https://doi.org/10.33271/nvngu/2022-1/076

O. Chukurna[1],
orcid.org/0000-0001-9285-7068,
V. Nitsenko[2],
orcid.org/0000-0002-2185-0341,
N. Tyukhtenko[3],
orcid.org/0000-0003-4634-9139,
O. Lomonosova[4],
orcid.org/0000-0002-1007-3786,
Z. Zhartay[5],
orcid.org/0000-0002-4676-4140,
V. Dobrovolskyi[1],
orcid.org/0000-0002-9388-9528

1 – Odesa National Polytechnic University, Odesa, Ukraine
2 – SCIRE Foundation, Warsaw, the Republic of Poland, e-mail: vitaliinitsenko@gmail.com
3 – Kherson State University, Kherson, Ukraine
4 – Admiral Makarov National University of Shipbuilding, Kherson Branch, Kherson, Ukraine
5 – Buketov Karagandy University, Karagandy, the Republic of Kazakhstan

SUBSTANTIATION OF THE GREEN APPROACH IN THE FORMATION OF A SUSTAINABLE SYSTEM OF ECOLOGICAL LOGISTICS

Purpose. Development of a methodology for substantiating a green approach in the formation of a sustainable system of ecological logistics.

Methodology. In the research process the following general scientific and applied research methods were used: correlation analysis was used to determine the relationship between CO_2 emissions and consumption of major energy sources; regression analysis – to determine the main trends in CO_2 emissions for the main regions of the world; the methodology for calculating emissions from fuel combustion by road transport – for assessing CO_2 emissions by various modes of transport; the improved methodology for assessing gas emissions and calculating the CO_2 emission factor – when forming a ring route during the transportation of goods.

Findings. The work studies global trends in the dynamics of changes in carbon emissions by areas of activity. Trend forecasting models have been developed for changes in the dynamics of carbon emissions for the main industrial regions of the world. Using the correlation-regression analysis of the relationship between the increase in the dynamics of CO_2 emissions and the consumption of energy resources of the world in the context of the world's major industrial regions, significant relationships were found between carbon emissions and the consumption of major energy sources. The work provides a methodological approach to determining the level of carbon emissions from vehicles and accounting for the carbon emission factor in the formation of logistics routes and tariffs for road transport in the context of the formation of sustainable systems of ecological logistics. As part of the methodological approach implementation, CO_2 emissions for road transport were estimated and calculations were performed for different types of cars. It was proposed to include the carbon emission factor in the calculation of the tariff for road transport, which will make it possible to form target funds at enterprises as part of the creation of a sustainable system of environmental logistics.

Originality. The methodological approach has been substantiated to determining indicators of the sustainability of ecological logistics systems in the context of developing a methodology for calculating CO_2 emissions, which makes it possible to solve the problem of forming transport routes taking into account environmental requirements in the field of reducing CO_2 emissions by various modes of transport.

Practical value. The proposed methodological approach to calculating emissions from fuel combustion by road, including the assessment of CO_2 emissions and the calculation of the carbon emission factor when forming a ring route during the transportation of goods is recommended for use by scientists, specialists and practitioners in the field of green logistics.

Keywords: *logistics systems, automobile transport, CO_2 emissions, green logistics*

Introduction. The direction of ecological logistics in modern economic and social policy becomes especially relevant within the global world. Currently, there is no developed approach to taking into account CO_2 emissions in the environmental logistics system. Approaches to taking into account the environmental coefficient in the formation of tariffs for freight transportation and planning of logistics routes remain unformed.

International experience in CO_2 regulation is based on the application of mechanisms developed and enshrined in the Kyoto Protocols. The Kyoto Protocol is the only international mechanism for regulating CO_2 emissions, which is implemented through carbon crediting activities. It is supported by the UNFCCC, the only organization with a global mandate for the overall effectiveness of emission control systems. However, enforcement of hydrocarbon lending decisions also depends on national cooperation.

In general, the carbon credit system stimulates higher prices for loans sold by enterprises with large quotas. Since this mechanism was implemented in several stages, as a result, in more favorable conditions, there are companies that are located in developed countries. In addition, this mechanism is not transparent enough in terms of quota pricing and the use of funds received from the implementation of quotas.

An alternative approach to CO_2 emissions is to introduce an environmental tax. However, this practice is also quite different and does not always reflect the targeted approach to receiving and distributing funds received from such a tax.

The above approaches to the implementation of the practice of taking into account CO_2 emissions in the system of environmental logistics have certain shortcomings and contribute to the actualization of the development of a methodological approach to take into account the carbon emission factor in the calculation of tariffs and logistics routes. The implementation of such a methodological approach will make it possible to create targeted environmental funds at enterprises, which will be spent on technical modernization and the transition to alternative energy sources. The introduction of such a methodological approach will facilitate the transition of logistics companies to create a sustainable system of environmental logistics and the formation of green supply chains.

Literature review. The methodological basis of the research is mainly composed of the works by foreign and domestic researchers in this field, the main of which are the following: Averkina M. [1], Bazaluk O., et al. [2], Chukurna O., et al. [3], Jiménez J. M. and Vargas M. V. [4], Kostyshin A. and Tibilova L. [5], Wang D.-F., et al. [6], Solekah A., et al. [7], Vitor W., et al. [8], and others.

The concept of a sustainable logistics system is directly related to a sustainable development strategy. According to a United Nations report, sustainable development refers to development that meets the needs of the present without compromising the opportunities of future generations [9].

To achieve sustainable development goals such as industrialization, innovation and infrastructure, sustainable cities and communities, responsible consumption and production, and climate action, an appropriate logistics infrastructure is needed. Therefore, most of the scientific studies on this topic associate sustainable logistics systems with the presence of an environmental component, namely, those that provide for reducing the impact of logistics operations on the environment.

Most of scientists interpret sustainable logistics systems as taking into account ways to reduce the factors of their influence on the environment and ecology. In this context, most of the studies on sustainable logistics systems have been implemented.

Vitor W., et al. [8] understood sustainable logistics systems precisely as systems that include the analysis and promotion of sustainable procurement, sustainable transportation, sustainable packaging, ecological distribution, recycling, design and control of green supply chains.

As a sustainable logistics system, Wang D.-F., et al. [6] understood a system aimed at reducing the impact of logistics operations on the environment.

In her research, Averkina M. focused on the formation of green logistics systems that should be integrated into the city system. The author substantiates the functions of green logistics as a reversible closed cycle system. The essence of the concept of "green" logistics system was substantiated. Undoubtedly, the conceptual provisions of green urban logistics proposed by the author are relevant. However, the author did not propose methodological principles for the formation of green logistics systems [1].

Trushkina N. substantiated the system of theoretical provisions for the use of green logistics as a modern concept of transformation of the transport and logistics system in Ukraine. Using analytical data, the scientist studied the development of green investment and environmental technologies in Ukraine, carried out a theoretical generalization of the stages of development of the concept of green logistics and analyzed the existing categorical apparatus of this area of science. However, the author did not propose methodological tools for green logistics [10].

Such scientists as Bazaluk O., et al. investigated the problem of circular economy, part of which is environmental logistics. Scientists have proven that the reduction of CO_2 emissions is facilitated by an alternative energy source, namely the use of green methanol. The possibility of potential methanol production using recycled waste and wind energy is proved [2].

At present there is no unified approach to defining the concept of a sustainable logistics system in the concept of environmental logistics. In scientific works devoted to green logistics, there is no uniform approach to the definition of a sustainable logistics system in the context of this conception.

Unsolved aspects of the problem. The authors of this study propose a unified methodological approach to calculating CO_2 emissions and taking it into account in the tariff policy of transport companies, based on the extended analysis of scientific literature on this topic.

The purpose of the article is to develop a methodology for substantiating a green approach in the formation of a sustainable system of ecological logistics.

Methods. The method for calculating emissions from the combustion of fuel from road transport is divided into two parts: the estimation of carbon dioxide emissions and the estimation of emissions of other gases.

Estimation of CO_2 emissions is calculated based on the amount and type of fuel combustion and carbon content. The amount of oxidized carbon does not vary depending on the fuel combustion technology used. Estimation of emissions of other greenhouse gases is more complex because it depends on the type of car, fuel, vehicle performance characteristics, type of exhaust gas control technology.

The proposed methodological approach was based on the method for calculating emissions of pollutants and greenhouse gases into the air from vehicles [11] and the method for calculating greenhouse gas ejection (CO_2-equivalent) [12]. Also based on the approach declared in Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe [13], the authors have improved the methodology for calculating CO_2 emissions. The approach proposed by the authors was implemented in experimental measurements of carbon emissions by different types of cars.

In contrast to the existing approach, the authors took into account the recommendations of the EU directives on the calculation of total CO_2 ejection in units (tons/year) and added this indicator to the resulting formulas (1, 2 and 3).

Thus, the author's approach to improving the methodology for calculating carbon emissions from fuel combustion by road is based on the implementation of the following stages.

At the first stage, assessment approaches were identified, which will be used to calculate the main CO_2 emissions from the automotive sector, according to the following formula

$$\sum E = E^R \cdot E^{NR} \cdot E^{P.PM} \cdot E^P, \qquad (1)$$

where E is total CO_2 emissions in units (tons/year); E^R is total emissions while driving; E^{NR} is total emissions from non-regulation traffic; $E^{P.PM}$ is total emissions when placing the car in the parking lot; E^P is other ejection.

Based on the EU protocols [13, 14] on recommendations for the calculation of harmful emissions from cars, the formula takes the following form

$$E = E^R \cdot E^{NR} \cdot E^P. \qquad (2)$$

The calculation of carbon dioxide emissions from fuel combustion in internal combustion engines is recommended based on fuel types and engine types. Carbon dioxide emissions by this method are estimated as follows. First, the consumption of each type of fuel is estimated by type of transport (cars, trucks, buses, special vehicles). Then the total CO_2 ejection are estimated by multiplying the amount of fuel consumed by the emission factor for each type of fuel and type of transport by the formula

$$E = M \cdot K_1 \cdot CV \cdot K_2 \cdot 44/12, \qquad (3)$$

where M is actual fuel consumption per year (tons/year); K_1 is the oxidation factor of carbon in the fuel (shows the proportion of burned carbon); CV is calorific value (J/ton); K_2 is carbon emission factor (ton C/J); *44/12* is the coefficient for conversion of carbon C emissions into carbon dioxide CO_2.

Results. To estimate carbon dioxide emissions from the motor transport sector for different fuels (petrol, diesel, liquefied petroleum gas, compressed natural gas), regional conversion factors of burned fuel into CO_2 emissions were calculated (net calorific values, carbon ejection factors) [15, 16]. Calculations of coefficients for recalculation, presented in Table 1 [14], were performed on the composition of fuel and their physical characteristics on the basis of the following data sources: DSTU data of different types of fuel; reference data; data obtained from some oil and gas fields.

Emissions of harmful substances when placing the car in the parking lot was calculated using the following formula

$$E^{P \cdot PM} = E \cdot k_1 \cdot k_2 \cdot k_3, \qquad (4)$$

Table 1

Coefficients for conversion of burned fuel into CO_2 emissions for vehicles

Type of fuel	Heat net value *TNZ TJ*/ thousand tons	Carbon emission factor, K_2, mC/TJ	Fraction of oxidized carbon, K_1
Gasoline	44.21	19.13	0.995
Diesel fuel	43.02	19.98	0.995
LPG	47.17	17.91	0.990
Natural gas	34.78	15.04	0.995

where k_1 is the coefficient that depends on the engine generation (Euro-1, Euro-2, Euro-3, Euro-4 etc.); k_2 is the coefficient that depends on the type of fuel used; k_3 is the coefficient that depends on the engine capacity.

Each manufacturer receives an indicator of the average level of ejection of all products produced by the line of cars, rather than a single copy. For each car, whose CO_2 emissions exceed the average set level, 5 euros is paid in excess of 1 g/km, 15 euros – for exceeding 2 g/km, 25 euros – 3 g/km, and after exceeding 4 g/km each gram costs the manufacturer 95 euros. From 2019, each gram of excess cost 95 euros.

The standard level of CO_2 emissions depends on the curb weight and is calculated for each car by the formula

$$CO_2 = 130 \cdot a \cdot (M - M_0),$$

where M is the curb weight of the car in kilograms; M_0 = one thousand three hundred and seventy-two kg; $a = 0.0457$.

Each manufacturer can get a bonus if they reduce their carbon dioxide emissions to 7 g/km, provided they use innovative technologies in their cars.

Taking into account the requirements of environmental logistics is becoming a global trend and is used in the calculations of international transport corridors (Fig. 1) [14, 17]. In the European Union, the main mode of freight transport is road transport, which plays a significant role in generating CO_2 emissions. Statistics show a significant percentage of CO_2 emissions in Ukraine by type of activity. In general, the total share of emissions from transport is 33 %.

The study of approaches to assessing the impact of greenhouse gas emissions from energy activities, posed the problem of forming a methodology for estimating greenhouse gas emissions from fuel combustion by road and various industries. This issue has become especially relevant in the context of the implementation of new technologies in the implementation of Smart City and Clean City programs.

Road transport produces significant greenhouse gas emissions, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). According to the methodology of the Intergovernmental Panel on Climate Change (IPCC), road transport, as one of the sources of greenhouse gas emissions, is included in the module “Energy activities”, as greenhouse gas emissions from vehicles are associated with fuel combustion. When estimating greenhouse gas emissions, one can use national emission factors or default greenhouse gas emission factors proposed in the IPCC reference manual.

CO_2 emissions in the transport sector are attracting the attention of global organizations and are becoming a global problem for humanity in the context of sustainable development strategies, as they relate to the environmental sector. Statistics show that in 2019 the total amount of CO_2 emissions from fuel combustion decreased slightly (–0.2 %) due to a significant reduction in specific energy consumption (–2.1 % in 2019). This result was made possible mainly by the replacement of coal with gas and the growing share of renewable energy sources in the world energy balance [14].

The main reductions in emissions were observed in the United States (–2.4 %) and Europe (–3.9 %), where a significant reduction occurred in Germany, Poland, Great Britain, Spain and Turkey due to lower energy demand (in particular, in energy sector) due to the slowdown in economic growth, moderate temperatures and the substitution of fossil fuels in the energy sector (gas instead of coal and the growth of the share of renewable energy sources). However, according to the World Energy Bulletin, CO_2 emissions in Asia have started to rise again, but at a slower pace than in previous years. CO_2 emissions have been rising for the third year in a row in China (+2.8 %), where the policy of replacing coal with gas has softened, as well as in countries that produce coal and hydrocarbons (Russia, Australia, Iran, South Africa and Algeria).

Over the last 20 years, significant shocks have been made to reduce global CO_2 emissions (Fig. 2) [14]. If we compare these data with the beginning of the 2000s, the statistics show a significant increase in CO_2 emissions from all types and sources of energy and transport. Between 1990 and 2003, the OECD-ECMT region accounted for 71 % of the world’s transport CO_2 emissions. Moreover, the share of transport in CO_2 emissions increased in all regions of the world. Its highest level was observed in more developed OECD member countries in 2003 and amounted to 30 %.

According to the forecasts of the International Energy Agency, by 2030 there will be seen the world’s largest emissions from electricity and heat production. In contrast, in OECD countries, growth in this sector is declining, but remains significant in transport. However, by the end of the forecast period in the energy sector, a significant part of emissions is accounted for those by transport – 31 % of total CO_2 emissions from fuel combustion.

Statistics from the International Energy Agency show a trend of steady increase in CO_2 emissions worldwide for all activities, the largest share of which is occupied by the energy sector and transport.

The proportions of CO_2 emissions between transport services and other energy end-users vary considerably between

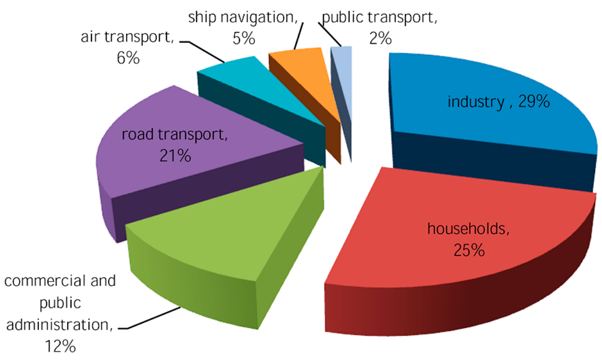

Fig. 1. Share of CO_2 *emissions from different activities in Ukraine*

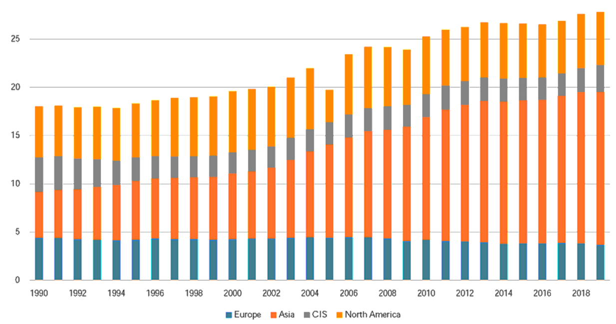

Fig. 2. The share of CO_2 *emissions by region of the world for the period 1990–2019*

countries, depending on the structure of the economy, the predominant industries and the efficiency with which energy is used by businesses and households. The structure of the economy of the European Union, in contrast to the economy of Ukraine, is dominated by services with relatively high energy efficiency in industry, the predominance of road transport in passenger and freight transport, the important role of sea and international air transport. That is why it is of scientific interest to evaluate the correlation between the increase in the dynamics of CO_2 emissions and the consumption of energy resources in the world in terms of large global industrial regions of the EU, CIS, Asia and North America.

According to the International Energy Agency, the most significant contribution to total CO_2 emissions is made by coal as an energy source. In the second place – oil and refined products and the third place is occupied by gas.

Correlation-regression analysis of the relationship between the increase in the dynamics of CO_2 emissions and energy consumption in the world in terms of large global industrial regions of the EU, CIS, Asia and North America allowed us to draw the following conclusions. The obtained results by regions turned out to have different correlation values. The results of correlation statistics are presented in Fig. 3 [14].

According to the results of the correlation analysis, the largest relationship between carbon emissions and consumption of major energy sources is observed in the industrial regions of the CIS and Asia. However, in the CIS region there is a clear correlation between all indicators, in Asia there is no relationship between carbon emissions and total electricity consumption.

The high correlation between carbon dioxide emissions and total electricity consumption in the CIS region is due to the large number of thermal power plants, which are large consumers of coal to generate electricity. This is due to the presence of major coal basins and proximity to the location of raw materials. Asia is a region where electricity is generated by nuclear power plants and alternative energy sources. However, both regions are industrialized, which explains the highest percentage of carbon dioxide emissions worldwide, namely in Asia. The region of North America ranks second in terms of carbon emissions, but a correlation analysis of the relationship between carbon emissions and other energy sources for this region shows a low level of correlation. This can be explained by most of the imports of major energy sources into the region. The data from global carbon statistics relative to the share of each region's contribution are presented in Fig. 4 [14].

According to world statistics, the first place in terms of the share of carbon dioxide emissions is occupied by the region of Asia (44 % of world carbon emissions), the second place is occupied by the region of South America (26 %), the region of Europe produces 19 % of all world emissions. The calculation of shares was carried out without taking into account the regions of Latin America, the Middle East and the Pacific Ocean.

There is also a high level of dependence between carbon dioxide emissions and consumption of petroleum products

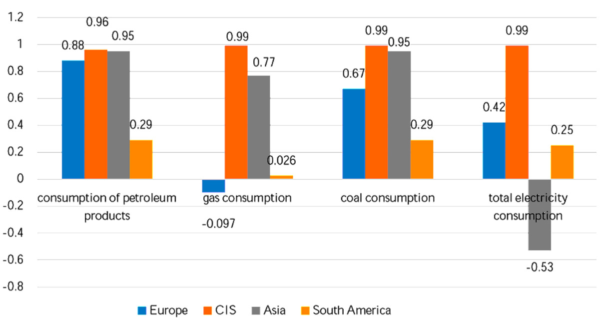

Fig. 3. Correlation statistics of the relationship between carbon dioxide emissions and consumption of major energy sources

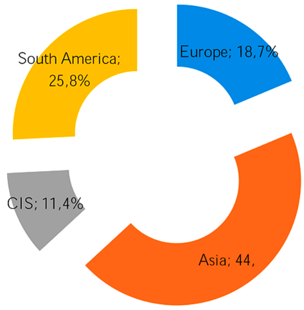

Fig. 4. Shares of contributions of each region of the world to total carbon dioxide emissions for the period 1990–2019

and coal in the European region. The general trend for almost all regions is a high level of dependence between carbon emissions and consumption of petroleum products and coal. This confirms the high impact of transport on increasing carbon emissions worldwide. These trends confirm the dynamics of increasing carbon emissions in Asia and the CIS. The European region and South America, on the other hand, show a declining trend in carbon emissions (Figs. 5–8).

The constructed regression equations have high indicators of reliability and adequacy of the trend and demonstrate the growth of carbon dioxide emissions in Asia and the CIS. This fact can be explained by the industrial development of these regions and the economic growth of China and Russia, which are the main consumers of energy resources in these regions.

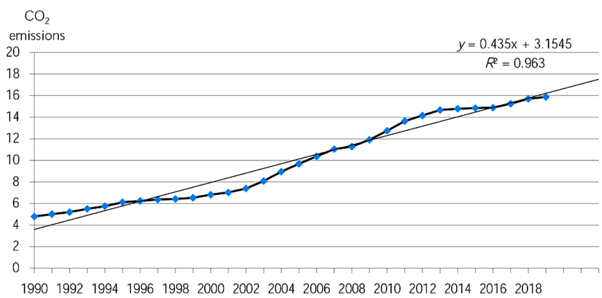

Fig. 5. Trend of CO_2 emissions for the Asian region

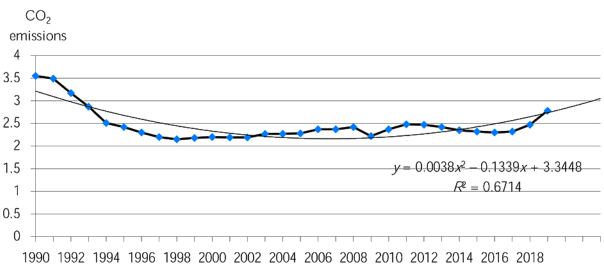

Fig. 6. Trend of CO_2 emissions for the CIS region

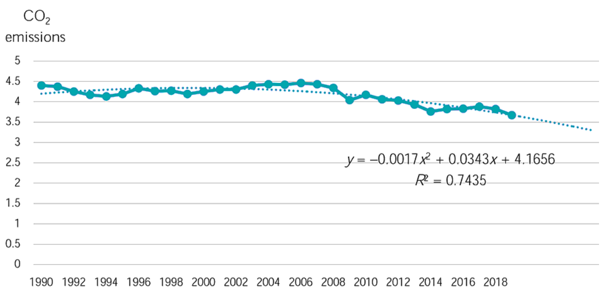

Fig. 7. Trend of CO_2 emissions for the European region

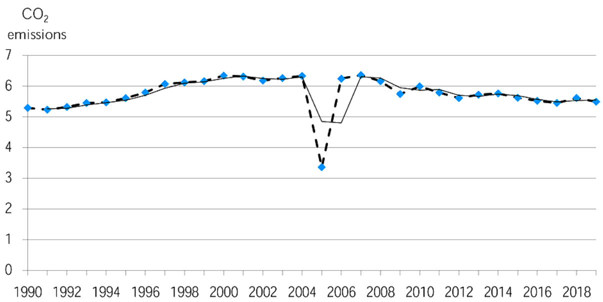

Fig. 8. CO_2 *emission trend for the South American region*

Forecasts built for the regions of Europe and South America show a decline, due to the introduction of environmental norms and standards in the countries of these regions.

Given the international influence on the formation of logistics chains involving different modes of transport, the role of environmental logistics, which aims to take into account environmental requirements for the construction of green supply chains, increases the relevance of developing methods for determining carbon emissions from vehicles. In addition, the challenges of the fourth industrial revolution raised the question of the formation of sustainable logistics systems such as "smart cities" or Smart City, in connection with which the problem of forming urban transport routes, taking into account the reduction of carbon emissions and also becomes relevant.

All these aspects brought to the fore the formation of methodological approaches to determining the level of carbon emissions from vehicles in the formation of logistics routes and sustainable logistics systems.

Emission calculations from vehicles are based on data on total fuel consumption. The specific heat of combustion and emission factors for each type of fuel were partially calculated taking into account the specifics of the fuel used.

With the help of the formed methodological approach to the estimation of CO_2 emissions for road transport, calculations were performed for different types of cars. The information for the calculations was taken from the official sources of car companies, the "online calculator" of the carbon footprint, as well as using the methodological approach presented above [18] (Fig. 9). As can be seen from the calculations, small cars have the largest amount of carbon emissions.

Below are graphs, separately for each car, showing what percentage of CO_2 it emits in different operating modes. All units will be presented in g/min.

The calculation of carbon emissions showed that all cars have high carbon emissions. When forming green supply chains and forming a general system of environmental logistics, the results obtained on the basis of a methodological approach to carbon emissions should be taken into account.

The second part of the technique involves adding a factor of carbon emissions in the formation of the ring route during transportation of goods.

Table 2

Total CO_2 emissions by type of car in different traffic conditions

Car brand	Renault Kangoo	BMW X5 Series	Audi A3	Toyota Yaris	Small class bus
In motion (g/km)	120	134	128	115	152
When parking (g/km)	24	35	25	20	300
In the automatic parking lot (g/km)	10	10	10	10	10

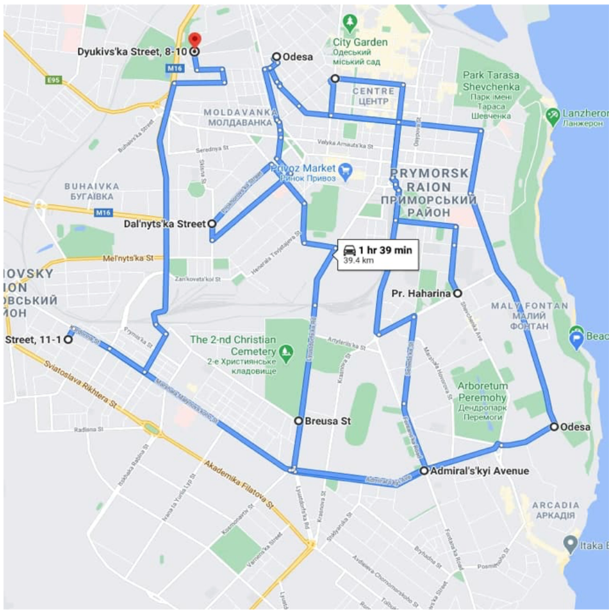

Fig. 9. The movement of a commercial vehicle along the route

From the data of the company Carbon footprint, and with the help of their Carbon Calculator [18], we will be able to calculate several car models, their damage to the environment and CO_2 emissions.

Personal transport.

From the database of the EU BMW X5 Series, E70 M A6, 2013, an average of 65 km per day emits 0.03 tons of CO_2.

0.03 tons: 65 km on EU 2013 BMW X5 Series E70 X5 M A6.

From the EU database Toyota Yaris 2016 1.5 VVT-I Auto travels an average of 65 km per day emits 0.01T CO_2.

0.01 tons: 65 km on EU 2016 TOYORA Yaris, 2016 1.5 VVT-I Auto – 16 alloys, 6AT.

From the EU Audi 2006 database, the A3 S 2.0 FSI emits an average of 84 km and emits 0.02T of CO_2. (The car works in the "Taxi" mode).

0.02 tons: 84 km on EU 2016 AUDI A3 S 2.0 FSI (150 PS), M6.

Commercial transport.

Renault Kangoo was chosen as an example for calculating the route of commercial vehicles. This car is used by many commercial companies, including logistics transport companies Meest Express, Nova Poshta LLC and others. This car has advantages due to its compactness, easy to operate and inexpensive to maintain. This brand of car has an engine with a volume of 1.2 to 1.9 liters, with a 50-liter tank.

We will calculate the formation of the ring logistics route with the addition of the emission factor of carbon dioxide, for the example, of the transport company LLC "Nova Poshta".

The car of the Nova Poshta company conditionally has to deliver 8 parcels a day to different addresses in Odesa on a ring route. For its route the car without traffic jams, on a flat road will pass 39.4 km. Fig. 9 presents the logistics route of the car.

According to the EU database, 2008 Renault Kangoo 1.5 Dci 84, m^5 travels an average of 39.4 km and emits 0.01 CO_2.

0.01 tons: 40 km on EU 2008 RENAULT Kangoo 1.5 dCi 84, M5.

Based on the international approach to setting the social price of CO_2 emissions, it is proposed to set the emission factor for carbon dioxide depending on the total amount of emissions for the year, which were made by the logistics company at social cost. The social cost of carbon offsets is tied to \$ 30 per tonne of emissions.

The social cost of carbon offsets under the EU Directives is tied to \$ 30 per tonne of emissions. However, this approach does not provide an economic justification for the cost of carbon emissions. With this in mind, the authors proposed a carbon emission factor, which is recommended to be taken into account when calculating transport tariffs. The method for calculating the carbon emission factor is based on the generally accepted economic approach to calculating the number of ton-kilometers performed in one working day [11], which was modified by the authors of the study.

Based on this, the carbon emission factor takes the following form

$$K_{CO_2} = \frac{E}{N_O} \cdot W_{rd}, \quad (5)$$

where K_{CO_2} is the coefficient of emission factor for carbon dioxide; E – is annual CO_2 emissions in units (tons/year); W_{rd} is the number of tonne-kilometers performed in one working day; N_O is the number of revolutions, which can be performed during operation on the ring route.

The proposed coefficient must be added when calculating the tariff for road transport. This approach provides an opportunity to form a trust fund for environmental logistics, which will be aimed at modernization and implementation of environmental technologies for green logistics in transport enterprises.

The proposed methodological approach is universal and can be used in the field of passenger transport in the implementation of "Smart City" programs within the framework of creating sustainable logistics systems. Moreover, a number of cities in the European Union are already implementing Smart City programs.

Quite an interesting infrastructure program has been implemented in many European cities, such as Budapest (Hungary). The essence of this program is that there are well-organized public transport systems throughout the city, which are controlled by an automated system. Most of the final metro stops are bus stations on the outskirts of the city.

Another program that is the result of the introduction of sustainable logistics systems is "Clean City". This program is under development and should be implemented in Germany soon. The program prohibits the entry of large-scale long-distance vehicles in large cities or restricts their travel schedule. This program will have a positive impact it will on the environment, but also have a positive impact on the condition of the road surface.

Conclusions. The problem of forming sustainable logistics systems in all functional areas of logistics is relevant for all countries. Harmonization of relations in the logistics sector in the context of the implementation of the strategy of sustainable development, posed the problem of forming sustainable logistics systems. That is why, in this study, the problem of CO_2 emissions in transport logistics systems, which aim to implement a strategy of sustainable development in the field of environmental logistics, was considered. The problem of high CO_2 emissions is inherent in the whole world. The European Union sets out its rules and conditions, which must be complied with by all trucking companies, in order to reduce emissions.

Today, the problem of carbon accounting in the system of environmental logistics is quite controversial and is regulated by two mechanisms: hydrocarbon loans and environmental tax. Both mechanisms are administrative and their implementation in practice depends on the international agreements and the tax system of each country. However, at the enterprise level there is no single approach to the methodology of accounting for carbon emissions in the formation of transport routes in logistics systems. Technological changes in the global economy and logistics stimulate the development of methods and tools aimed at using environmental principles and approaches also at the micro level. In addition, the problem of creating sustainable logistics systems within the concept of environmental logistics is particularly acute in large cities, which has influenced the active implementation of the EU program "Smart City". This also raises the issue of forming the principles and approaches of environmental logistics at the meso level.

The article examines global trends in the dynamics of changes in carbon emissions by industry. Trend forecast models of changes in the dynamics of carbon emissions by major industrial regions of the world have been developed. Correlation-regression analysis of the relationship between the increase in the dynamics of CO_2 emissions and the consumption of the world's energy resources in terms of large global industrial regions has revealed significant links between carbon emissions and consumption of major energy sources. The results show that the greatest relationship between carbon emissions and consumption of major energy sources is observed in the industrial regions of the CIS and Asia. However, according to statistics, the share of the CIS in total carbon emissions is insignificant, while the Asian region ranks first in the world in terms of carbon emissions.

The article forms a methodical approach to determining the level of carbon emissions from vehicles and taking into account the carbon emission factor in the formation of logistics routes and tariffs for road transport in the context of the formation of sustainable logistics systems. The methodological approach is based on the calculation of emissions from the combustion of fuel from road transport, which consists of estimating carbon dioxide emissions and estimating emissions of other gases and calculating the carbon emission factor in the formation of a ring route in the transportation of goods. As part of the implementation of the methodological approach, CO_2 emissions for road transport were estimated, calculations were performed for different types of cars. It is proposed to add the carbon emission factor to the calculation of the tariff on road transport, which will allow forming trust funds for environmental logistics at enterprises within the framework of creating a sustainable logistics system.

References.

1. Averkina, M. F. (2015). Features of formation of "green" logistics systems of cities of Ukraine. *Current economic problems, 1*(163), 215-219.

2. Bazaluk, O., Havrysh, V., & Nitsenko, V. (2021). Energy and Environmental Assessment of Straw Production for Power Generation. *E3S Web of Conferences, 228*, 01010. https://doi.org/10.1051/e3sconf/202122801010.

3. Chukurna, O., Pylchenko, A., & Dobrovolskyi, V. (2019). Ecological logistics: problems of formations of green supply chain. *Zeszyty naukowe, 11*, 103-118.

4. Jiménez, J. M., & Vargas, M. V. (2018). Models of environmental behavior in ecological economics: a literature review. *Estudios de Economía Aplicada, 36*(1), 309-316. https://doi.org/10.25115/eea.v36i1.2531.

5. Filyppova, S., Bovnegra, L., Chukurna, O., Vudvud, O., & Dobrovolskyi, V. (2021). Assessment of the Impact of Automatic Parking on Emissions of Harmful Substances in the Green Logistic System. *Lecture Notes in Networks and Systems, 233*, 815-822. https://doi.org/10.1007/978-3-030-75275-0_89.

6. Wang, D.-F., Dong, Q.-L., Peng, Z.-M., Khan, S., & Tarasov, A. (2018). The Green Logistics Impact on International Trade: Evidence from Developed and Developing Countries. *Sustainability, 10*, 2235. https://doi.org/10.3390/su10072235.

7. Solekah, N. A., Handriana, T., Usman, I., & Supriyanto, A. S. (2020). Green Marketing Tools, Supply Chain, Religiosity, Environmental Attitude and Green Purchase Behavior. *International Journal of Supply Chain Management, 9*(4), 371-377.

8. Martins, V. W. B., Anholon, R., Quelhas, O. L. G., & Leal Filho, W. (2019). Sustainable Practices in Logistics Systems: An Overview of Companies in Brazil. *Sustainability, 11*, 4140. https://doi.org/10.3390/su11154140.

9. UN. Official website (2021). Retrieved from https://www.un.org/sustainabledevelopment/ru.

10. Trushkina, N. V. (2019). Transformation of transport and logistics system in Ukraine on basis of green logistics. *Economic Bulletin of Donbass, 2*(56), 151-161. https://doi.org/10.12958/1817-3772-2019-2(56)-151-161.

11. *Methods for calculating emissions of pollutants and greenhouse gases into the air from vehicles* (n.d.). Retrieved from https://ukrstat.org/en/metod_polog/metod_doc/2008/452/metod.htm.
12. *Methodology for calculating greenhouse gas emissions* (CO_2 *equivalent*) (n.d.). Retrieved from https://sro150.ru/index.php/metodiki/371-metodika-rascheta-vybrosov-parnikovykh-gazov.
13. European Union Directive (2015). *2015/1480/EC of the European Parliament and of the Council of 28 August 2015 amending several annexes to Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council laying down the rules concerning reference methods, data validation and location of sampling points for the assessment of ambient air quality*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015L1480.
14. European Union Directive (2015). *2015/1513 of the European Parliament and of the Council of 9 September 2015 Amending Directive 98/70/EC Relating to the Quality of Petrol and Diesel Fuels and Amending Directive 2009/28/EC on the Promotion of the Use of Energy from Renewable Sources*. European Union: Brussels, Belgium.
15. *Impact of sea and river transport on the environment* (n.d.). Retrieved from https://spravochnick.ru/ekologiya/ekologicheskie_problemy_razlichnyh_vidov_transporta_na_okruzhayuschuyu_sredu/vozdeystvie_morskogo_i_rechnogo_transporta_na_okruzhayuschuyu_sredu/.
16. Ma, B. (2020). Value Shaping of Ecological Man: External Standard and Internal Idea. *Future Human Image, 13*, 57-65. https://doi.org/10.29202/fhi/13/6.
17. Havrysh, V., Nitsenko, V., Perevozova, I., Kulyk, T., & Vasylyk, O. (2021). Alternative Vehicle Fuels Management: Energy, Environmental and Economic Aspects. *In: Zaporozhets A. (eds). Advanced Energy Technologies and Systems I. Studies in Systems, Decision and Control*, *395*, 91-115. Springer, Cham. https://doi.org/10.1007/978-3-030-85746-2_5.
18. National Datasheets on GOs and Disclosure (n.d.). Retrieved from https://www.aib-net.org/facts/national-datasheets-gos-and-disclosure.
19. Statistical Yearbook of World Energy (2020). Retrieved from https://yearbook.enerdata.ru/co2-fuel-combustion/CO2-emissions-data-from-fuel-combustion.html.
20. State Statistics Service of Ukraine (2020). Retrieved from http://www.ukrstat.gov.ua.

Обґрунтування зеленого підходу при формуванні стійкої системи екологічної логістики

О. П. Чукурна[1], *В. С. Ніценко*[2], *Н. А. Тюхтенко*[3], *О. Е. Ломоносова*[4], *Ж. М. Жартай*[5], *В. В. Добровольський*[1]

1 – Національний університет «Одеська політехніка», м. Одеса, Україна
2 – Фонд SCIRE, м. Варшава, Республіка Польща, e-mail: vitaliinitsenko@gmail.com
3 – Херсонський державний університет, м. Херсон, Україна
4 – Херсонська філія Національного університету кораблебудування імені адмірала Макарова, м. Херсон, Україна
5 – Карагандинський університет імені академіка Є. О. Букетова, м. Караганда, Республіка Казахстан

Мета. Розроблення методики щодо обґрунтування зеленого підходу при формуванні стійкої системи екологічної логістики.

Методика. У процесі дослідження були використані такі загальнонаукові та спеціальні методи: кореляційний аналіз був використаний з метою визначення взаємозв'язку між викидами CO_2 і споживанням основних джерел енергії; регресійний аналіз – для визначення основних трендів викидів CO_2 для основних регіонів світу; методика розрахунку викидів від спалювання палива автомобільним транспортом – з метою оцінки емісії CO_2 різними видами транспорту; удосконалена методика оцінки емісії газів і розрахунок коефіцієнта викидів CO_2 – при формуванні кільцевого маршруту при транспортуванні вантажів.

Результати. У роботі проведене дослідження світових тенденцій щодо динаміки зміни викидів вуглецю за сферами діяльності. Розроблені трендові прогнозні моделі зміни динаміки викидів вуглецю за основними промисловими регіонами світу. За допомогою кореляційно-регресійного аналізу взаємозв'язку між збільшенням динаміки викидів CO_2 і споживанням енергетичних ресурсів світу в розрізі великих світових промислових регіонів, були виявлені значні зв'язки між викидами вуглецю та споживанням основних джерел енергії. У роботі сформовано методичний підхід щодо визначення рівня викидів вуглецю від транспортних засобів і врахування коефіцієнта емісії вуглецю при формуванні логістичних маршрутів і тарифів на автомобільному транспорті в контексті формування стійкої системи екологічної логістики. У рамках реалізації методичного підходу були оцінені викиди CO_2 для автомобільного транспорту та здійснені розрахунки для різних типів автомобілів. Запропоновано включати коефіцієнт емісії вуглецю до розрахунку тарифу на автомобільному транспорті, що дозволить сформувати цільові фонди на підприємствах у рамках створення сталої системи екологічної логістики.

Наукова новизна. Обґрунтовано методичний підхід до визначення показників стійкості екологічних логістичних систем у контексті розробки методики розрахунку викидів CO_2, що дозволяє вирішити проблему формування транспортних маршрутів з урахуванням екологічних вимог у сфері зниження викидів CO_2 різними видами транспорту.

Практична значимість. Запропоновано методичний підхід із розрахунку викидів при спалюванні палива від автомобільного транспорту, що включає оцінку емісій CO_2 і розрахунок коефіцієнту викидів вуглецю при формуванні кільцевого маршруту при транспортуванні вантажів, рекомендується до використання науковцями, спеціалістами та практиками у сфері зеленої логістики.

Ключові слова: *логістичні системи, автомобільний транспорт, викиди* CO_2*, зелена логістика*

The manuscript was submitted 23.06.21.