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COMPLEX ASSESSMENT OF ROAD TRANSPORT HAZARDS

Summary. *In this paper, it is proposed to carry out the assessment of road transport hazards using the minimization of the negative impact by three main components: impact of changes in emissions of toxic elements of pollutants from the exhaust gases of car engines, change of noise pollution of the environment and change of the number of accidents. The method of determination of equivalent losses which will be as a result of the release of a conventional ton of toxic components of pollutants from the exhaust gases of car engines and the impact of noise pollution of the environment on three groups of components – drivers and passengers, pedestrians and residents of adjacent territories is justified. Special attention is paid to determining equivalent losses due to traffic accidents with injured or dead.*

For example, a study to determine the change in environmental hazards of road transport for the section of Lubinska Str. in Lviv, depending on the main indicator of traffic flow – the speed of traffic was carried out. It is established that for the speed of 25 km/h the minimum environmental damage will be 1093 thousand UAH per year, and the minimum total hazards of road transport, taking into account the possibility of an accident at 12 km/h will be 1239 thousand UAH per year.

With the help of the obtained model, it is possible to determine the amount of hazards from road transport, which allows taking into account environmental, social and economic components when studying the levels of the negative impact of transport on the environment and ensuring minimum accident rates on the studied section of the road network. Conducting preliminary theoretical research to find rational solutions when applying schemes to improve traffic organization will be especially useful.

Key words: *road network, exhaust gases of car engines, traffic flow noise, emissions of harmful components, road transport hazards, specific losses, speed of movement, road accidents, socio-economic losses.*

1. INTRODUCTION

The provision of openness, security, sustainability and environmental sustainability of settlements was provided in the Ukraine development strategy to 2020 and different projects of further periods [1, 2, 3, 4]. All legislative initiatives focus on the development of transport and reducing its negative impact on society and the environment, as it is transport, especially road transport, which ensures the mobility and functioning of the industry. At the same time, transport accounts for about 17 % of global greenhouse gas emissions from total emissions caused by human activities [5]. The world community has begun an active phase of implementing various strategies to reduce carbon footprint and consumption of non-renewable resources, which has led to the introduction of relevant legislative initiatives. The transition to renewable energy in Ukraine by 2050 also involves using the European Green Course [6]. It will allow the country to move with the general trend of reducing greenhouse gas emissions in all sectors of the economy.

The structure of greenhouse gas emissions in Ukraine by different sectors generally corresponds to world proportions [7]: the primary emission of greenhouse gases is energy – 66 %, all modes of transport – 15 % from all emissions. At the same time, the transition to renewable energy in Ukraine by 2050 involves the transfer of 20 % of transport to renewable energy sources, which should reduce emissions of both greenhouse gases and toxic components in the exhaust gases of transport. However, unlike other transport sectors, road transport in Ukraine today has several significant problems, the solution most of which requires the political will of the leadership to introduce unpopular legislative initiatives.

2. RESEARCH STATEMENT

In Ukraine and the world, there is a steady increase in the vehicle's number, which leads to an increase in the levels of danger from the car's operation. In addition to the traditional emissions of toxic components due to the combustion of fossil fuels in the power plants of its power units, excessive noise during the operation of any vehicle is also essential, including an electric car. The impact of traffic noise on the citizens of large cities is becoming decisive today concerning the primary indicator of negative interaction between transport and the population. It is estimated that in 2018, every European spent 1.250 euros on health problems due to poor air quality [8]. Therefore, today the main environmental indicators of the safety of a modern car operation should be the composition of the exhaust gases of its engines and the level of noise and their impact on the environment.

In addition, the use of cars and the interaction of traffic flow with each other and with other road users cause an increase in the number of road accidents. World statistics put the death rate from road accidents in the 9th place with a rate of more than 1.35 million deaths in 2021 in the world and more than 6 thousand deaths in road accidents in Ukraine (according to the WHO) and about 4.7 thousand deaths according to Ukrainian data [9, 10].

Lack or insufficient amount of information about accidents or their causes, but also about the number of deaths in accidents does not allow determining their location for the proper application of measures to reduce the number of fatalities. At the same time, today, there are many studies aimed at studying the impact of errors or drivers' age on the probability of accidents made by them [11, 12]. Various factors influencing road safety are considered. Special attention is paid to the impact of traffic and road characteristics on road safety. It is established that some factors, including speed, congestion, and curvature of the road in the plan, have an ambiguous impact.

According to official data [13], on average, in Ukraine, road accidents due to deficiencies in the maintenance of roads were recorded in 1.21 % of cases, and the operation of technically defective vehicles led to 2.2 % of road accidents. At the same time, according to various studies, statistics do not always correspond to the real causes of accidents with significant discrepancies [14, 15]. Statistics on the distribution of the causes of all road accidents in Ukraine, according to independent experts, show a different impact on the causes of events [13]: due to erroneous human actions – 60–70 %; due to the unsatisfactory condition of roads and inconsistency of road conditions with the nature of traffic – 20–30 %; due to technical malfunctions of the car – 10–15 %.

In recent years, there has been a growing number of problems in road transport. These problems include increased wear of the fleet, a significant increase in the average age of vehicles, and a lack of state control over the technical condition of cars through a system of mandatory control of the technical condition for private transport. It does not allow providing traffic safety and significantly increases the negative impact on the environment. The motorization level in Ukraine today has reached 245 cars per 1.000 population [16], and it will continue to grow, exacerbating traffic safety problems. In addition, the car fleet is constantly replenished with used vehicles imported from abroad. In particular, almost half a million more cars were registered last year, 43 % were older than 10 years and less than 4 % were hybrids and electric vehicles (Fig. 1) [17]. It has led to an increase in road accidents over the last year by 13.9 % compared to 2020 (from 135.626 to 154.480) [18].

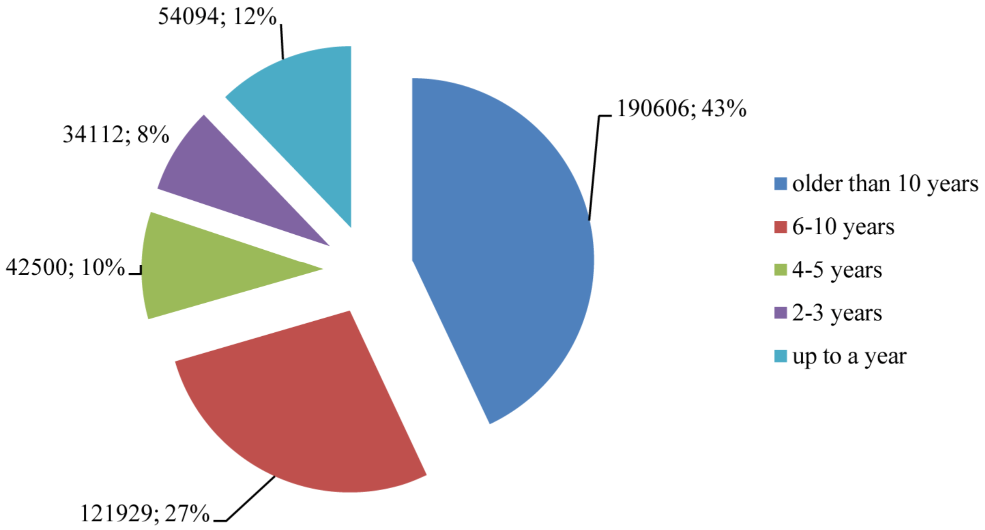

Fig. 1. Structure of the market of registration of used cars by age (9 months 2021, units and % of the market) [17]

Thus, today there is an urgent need to find the development of effective ways to reduce the harmful effects of transport on the environment (pollution by toxic components of exhaust gases, excessive noise) and reduce the number of accidents. However, this is not possible without the introduction of mandatory control of the technical condition of vehicles. Despite the importance of the problem, the task of reducing the accident rate of cars on the road network is declarative, as no effective means are used to reduce the number of accidents in accident-hazardous areas.

This study aims to develop a system of indicators that would reduce the environmental and emergency hazards of road transport, which will allow their use in modelling the changes in the characteristics of traffic flows.

3. RESEARCH METHODOLOGY

Many studies on road transport allow identifying nine relevant areas [19]. At the same time, there are 4 groups of fundamental indicators of socio-economic development – economic, social, environmental and organizational [20].

It is proposed to evaluate the efficiency of transport E in the implementation of various organizational tools by minimizing costs for the three main components:

$$E = M_{ef} \cdot c_{ef} + I_{noise} \cdot c_{noise} + P_{ac} \cdot c_{ac}, UAH \longrightarrow \min, \quad (1)$$

where M_{ef} – emissions of toxic components of pollutants from the exhaust gases of car engines, cond. t; c_{ef} – monetary equivalent of losses caused by the emission of a conditional ton of toxic components of pollutants from the exhaust gases of car engines, UAH / cond. t; L_{noise} – noise pollution, dBA; C_{noise} – the monetary equivalent of losses caused by noise pollution, UAH / dBA; P_{ac} – predicted number of accidents, units; C_{ac} – the monetary equivalent of damages caused by each type of road accident, UAH / Accident unit.

When analyzing the impact of road transport on the environment, primary attention is paid to the composition of engine exhaust gases and their effects on the environment. Based on previous research, the method [21] for determining environmental and economic losses from changes in traffic flows indicators from emissions of harmful substances into the atmosphere has been improved [22]. Moreover, the method allows taking into account the negative impact of toxic exhaust emissions from car engines on three groups of participants [22]: the first group – drivers and passengers of vehicles, the second group is pedestrians moving parallel to traffic flows and the third – residents of adjacent areas.

Determination of losses from emissions of harmful substances into the atmosphere is carried out at the cost of environmental damage from the total emissions (M_0) and damage to human health from the total emissions (M_i). Annual losses are determined by the formula [22]:

$$M_{ef} = \left[M_0 \cdot C_{mo} \cdot S + \sum_{1}^{i=3} \left(N_i \cdot C_{mi} \right) \right] \cdot \varPhi_{year} \cdot K_c, UAH / year, \quad (2)$$

where M_0 – specific volume of emissions, kg/km; C_{mo} – the cost of environmental losses from the emission of 1 kg of harmful substances reduced to CO, UAH/kg; S – the length of the study area, km; N_i – the number of each of the groups of consumers of emissions (three groups – the first is drivers and passengers, the second group is pedestrians and the third – residents of nearby houses), persons; C_{mi} – the cost of environmental losses from human exposure for an hour of harmful substances of such concentration that is equivalent to the specific amount of emissions of M_i, UAH/person; $\varPhi_{year}$ – annual time fund, h; K_c – social coefficient of ecological losses.

The specific amount of emissions will be determined [21]:

$$M_0 = Q \cdot m \cdot \left[K_{\Pi H} \left(K_{mv} \cdot K_{iv} - 1 \right) + H_t \cdot K_{mv} \cdot K_{iv} \right], kg / \left(hour \cdot km \right), \quad (3)$$

where Q – estimated traffic intensity in both directions, veh/hour; m – the base value of the total CO emissions of the car, kg/km [22]; $K_{\Pi H}$ – dynamic volume/capacity ratio; K_{mv} – the rate of change of emissions from speed; K_{iv} – the coefficient of change of emissions from the variance of the velocity; H_t – coefficient that takes into account the age of the vehicles.

The calculation of losses from traffic noise is estimated at the cost of damage to human health. Annual normative (with the accepted standard $L_i \approx 35$ dBA) losses were determined by the formula [22]:

$$I_L = \sum \left(K_{L_i} \cdot N_i \right) \cdot \varPhi_{year} \cdot S \cdot C_c \cdot K_c, UAH, \quad (4)$$

where K_{Li} – the ratio of specific losses of national income (GDP) from the increased noise level for each category of consumers; N_i – specific (per 1 km) number of consumers of this category people/km (consumers of environmental impact); C_c – specific hourly value of GDP per capita, UAH/hour; K_c – social coefficient of ecological losses.

The ratio of specific losses of GDP from the increased noise level for each category of consumers is determined taking into account the noise level thrown together to the consumer [21]:

$$K_{L_i} = 1.8 \cdot 10^{-7} \cdot L_i^{3.39} - 0.0312, \quad (5)$$

where L_i – thrown together (to the consumer) noise level, dBA.

Thrown together noise level for every group of consumers will determine:

– for drivers:

$$L_1 = L_0 + \Sigma d_1, dBA; \quad (6)$$

– for pedestrians:

$$L_2 = L_0 + \Sigma d_2, dBA; \quad (7)$$

– for residents:

$$L_3 = L_0 + \Sigma d_3, dBA, \quad (8)$$

where Σd_1, Σd_2, Σd_3 – sum of corrections in the calculation of noise generated for each of consumer groups, dBA.

The basic noise level is determined [21]:

$$L_0 = 4.3 + 10 \cdot \lg \left[Q \cdot V^2 \cdot \left(14 \cdot K_{\Pi H} - 13 \right) \right] + \Sigma d_0, \quad (9)$$

where Σd – sum of corrections in calculating noise generated, dBA (taking into account the type of pavement, landscaping, shielding, street width and building height, speed variance).

According to research results, the values of the adjustment factors for determining the level of traffic impact on the environment are established, taking into account the following characteristics [21]:

– changes in emissions from the speed of traffic flow;
– the share of electric vehicles in the traffic flow;
– the share of vehicles with gasoline and diesel engines in the flow;
– coefficients of protection of drivers and passengers, pedestrians and residents;
– dynamic volume/capacity ratio of electric vehicles;
– the vehicle's age factor and the corresponding coefficients of increase in emissions with increasing age of cars with petrol and diesel engines.

Determination of both the level of damage and the equivalent value of losses from the harmful effects of exhaust emissions from car engines and the noise level generated by traffic flows is clear. However, the issue of taking into account the change in the estimated number of accidents and the corresponding monetary equivalent of the damage caused by the road accident is particularly relevant.

Regarding the impact on the estimated number of road accidents, the unambiguous and greatest impact is the vehicle's speed at the time of the accident [23]. Although it is one of the many causes of accidents, it determines the severity of injuries or even deaths. For every 5 km/h of the increase in speed in the zone of 60 km/h, the risk of injury in the accident doubles. At a speed of 65 km/h the probability of an accident that will lead to damage doubles, at a speed of 70 km/h it increases in 4 times, and at 80 km/h – in 32 times [23]. In this regard, it is proposed to use the value of changes in the speed of traffic as the main factor contributing to accidents and injuries or deaths.

Based on the previous analysis, it is proposed to use known models, which, according to statistics of various types of accidents, allow determining both the estimated number of accidents after changes of speed and the number of victims on certain sections of roads [24].

These models in the form of corresponding equations are given in Table 1 [24].

Table 1

Models for the determination of the estimated number of road accidents based on the change in traffic flow speed [24]

№	Type of road accident	Number of events of this type	The total number of dead or injured
1	Accidents with the dead	$N_1 = \left(\frac{V_1}{V_0}\right)^4 Y_{01}$	$Z_1 = \left(\frac{V_1}{V_0}\right)^4 Y_{01} + \left(\frac{V_1}{V_0}\right)^8 (Z_{01} - Y_{01})$
2	Accidents with fatal and severe injuries	$N_2 = \left(\frac{V_1}{V_0}\right)^3 Y_{02}$	$Z_2 = \left(\frac{V_1}{V_0}\right)^3 Y_{02} + \left(\frac{V_1}{V_0}\right)^6 (Z_{02} - Y_{02})$
3	Accidents with injuries (all)	$N_3 = \left(\frac{V_1}{V_0}\right)^2 Y_{03}$	$Z_3 = \left(\frac{V_1}{V_0}\right)^2 Y_{03} + \left(\frac{V_1}{V_0}\right)^4 (Z_{03} - Y_{03})$

The models do not predict the estimation of the number of accidents with minor injuries or the number of victims of minor injuries. The model allows determining the estimated number of road accidents after changing the speed V_0 and the number of victims by the value of speed ratio after improvement or application of some restrictions V_1 to the base in this area V_0 and by known statistics of the number of events of this type Y_{0i} and the number of dead or injured Z_{0i}.

To analyze the road sections of modern cities and determine the degree of their accidents and the risk of accidents, one can use maps of accident types with the given types and quantities of accidents of these types on the city's road network. For example, for Lviv, the ZAXID.NET website analyzed all road accidents that occurred in Lviv for three years (2018–2020) and created a map showing the number of accidents on the city streets [25]. Data on accidents and the number of victims are taken from official statistics of the Patrol Police of Lviv Region, which tracks the GPS coordinates of each accident (Fig. 2).

All accidents are marked in red on the map, which allows identifying dangerous areas. It is possible to filter accidents by showing only similar cases with the help of two filters: selecting accidents with victims (whether only fatal or without victims) and sorting road accidents by a specific type of transport (for example, only with cyclists or only with trams) [25].

Regarding determining the monetary equivalent of damages caused by accident, it is established that in Ukraine today, there is a problem with formalising the concept of “economic equivalent of human life value”. However, the closest to this concept is used in regulations when paying by government agencies or insurance companies the compensation for injury or death [26, 27].

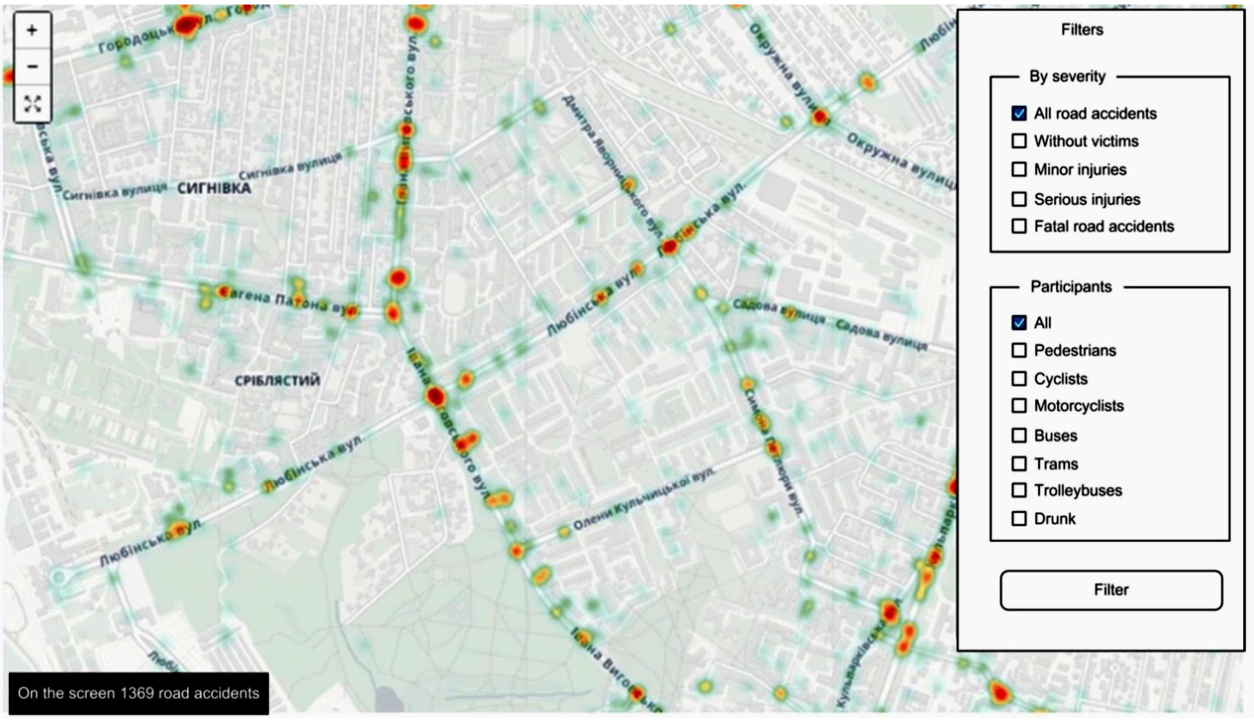

Fig. 2. Fragment of the road accident map view in Frankivsk district of Lviv city [25]

Some institutions researched to assess the cost of life and total losses from accidents and determine the value of socio-economic losses from accidents. At the request of the National Program of Ukraine for the Prevention of Road Traffic Injuries of Children and Youth, “Traffic Challenge”, a method for determining the cost of economic losses from accidents, was developed [27]. The methodology contains three approaches [27]:

– the first approach involves the calculation of economic losses and costs of the state – the cost of living is $ 79 618, and the total annual loss of the state from all deaths is $ 485 million or 0.53 % of GDP;
– the second approach, in addition to calculating economic losses and government expenditures, takes into account household losses: by the second method, the cost of living is $ 177 108, and the total annual loss of the state is $ 1 billion 197 (1.32 % of GDP);
– the third calculation of socio-economic losses by the gross method, or the European calculation, estimates the death of a Ukrainian at $ 400 378, and the total economic damage from the accident is $ 2.074 billion (or 2.5 % of GDP).

In addition, in the State Enterprise “DerzhdorNDI”, named after M.P. Shulgin at the request of the State Agency of Motor Roads of Ukraine in 2016–2017, work was carried out to develop and fill the information and analytical system to determine the socio-economic losses from accidents. In 2019, an appropriate methodology was developed [28]. The amount of socio-economic losses from accidents is estimated based on the calculation of direct and indirect economic losses. For example, the analysis of socio-economic losses from road accidents showed that they account for 1.25 % of GDP in actual prices for 2018 or UAH 1295012 per victim (according to the NBU exchange rate $ 46 771) or UAH 44 333.4 million in absolute terms for 2018 [28].

4. ANALYSIS OF THE RESULTS OBTAINED

Here are the results of the calculation of the efficiency of road transport *E* (possible reduction of its harmfulness) on the accepted section of the road network of Lviv – Lyubinska Str. – from the intersection with Vyhovskoho Str. to the Okruzhna Str. This section of the road is characterized by heavy traffic and is one of the district's arterial streets (Fig. 3).

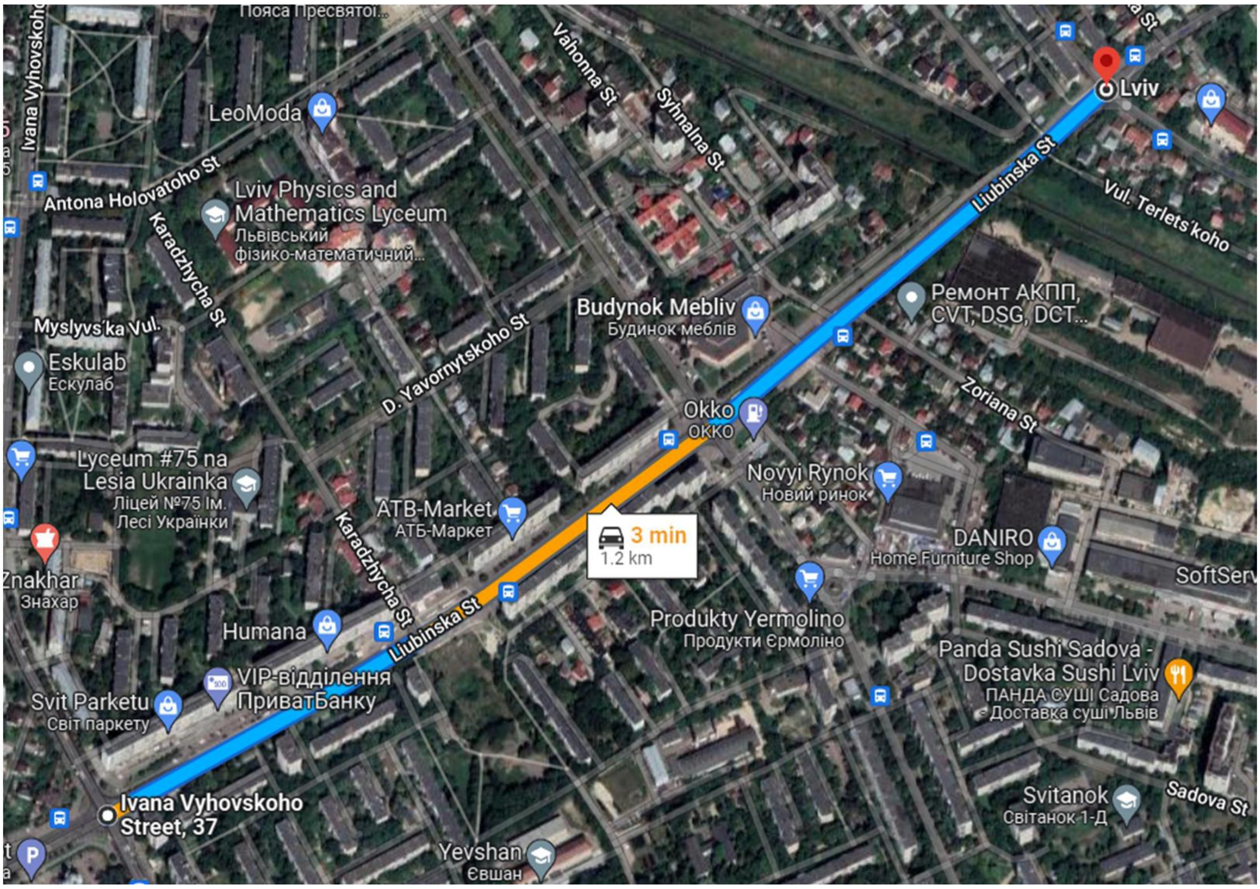

Fig. 3. An investigated section of Lubinska St., Lviv

On the investigated section of the street with a total length of 1.2 km, the traffic flow indicators were determined (measurement time 1200–1220). Observations have identified the following indicators:

- speed of traffic flow movement, 40 km/hour;
- traffic flow intensity, 1680 auto/hour;
- the width of the street and the roadway, respectively 60 and 20 m;
- the sum of building heights on both sides, 54 m;
- total, including walking on sidewalks and pedestrian crosswalks, the intensity of pedestrian traffic, 1290 persons/hour;
- number of residents of adjacent buildings, 1958 persons;
- share of electric transport in traffic flow – 1 %;
- distance from the middle of the trajectory of the nearest row of traffic flow to the middle of the sidewalk – 15 m;
- the number of rows of trees and bushes that protect pedestrians from environmental impact;

- the number of rows of trees (and for one-story buildings also bushes) that protect pedestrians from ecological impact – 1;
- share of public transport – 2 %.

According to the formula (3), the determination of the specific volume of emissions for a fixed distance of the street section per time unit is carried out:

$$M_0 = 1640 \cdot 0.2 \cdot \left[1.12(1.3 \cdot 1.049 - 1) + 1.279 \cdot 1.3 \cdot 1.049\right] = 70.91\, kg / (hour \cdot km).$$

Let`s determine the annual economic losses from emissions of harmful substances into the atmosphere by formula (2):

$$M_{ef} = \left[70.91 \cdot 0.025 \cdot 1.2 + 97 \cdot 0.0403 + 547 \cdot 0.0255 + 1632 \cdot 0.0166\right] \cdot 4200 \cdot 1.5 = 283391\, UAH / year.$$

Total losses from noise generated by traffic flows (formula (6)):

$$L_0 = 4.3 + 10 \cdot \lg\left[1680 \cdot 40^2 \cdot (14 \cdot 1.12 - 13)\right] + 1.111 = 77.51\, dBA.$$

Let`s determine the consolidated noise level for each of the consumer groups (formulas (7) – (9)):

- for drivers:

$$L_1 = 77.51 - 12 = 65.51\ dBA;$$

- for pedestrians:

$$L_2 = 77.51 - 4.21 = 73.30\, dBA;$$

- for residents:

$$L_3 = 77.51 - 19.49 = 58.02\, dBA.$$

The coefficient of specific losses from the increased noise level for each group of consumers will be determined considering formula (5):

- for drivers:

$$K_{L_1} = 1.8 \cdot 10^{-7} \cdot 65.51^{3.39} - 0.0312 = 0.227;$$

- for pedestrians:

$$K_{L_2} = 1.8 \cdot 10^{-7} \cdot 73.30^{3.39} - 0.0312 = 0.347;$$

- for residents:

$$K_{L_3} = 1.8 \cdot 10^{-7} \cdot 58.02^{3.39} - 0.0312 = 0.140.$$

Then, for the given traffic conditions, the loss from traffic noise in the considered section of the road network will be (according to formula (4)):

$$I_L = (0.227 \cdot 97 + 0.347 \cdot 547 + 0.140 \cdot 1632) \cdot 4200 \cdot 1.2 \cdot 0.25 \cdot 1.5 = 833071\, UAH.$$

In order to determine the monetary equivalent of damages caused by accidents using the data on accidents and the presence of victims taken from the official statistics of the Patrol Police of Lviv region (Fig. 4) [21], information was obtained on the number of accidents of a particular type and the number of victims for the past 3 years: road accident with victims – 6 accidents, 6 victims; accidents with fatal and severe injuries – 8 accidents, 8 victims; accidents with injuries (all) – 39 accidents, 27 victims [21].

For the section of the road network – Lubinska Str. – from the intersection with Vyhovskoho Str. to Okruzhna Str., according to the method [28], the socio-economic losses from the road accidents were determined. For the accepted values based on direct and indirect economic losses calculation, the sum of social and economic losses from road accidents will make 3729842.7 UAH/year.

Using the model to determine the estimated number of accidents after changes in traffic speeds, the estimated number of road accidents of this type and the total number of dead or injured in these events were determined. For example, the quantitative indicators for the studied street were determined by reducing the speed of traffic from 40 to 35 km/h (for a speed of 40 km/h: road accidents with fatalities – 6 accidents, 6 deaths; road accidents with fatal and severe injuries – 8 accidents, 8 victims; road accidents with injuries (all) – 39 accidents, 27 victims) [25], and for a speed of 35 km / h:

– accidents with the dead

$$N_1 = \left(\frac{35}{40}\right)^4 6 = 3.52 \approx 4\,\textit{events};$$

– accidents with fatal and severe injuries

$$N_2 = \left(\frac{35}{40}\right)^3 8 = 5.36 \approx 5\,\textit{events};$$

– accidents with injuries (all)

$$N_3 = \left(\frac{35}{40}\right)^2 27 = 20.67 \approx 21\,\textit{events}.$$

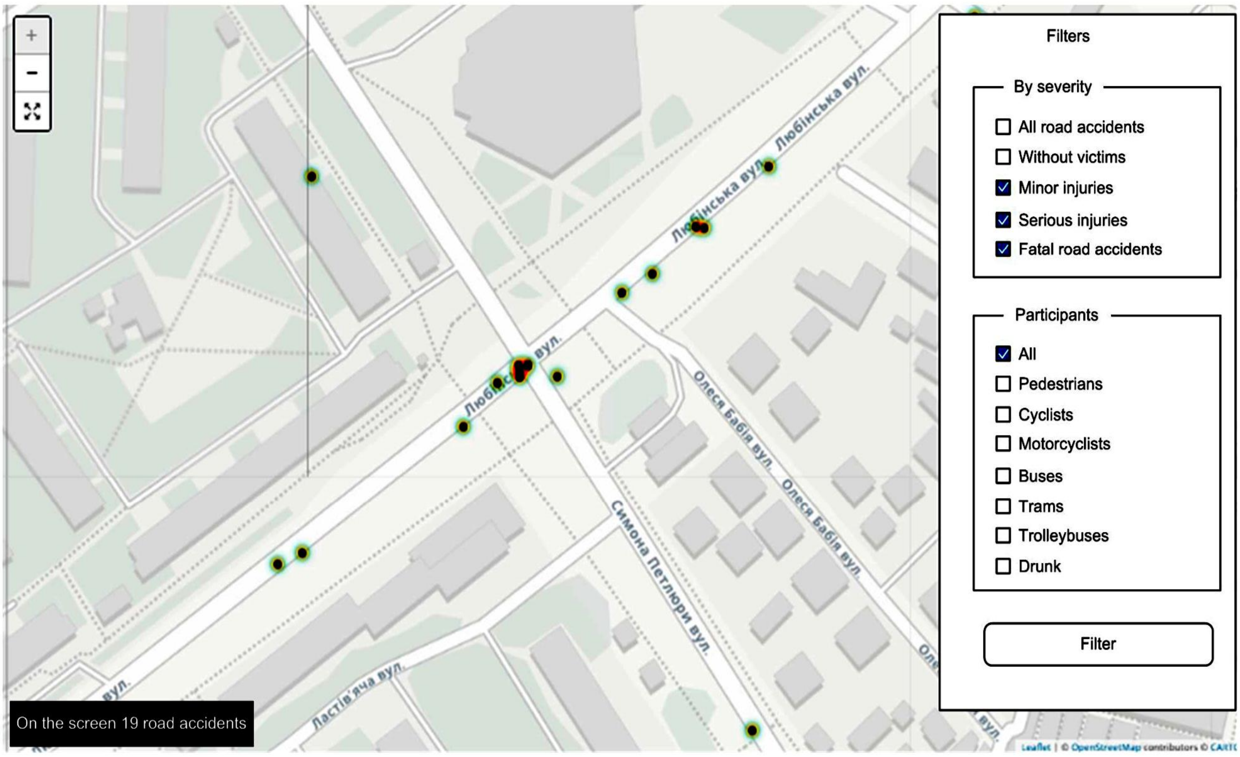

Fig. 4. A fragment of the view of the accident map in the investigated section of Lubinska Str., Lviv, indicating the type and location of the accident

Calculations show that if the traffic speed on the investigated section of the road is reduced by 5 km/h, the number of road accidents with fatalities will decrease by 41.3 %, and the number of road accidents with fatal and severe injuries will decrease reduce by 23 %. The number of road accidents with injuries will decrease by 23.5 %.

In order to assess the reduction of road traffic hazards for the given section of the road by minimizing costs for the three main components, the assessment of socio-economic losses for each of the groups of components and their amount was estimated using a typical method of improving the safety of road network – limiting the maximum allowable speed of traffic flow. Based on the obtained results, graphs of changes in losses from noise, exhaust fumes emissions and road accidents were constructed (Fig. 5).

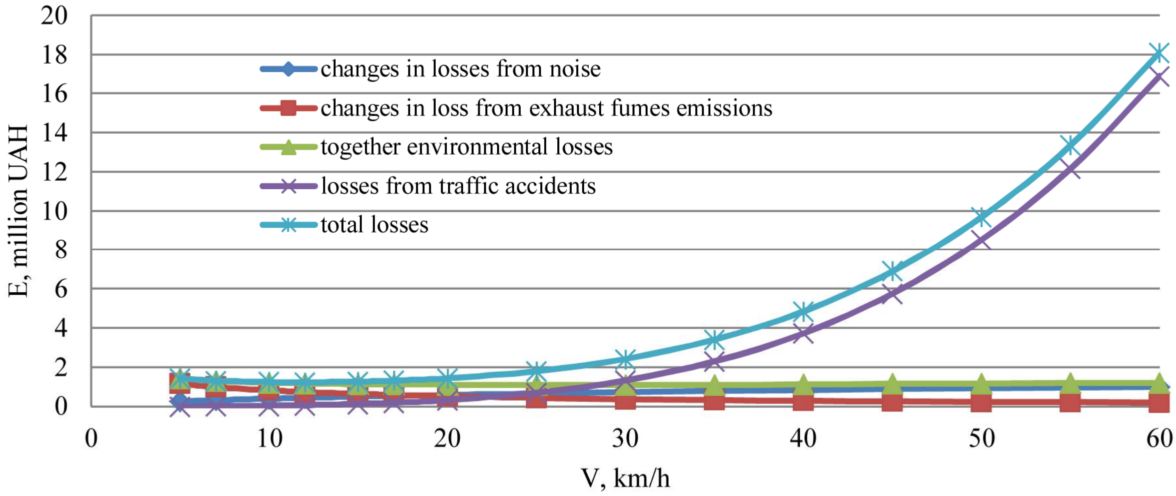

Fig. 5. Change of the economic dangers of road transport of the section of Lubinska Str. in Lviv from noise, exhaust emissions and road accidents depending on the speed of traffic

Special attention is paid to the speed range of traffic flow – 5–35 km/h (Fig. 6) because it is at this speed range, there are two minimums. It is made to qualitatively analyze and find the minimum hazards of road transport for each group of components.

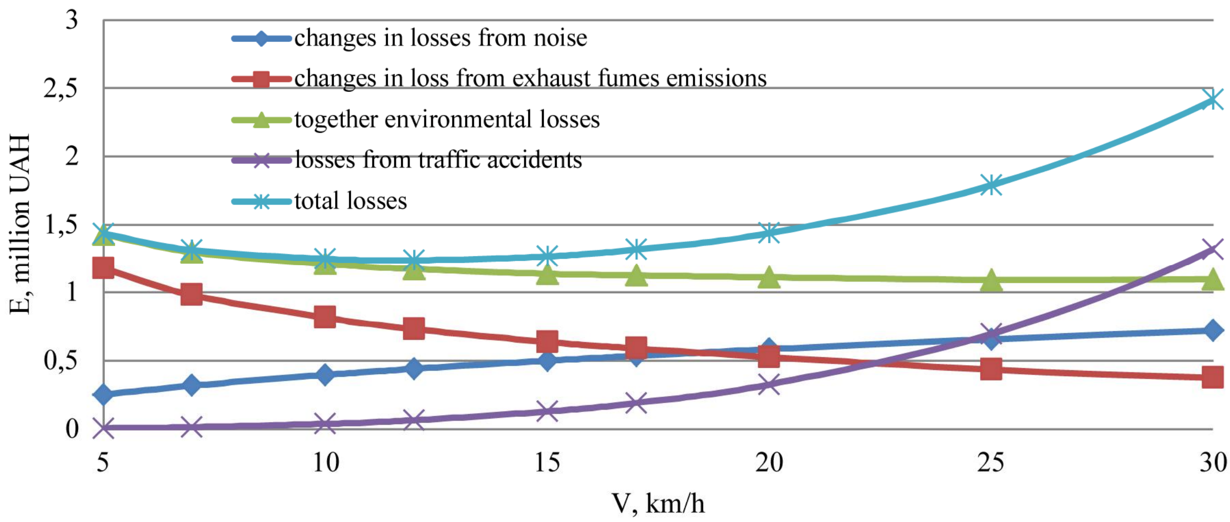

Fig. 6. Change of economic hazards of road transport of the section of Lubinska Str. in Lviv from noise, exhaust fumes emissions and road accidents depending on the speed of traffic flow (for the range 5–35 km/h)

First, in the range of speeds of 25–35 km/h, there is a zone of minimal environmental losses, in which the value of environmental losses from the impact of traffic flow is in the range of 1093–1110 thousand UAH in a year. At such speed values, the noise load level does not significantly reduce the efficiency of the traffic flow due to the reduction of emissions of toxic components from the exhaust gases of car engines. As the speed of traffic flow increases, the increase in the impact of noise load causes an increase in environmental losses, significantly outweighing the harmful effects of exhaust emissions.

The second range of the minimum is observed for the total hazards of road transport in the range of speeds of 10–15 km/h, respectively 1250–1267 thousand UAH in a year. At such values of traffic flow speeds on a given section of Lubinska Str. in Lviv, there will be minimal hazards of road transport (actions from noise, exhaust emissions and road accidents).

5. CONCLUSIONS

Today, when implementing any measures to improve the road network or restrictive measures to limit the maximum speed on sections of roads, it is necessary to assess the hazards of road transport by minimizing costs, taking into account environmental safety indicators and reducing road accidents rate at the site of improvement.

The developed model for determining the hazards of road transport allows taking into account environmental, social and even economic components in terms of priorities. They are designed to reduce both the negative impact of transport on the environment and ensure the smoothness of the adoption of improvements. Moreover, changing one of the factors inevitably causes a shift in the rest and the search for a minimum damage value. It makes it possible to find rational solutions to both the problems of improving the organization of road traffic and the introduction of prohibitions or restrictions, such as limiting the age of the vehicle or banning the movement of cars with diesel engines.

According to the results of the calculations, a minimum from the environmental hazards of road transport was established separately for the section of Lubinska Str. in the city of Lviv – it is 1093 thousand UAH per year for the value of the traffic flow speed of 25 km/h. The minimum for the total hazards of road transport was determined separately, taking into account the possibility of road accident occurrence, which, for this street per year for a speed of 12 km/h, will be 1239 thousand UAH.

The obtained results will be further used to develop a mathematical model of the functioning of urban transport systems.

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КОМПЛЕКСНА ОЦІНКА НЕБЕЗПЕКИ АВТОМОБІЛЬНОГО ТРАНСПОРТУ

Анотація. *У роботі запропоновано проводити оцінювання небезпек автомобільного транспорту за допомогою мінімізації негативного впливу за трьома основними компонентами: впливу зміни викидів токсичних компонентів забруднюючих речовин з відпрацьованими газами двигунів автомобілів, зміни шумового забруднення довкілля та зміни кількості дорожньо-транспортних пригод. Обґрунтовано методику визначення еквівалентних збитків, які буде завдано у результаті викиду умовної тонни токсичних компонентів забруднюючих* *речовин з відпрацьованими газами двигунів автомобілів та впливу шумового забруднення довкілля на три групи споживачів – водіїв та пасажирів, пішоходів та мешканців прилеглих територій. Особливу увагу присвячено визначенню еквіваленту збитків через дорожньо-транспортні пригоди із потерпілими чи загиблими.*

Для прикладу проведено дослідження визначення зміни екологічних небезпек автомобільного транспорту для частини вулиці Любінської у місті Львів залежно від основного показника транспортного потоку – швидкості руху транспорту. Встановлено, що для за швидкості транспортного потоку 25 км/год мінімальна екологічна шкода становитиме 1093 тис. грн на рік, а мінімум сумарних небезпек автомобільного транспорту з урахуванням можливості виникнення ДТП за швидкості 12 км/год становитиме 1239 тис. грн на рік.

За допомогою отриманої моделі можна провести визначення суми небезпек від автомобільного транспорту, які дозволяють враховувати екологічну, соціальну і економічну складові при дослідженні рівнів створюваного негативного впливу транспорту на довкілля та забезпечити мінімальні показники аварійності на досліджуваній ділянці вулично-дорожньої мережі міст. Особливо корисним буде проведення попередніх теоретичних досліджень для пошуку раціональних рішень при застосуванні схем удосконалення організації дорожнього руху.

Ключові слова: *вулично-дорожня мережа, відпрацьовані гази двигунів автомобілів, шум транспортних потоків, викиди шкідливих компонентів, небезпеки автомобільного транспорту, питомі втрати, швидкість руху, дорожньо-транспортні пригоди, соціально-економічні втрати.*