РОЗДІЛ 1

Економіка природокористування і еколого-економічні проблеми

Complex Solution of Ecological and Economic Problems of Traffic Jams

Oleksandr M. Matsenko[i], *Yaroslav S. Kovalev*[ii], *Olena M. Tkachenko*[iii], *Yaroslava V. Chorna*[iv]

The article explores the congestion level in traffic of motor vehicles and its negative environmental and economic consequences in case of Kiev. The amount of pollution from traffic jams in Kiev and the number of vehicles which got into them in 2009-2018 is analyzed. The loss of earnings on the side of automobile owners from their standby are calculated with corresponding quantitative expressions found and described. For the course of the research, the methods of system-structural and comparative analysis were used for analyzing the environmental and economic problems of modern automobile systems; methods of formal logical analysis were used for substantiating the innovative infrastructure of transport routes. Separately economic and statistical methods were used in the study for trends development, structure analysis, and estimation of the influence of road congestion on the environmental and economic sphere. Pearson test has indicated a close relationship between the number of cars in Kiev and the number of values from traffic jams in environmental and economic sphere. Solutions to this problem are offered in forms of automated traffic control systems, improvisation of organizational and technical methods for the distribution of traffic flows over time, namely reverse traffic, road junctions, smart traffic lights, road extension, and the transition to alternative modes of transport. In all countries of the world there are new research methods that affect pollutants from motor vehicles. It is proved that they are forced by the recipients. In addition, landscaping can improve landscape design, reduce greenhouse gas emissions, surface water runoff and noise pollution. In this regard the policy implication of the research are aimed to eliminate the negative consequences from the use of vehicles during traffic jams, and the necessary number of trees for planting in Kiev is calculated.

Keywords: motor transport, congestion, traffic jam, motor vehicle, greening, compensation effect, lost profits, losses.

УДК [001.895:658.589]+[339.138:658] *JEL Codes*: Q51, R11, R4, C2

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Introduction. Every day billions of people use the services of motor vehicles, which are the ultimate consumer good in ensuring the communications of society. The intensification of the processes of implementing European and world standards into the road transport system of Ukraine remains the foremost goal of the progress of the road transport complex of Ukraine for at least the next ten years. However, the development of effective communications, especially in large cities of Ukraine, is particularly acute hampered by the problem of traffic jams. In addition, the problem of environmental and economic losses caused by traffic congestion, which requires an early resolution, is now becoming especially acute and important. In this scientific work, various types of losses and lost profits from traffic jams are estimated and ways to solve the congestion of transport routes and reduce their environmental impact are given, that indicates the relevance of the study**.**

Analysis of the recent publications. A lot of works by O. Balatsky, V. Blagi, M. Burmaki, V. Dikan, V. Gizhevsky, M. Govorushchenko, D. Gorovoy, K. Gorovoy, Yu. Gutarevich, L. Hens [1], L. Melnyk [2, 3], O. Matsenko [4] were devoted to environmental and economic optimization of transport systems of Ukraine. However, the question of the negative consequences of the effects of vehicle emissions and the load of these systems as a whole remain unanswered.

The purpose of the work is to consider the environmental and economic aspect of the impact of traffic jams and motor vehicle emissions in Ukraine and to find effective ways to solve this problem. The goal is realized by setting the following tasks:

- to determine the environmental and economic problems of traffic jams in urban areas;
- to assess the environmental and economic consequences of emissions and traffic congestion;
- to propose methods to reduce the effects of emissions and congestion on motorways.

Research results. The effective functioning of motor transport systems is one of the conditions for the effectiveness of the modern economy. According to the Ministry of Infrastructure of Ukraine for 2018, the automobile transport system has more than 9.2 million vehicles, including: 6.9 million cars; 250 thousand buses; 1300000 trucks; more than 840 thousand units of motor vehicles.

The number of cars per 1000 citizens has amounted to 219 cars in 2018, although in 2016 this figure was at the level of 202 cars. It seen that there is a positive trend towards an increase in the number of vehicles in Ukraine. The most motorized city is Kyiv. In the capital of Ukraine in 2018 there were 364 cars per 1000 inhabitants. Kyiv region does significantly lags behind the capital having 276 cars per 1000 citizens. The next city is Odessa, Kharkov, Rivne and Volyn regions.

The network of public roads is divided into roads of national importance – 53.0 thousand km and local roads – 117.9 thousand km [5]. The structure of public road complexes is shown in figure 1.

Roads with improved types of pavement (cement concrete, asphalt concrete, black roads) account for 82 % of the total length of paved roads, other paths with transitional types (white gravel and gravel, pavement). The shares of public roads by type of pavement are presented in figure 2.

It is advisable to evaluate the influence of motor transport on air pollution in comparison with other sectors of the national economy. As can be seen from figure 3, road transport is now a leader among the main air pollutants.

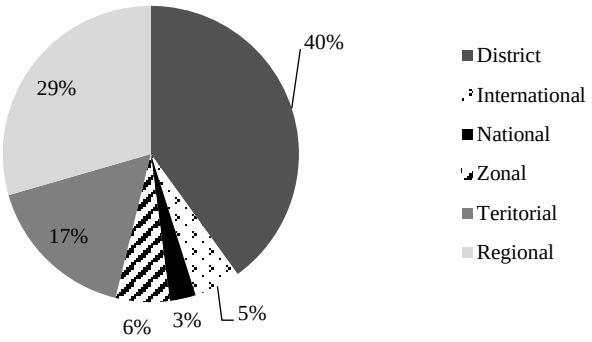

Figure 1. The structure of the network of public roads in Ukraine in 2018

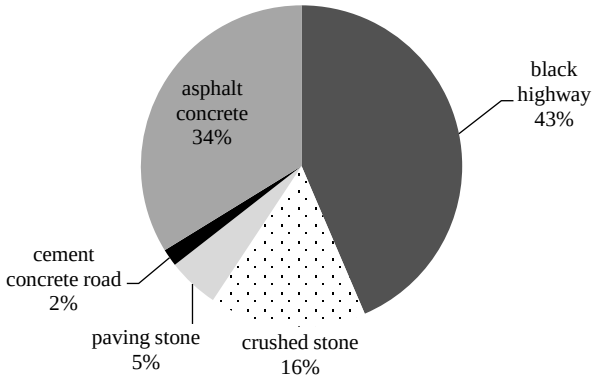

Figure 2. Distribution of public roads by type of pavement in Ukraine in 2018

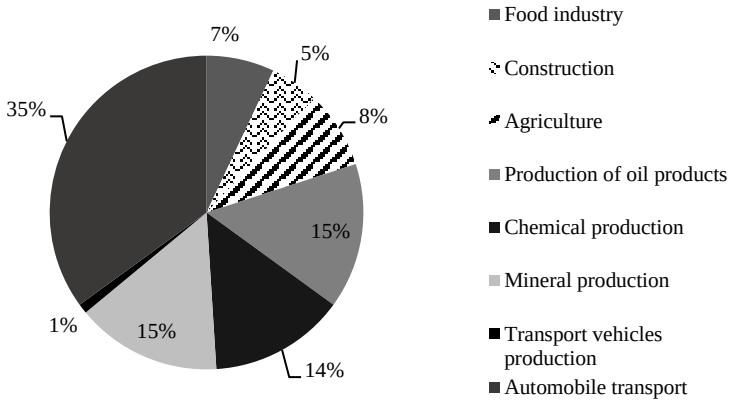

Figure 3. Emissions of pollutants into the atmosphere as a result of the activities of the main sectors of the national economy

Based on the analysis of these data, a tendency to increase the number of vehicles in Ukraine is seen [6]. In addition, each year there is growth in the number of paved roads is disproportionately small (according to the State Statistics Service of Ukraine) [7]. Currently, there is a big problem of congestion in Ukraine's transport routes. At the global level, the transport sector is also characterized by the problem of high congestion. Almost every day, every large city or even country suffers significantly from financial losses caused by vehicle downtime [8]. For example, table 1 shows some of these countries and their loses from traffic congestion.

Table 1

Economic losses from traffic congestion in different territories or countries for 2018 [9]

Area	**Losses, bln. dollars**
USA	305
UK	52,01
NYC	33,7
Los Angeles	19,2
Manila	18,615
Bangladesh	11,4
San Francisco	10,6
Atlanta	7,1
Jakarta	5
Dhaka	4,463
Greater Toronto and Hamilton Area (GTHA)	3,3

As already mentioned, every year the number of cars in Ukraine is growing. Therefore, the problem of traffic congestion is becoming increasingly acute. Considering the most pressing problems caused by traffic congestion, one can find the most important ones. Firstly, traffic congestion is a delay, which leads to new problems. In the morning additional stress occurs, caused by traffic jams that can delay people from working, and leads to a decrease in the productivity of various enterprises (so called "Road rage") [10]. Secondly, stopping and starting the car causes more fuel combustion than high speed on an open road, and this in turn contributes to the amount of emissions by vehicles. Acoustic (noise) pollution on central highways is another negative consequence of the impact of vehicles [11]. The next equally important issue is the delay in emergency services due to traffic jams. There is a close interconnection of all these problems among themselves, in which it is even difficult to detect the first launching cause. This situation is reminiscent of the butterfly effect, in which problems arise on a global scale from small traffic jams.

Traffic congestion is an urgent problem in the urban transport system. It has a great influence on the environmental situation in cities. Harmful substances, during the operation of vehicles, enter the air with exhaust gases, fumes from the fuel systems, as well as during refueling of the vehicle. Emissions of carbon oxides (carbon dioxide and carbon monoxide) are also affected by the road surface and the mode and speed of the car. For example, if you increase the speed of a car and sharply decrease it during braking, then the amount of carbon oxides in exhaust gases increases by 8 times. The amount of hazardous gases emitted by automobiles is mainly determined by the fuel consumption of automobiles. A company INRIX has determined that during traffic jams, cars per 1 hour spent consume an additional 0.8 liters of gasoline or 0.6 liters of diesel [12].

In the course of the study, it is analyzed the number of cars in Kyiv and emissions from traffic jams in the capital of Ukraine in 2009-2018 (Table 2).

Table 2

Statistical data for the study [13]

Years	Emissions from traffics in Kyiv, t							Automobiles in Kyiv, thousand units
	CO	Hydrocarbons	Nitrogen oxides	Sulfuric acid anhydride	Aldehydes	Soot	Plumbum	
2009	6064	340	407	117	22	71	7	906
2010	6312	354	424	122	23	74	7	936
2011	6569	369	441	127	23	77	7	951
2012	6838	384	459	132	24	80	8	1026
2013	7117	399	478	138	25	84	8	1064
2014	7407	415	497	143	26	87	8	1055
2015	7709	432	518	149	28	91	9	1048
2016	8024	450	539	155	29	94	9	1051
2017	8352	468	561	161	30	98	9	1052
2018	8692	488	584	168	31	102	10	1060

Using STATISTICA software, the Pearson correlation coefficient was calculated. It is 0.82, which indicates a high correlation between the increase in traffic jams in Kyiv and the number of cars in the Ukrainian capital. The program also determines the regression coefficient b for the seven major emissions from motor vehicles, which shows how much each emission increased when the vehicles were increased by 1000 pieces (Table 3).

Table 3

The regression coefficient *b* for the seven major vehicle emissions

Emissions	CO	Hydrocarbons	Nitrogen oxides	Sulfuric acid anhydride	Aldehydes	Soot	Plumbum
b	12,21	0,685	0,82	0,236	0,0436	0,1436	0,0137

Analyzing data, the following could be stated: in Kyiv, with an increase of 1000 cars, carbon monoxide emissions increased on average by 12.21 tons, hydrocarbons by 0.685 tons, nitrogen oxides by 0.82 tons, sulfuric anhydrides by 0.236 tons, aldehydes by 0.0436 tons, soot emissions by 0.1436 tons, and lead by 0.0137 tons.

According to the TomTom Traffic Index, in 2018 Kyiv took 13th place in the ranking of world cities in terms of traffic congestion. The value of this level reached 46 %, which is 2 % more than in the previous year. Thus, Kyiv "overtook" Los Angeles and Tokyo, which improved their performance and were in 24-25 places, respectively [14].

According to the National Transport University of Ukraine, Kyiv residents spend 350 hours a year in traffic jams. Based on available data (the costs of certain types of fuel (gasoline, diesel) the annual amount of time spent in traffic jams, the average hourly wage in Kyiv) it is possible to calculate the undesirable costs from motor cars and their lost opportunities (alternative benefits) (Table 4).

Table 4

Financial losses for one motor car per year according to 2018

The monetary expression of losses from traffic jams depending on fuel per 1 motorist				
Fuel	Time spent in jams, hours/year	1 hour expenditure in jams, liters	Cost UAH/1 liter	Total, UAH
Gasoline	350	0,8	33,2	9296
Diesel	350	0,6	31,7	6657

In addition to these explicit losses, it is calculated the implicit costs, e.g. alternative benefits. As already mentioned, every year residents of the capital spend an average of 350 hours useless, idle in traffic jams. Let's draw an analogy with the average hourly wage in Kyiv, which in 2018 was 81 UAH. Thus, an easy mathematical calculation will get:

Lost profit = 81 * 350 = 28350 UAH / year per one person.

Thus, in the work it is proposed several solutions for the problem of traffic jams. The first and urgent step in solving the problem of traffic jams in Ukraine is the implementation of an automated traffic control system. In general, the subsystems of the city ATCS can be represented as a combination of road telematics devices, controllers and workstations (AWS) included in the data exchange network with the organization of central and local control centers, depending on the density and intensity of traffic. For digital monitoring and cloud management, the FANSCI system is proposed [15]. Secondly, it is necessary to clean up the parking lot. It's no secret that often the sides of the streets are occupied by parked cars. Sometimes drivers leave cars, blocking two lanes. Another aspect is the construction of intercepting parking lots at the entrances to the city).

To solve the problem of traffic congestion, some organizational and technical methods for traffic flows have to be created, namely reverse traffic, road junctions, smart traffic lights, and widening of roads. The EU experience shows that the way to satisfy the need for private cars is wrong, and it is needed to learn more about other, safer modes of transport, and use them. After all, alternative transport (bicycle, rollers, gyro scooter, segway) can not only solves the problems of air pollution and noise, but also improves the quality of life in the city.

The significant impact of traffic emissions on urban populations around the world has motivated the researchers to reduce the impact of these pollutants. So, it has been proven that planting trees between roads and houses reduces the amount of pollution that people experience. According to 2018, more than 10 thousand tons of pollutants got into the air basin of Kyiv during traffic jams. This problem can be solved by planting a sufficient number of green spaces. Poplar is recognized as a “champion” among trees, not only for air purification, but also for oxygenation. It is known that one poplar aged 25-30 years in 5 months from May to September absorbs 7 times more harmful emissions than any other tree. Over a year, such a single tree can absorb and retain up to 26 kg of emissions of hazardous substances into the air [16]. It is calculated how many trees need to be planted in Kyiv in order to compensate for emissions from traffic congestion in 2018: 10074596.5 / 26 = 387485 (poplars).

Conclusions. Analyzing all of the above, one can conclude that the number of cars is growing every year, which leads to an increase in traffic jams. They pose a number of new problems, such as environmental pollution and the economic loss of downtime. The largest negative impact is experienced by large cities, in particular Kyiv.

The study found that the increase in emissions in traffic jams depends on 82 % of the growth of the vehicle fleet in Kyiv, and in addition to the effects of hazardous emissions from vehicles, people experience noise discomfort.

For 2018, one person loses 350 hours in traffic jams in Kyiv. Spending additional gasoline, drivers lose 9296 UAH, and diesel drivers – 6657 UAH. Based on the average hourly wage in Kyiv, the lost alternative benefits is amounted to UAH 28350 per person per year.

One way to solve the problem of traffic jams is to introduce an automated traffic control system. For digital monitoring and cloud management, the FANSCI system is offered.

Another aspect is the construction of intercepting parking lots at the entrances to the city. To solve the problem of traffic congestion, some organizational and technical methods for distributing of traffic flows over time have to be created, namely reverse traffic, road junctions, smart traffic lights, and widening of roads. And the transition to alternative transport (bicycle, rollers, gyro scooter, segway) not only solves the problems of air pollution and noise, but also improves the quality of life in the city.

It has also been proven that planting trees between roads and houses reduces the amount of pollution. To compensate for emissions from traffic congestion in the capital of Ukraine, 387,485 poplars must be planted.

Thus, the urban transport system can be created through an integrated complex planning approach, taking into consideration all types of transport in cities and suburbs.

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Комплексное решение эколого-экономических проблем автотранспортных пробок

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В статье проанализирован уровень загруженности автотранспортных потоков и их негативные последствия в г. Киев. Исследовано количество выбросов от пробок и количество авто в г. Киев, которые попадают в них, по 2009-2018 гг., посчитано упущенные выгоды от простоев автомобилистов, найдено их количественное выражение. В ходе исследования была использована методика системно-структурного и сравнительного анализа - при анализе эколого-экономических проблем современных автотранспортных систем; методы формально-логического анализа - при формировании методов внедрения инновационной инфраструктуры автотранспортных путей, определении направлений уменьшения негативных воздействий заторов экономико-статистические методы – при исследовании тенденций развития и структуры влияния загруженности автодорог на эколого-экономическую сферу. Как пути решения данной проблемы предложено учета розы ветров при архитектурном планировании г. Киев, применения автоматизированных систем управления дорожным движением, имплементация организационно-технических методов распределения автотранспортных потоков во времени, а именно: реверсивное движение, дорожные развязки, «умные» светофоры, расширение дорог, а также переход на альтернативные виды транспорта. Значительное влияние выбросов от дорожного движения на городское население во всем мире мотивировал нас на исследование методов уменьшения влияния этих загрязняющих веществ. Так, доказано, что посадка деревьев между автомобильными дорогами и домами уменьшает количество загрязнения, которому подвергаются люди. Кроме качества воздуха и общих преимуществ для

здоровья, озеленение может улучшить эстетику, уменьшить выбросы парниковых газов, контролировать сток поверхностных вод и уменьшить шумовое загрязнение. Поэтому для нивелирования негативных последствий от выбросов автотранспорта во время пробок рассчитано необходимое количество деревьев для посадки в г. Киев.

Ключевые слова: автотранспорт, загруженность, пробка, автотранспортное средство, экологизация, компенсационный эффект, упущенные выгоды, убыток.

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Комплексне вирішення еколого-економічних проблем автотранспортних заторів

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У статті проаналізовано рівень завантаженості автотранспортних потоків та його негативні наслідки в м. Київ. Досліджено кількість викидів від заторів та кількість авто в м. Київ, які потрапляють в них, за 2009-2018 рр., пораховано упущені вигоди від простоїв автомобілістів, знайдено їх кількісне вираження. В ході дослідження була використана методика системно-структурного і порівняльного аналізу – при аналізі еколого-економічних проблем сучасних автотранспортних систем; методи формально-логічного аналізу – при формуванні методів впровадження інноваційної інфраструктури автотранспортних шляхів, визначенні напрямів зменшення негативних впливів заторів; економіко-статистичні методи – при дослідженні тенденцій розвитку та структури впливу завантаженості автодоріг на еколого-економічну сферу. Як шляхи вирішення даної проблеми запропоновано врахування рози вітрів при архітектурному плануванні м. Київ, застосування автоматизованих систем управління дорожнім рухом, імплементація організаційно-технічних методів розподілу автотранспортних потоків у часі, а саме: реверсивний рух, дорожні розв'язки, «розумні» світлофори, розширення доріг, а також перехід на альтернативні види транспорту. Значний вплив викидів від дорожнього руху на міське населення у всьому світі мотивував нас на дослідження методів зменшення впливу цих забруднюючих речовин. Так, доведено, що посадка дерев між автомобільними дорогами та будинками зменшує кількість забруднення, якому

піддаються люди. Окрім якості повітря та загальних переваг для здоров'я, озеленення доріг може покращити естетику, зменшити викиди парникових газів, контролювати стік поверхневих вод та зменшити шумове забруднення. Тому за для нівелювання негативних наслідків від викидів автотранспорту під час заторів розраховано необхідну кількість дерев для посадки у м. Київ.

Ключові слова: автотранспорт, завантаженість, затор, автотранспортний засіб, екологізація, компенсаційний ефект, упущені вигоди, збитки.

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