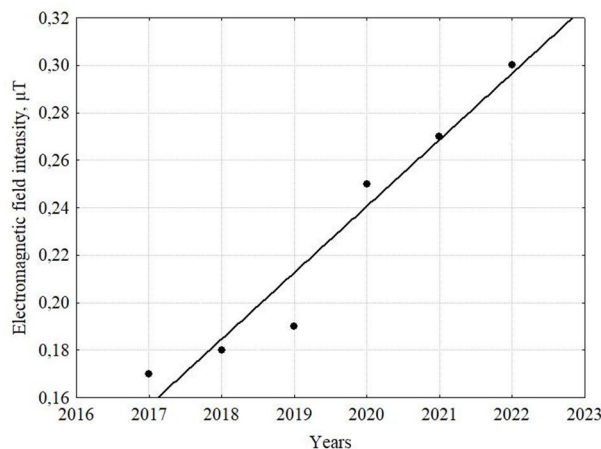


Fig. 5. The nature of the change in electromagnetic field intensity created by traffic flows on the arterial streets of the city

It is obvious that the nature of the change of each hazard over the course of 5 years tends to increase: the number of dead – by 10 %; air pollution – by 4.5 %; noise pollution – by 31 %; electromagnetic field – twice.

The chronological abscissa was replaced by the annual values of motorization levels to find the dependence of the influence of each hazard on motorization. The values of the four hazards were plotted along the ordinate. Thus, we obtained graphical dependences of mortality under the wheels of vehicles (Fig. 6), air pollution by exhaust fumes (Fig. 7), noise pollution (Fig. 8) and electromagnetic radiation of the road network space (Fig. 9) on the growth of motorization in cities. Each of the sought-after dependencies of the influence of motorization is described by the following formulas:

- the number of persons killed in road accidents:

$$RA = 0.0154MR^2 - 1.2471MR + 2984.8204; \quad (6)$$

- pollution of the air basin of the city by exhaust fumes of internal combustion engines of cars, using the example of carbon monoxide, thousand tons:

$$CDE = 0.0105MR^2 - 3.9679MR + 1607.1655; \tag{7}$$

- noise pollution near road networks in cities, dB:

$$TN = 0.2952MR + 5.5795; \tag{8}$$

- change in the intensity of electromagnetic fields above the intensive traffic flow, μT :

$$ER = 0.0025MR - 0.3388. \tag{9}$$

In these formulas: MR – value of motorization level, cars/1000 inhabitants.

The given approximations were obtained with a confidence probability of 0.985.

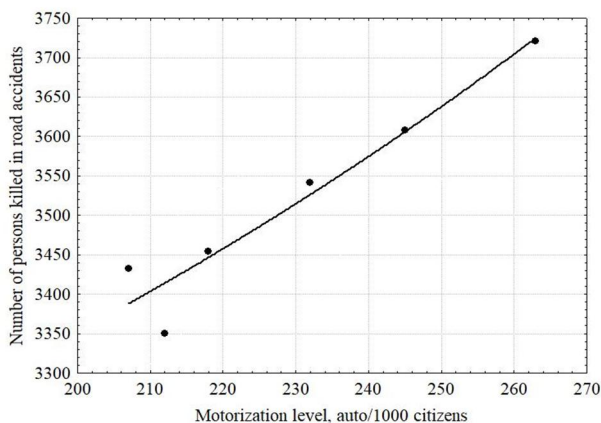


Fig. 6. Dependence of the number of people killed in traffic accidents on the growth of motorization

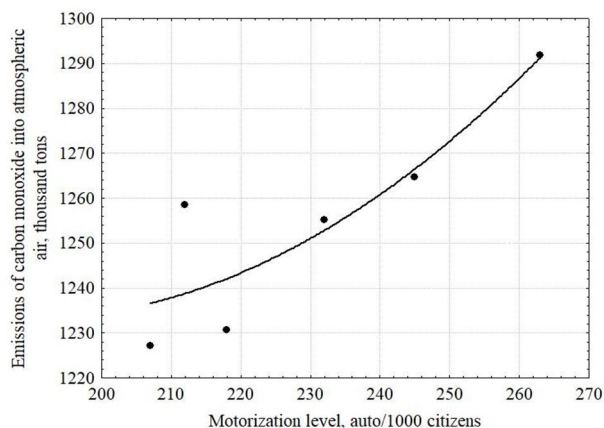


Fig. 7. Dependence of pollution of urban air basin by exhaust fumes of internal combustion engines of cars

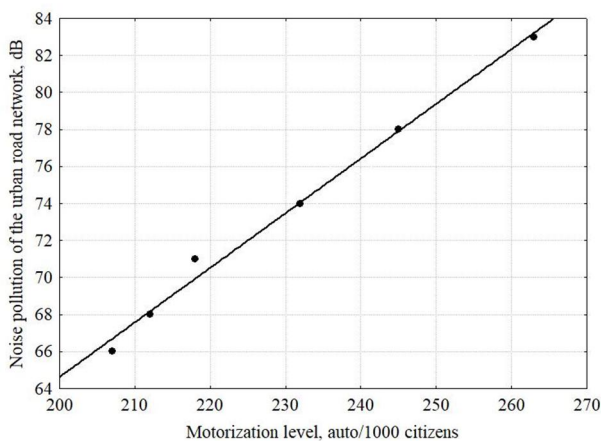


Fig. 8. Dependence of noise pollution of the road network of the city on the growth of motorization

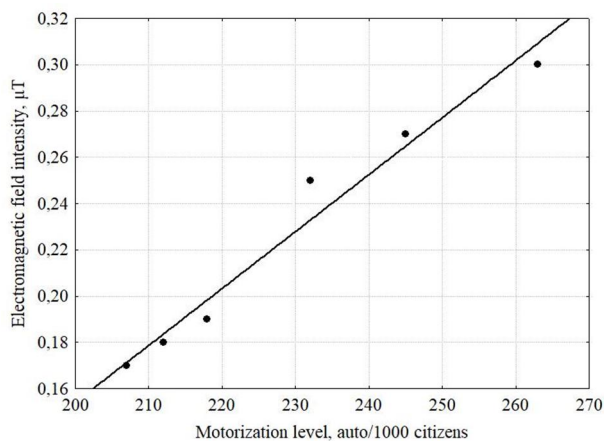


Fig. 9. The dependence of changes in the electromagnetic field (magnetic component) created by traffic flow on the arterial streets of the city on the growth of motorization

The obtained results indicate the specific impact of the growth of motorization on each hazard. The percentage growth of harms from the increase in motorization is similar, as in the chronological dependence. It affects the deterioration of the health of the urban population.

6. CONCLUSIONS AND FURTHER RESEARCH PERSPECTIVES

The same trends in the growth of harm from road transport – the death of people because of road accidents, pollution of the air basin with exhaust fumes from internal combustion engines of cars, noise pollution of the urban road network, intensity of electromagnetic radiation of traffic flows – testify to their direct connection with the excessive growth of motorization level, including urban population. An effective (but not

instantaneous and not final) way out of these situations, which collectively continue to pose an insurmountable problem in the urban transport systems, can be provided in the future by an intelligent transport system with the widest possible use of artificial intelligence [17, 19, 20]. It will combine the following subsystems into a combined technical and technological complex: traffic management (optimization of intersection passage, including for public transport, arrangement of road network with appropriate reconstructions), road safety (minimization of road accidents, environmental pollution by exhaust fumes of internal combustion engines, electromagnetic radiation, road noise), and information subsystem (with relevant traffic monitoring and control centers based on satellite and terrestrial automated or automatic means).

In connection with the above, further scientific research in this direction should be continued, aiming to develop a state approach to establishing stricter (European) requirements for reducing the impact of these harmful substances in the complex.

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ХАРАКТЕРИСТИКА ВПЛИВУ АВТОМОБІЛІЗАЦІЇ НА МІСЬКЕ НАСЕЛЕННЯ

Анотація. Відомо, що найважливішим для підтримання доброго здоров'я містян є збереження їхнього життя від можливих смертельних ДТП, забезпечення чистоти повітряного простору, ізолювання від надмірних шумових забруднень, електромагнітних полів. Перелічені негативні впливи генерують інтенсивні транспортні потоки, які є основною компонентою транспортних систем. З урахуванням надзвичайної важливості забезпечення нормального життєвого простору для міського населення, який формується, зокрема, нормативами функціонування транспортної системи, актуалізувалось завдання щодо виявлення закономірностей зміни автомобілізації упродовж останніх п'яти років. Автомобілізацію раніше вважали однією із характеристик добробуту населення. Зростання уже нині супроводжується у великих містах і негативними явищами, такими як: ДТП із втратами життів населення; погіршення якості повітряного басейну; надмірні транспортні шуми; надмірні електромагнітні поля, які спричиняють інтенсивні транспортні потоки. Усі ці негативні характеристики зростання рівня автомобілізації стали предметом цього дослідження. На підставі статистичних даних визначено хронологічну закономірність підвищення показника автомобілізації, виявлено тенденції змін шкідливостей за роками (вони описуються показниковими та прямолінійними рівняннями): є постійні зростання за 2017–2022 рр. Визначено також функціональні залежності впливу рівнів автомобілізації на кожну із шкідливостей: вплив автомобілізації на смертельні ДТП та забруднення повітря описуються показниковими рівняннями, а шумові та електромагнітні – прямолінійними неспадними рівняннями.

На основі отриманих результатів зроблено висновки щодо зменшення їх впливу заміною звичайних транспортних систем на інтелектуальні транспортні системи з елементами штучного інтелекту.

Ключові слова: рівень автомобілізації; аварійність; викиди вуглецю; транспортний шум; електромагнітне випромінювання; транспортний засіб; дорожньо-транспортна пригода.