

Navigating Challenges and Exploring Opportunities within a Green Economy Framework: Case of Urban Transport Networks in Ukraine

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Abstract

The problem of the negative impact of human activity on the environment has recently gained considerable popularity, particularly in the transport industry, which is rapidly developing in the context of economic development. Therefore, the study of current trends in the development of transport infrastructure in terms of compliance with the goals of the green economy is timely and relevant. The research aims to determine the peculiarities of the Ukrainian transport industry based on compliance with the criteria of green infrastructure efficiency. We performed the methods of analysis and synthesis, induction and deduction, and deducted graphs to determine the structure of the transport system and formulate criteria for green economy development. Quantitative, comparative, and trend analysis were used with the determination of probability based on forecasting for analysis of fossil fuels use and transport volume. The structure of the transport system, which includes transport for various purposes, routes and institutions that ensure its functioning, was determined. Based on the structure analysis, we proved the need for an integrated approach to assessing the environmental impact of the transport industry. We proposed to use the criteria for the effectiveness of green infrastructure. We analysed fuel use, freight and passenger traffic dynamics in recent years and identified trends based on trend lines. We identified the negative impact of the transport industry on the environment due to the growth in fuel consumption and the increase in freight and passenger traffic by road. The study proposes a list of organisational and managerial steps to reduce the negative impact of the transport industry on the country's environment.

Keywords

Transport industry; Sustainability; Transport volume; Fossil fuels; Green management; Freight turnover; Passenger traffic; Trend analysis

Introduction

In the modern world, the development of technological progress, economy and production fully meet the needs of society. At the same time, excessive use of resources and damage to the environment encourages more rational use of the earth's subsoil. Society must realize the consequences of such consumer behaviour, which threatens the planet's future. In this regard, the topic of green economy and sustainable development has recently gained popularity, which involves the search for optimal methods of production and other economic activities to reduce the negative impact on the environment. Therefore, present studies and political programs are devoted to a green economy.

The problem of achieving progress in the development of the green economy lies in the theoretical blurring of the concept. Merino-Saum *et al.* (2020) analyzed 95 definitions of the concept of green economy and found that the lack of a single concept leads to different, often ineffective approaches to achieving environmental sustainability of the economy. Therefore, it is important to determine the main directions and criteria for increasing the efficiency of the development of the green economy. Another negative factor is the scale of the problem, which includes different areas and industries in different parts of the world (Soderholm, 2020).

The growth of greenhouse gas emissions, mainly Carbon monoxide has emerged as a crucial problem for a green economy. The higher level of Carbon monoxide emissions already has negative consequences, namely climate change, the occurrence of drought, a decrease in crop yields, and the melting of glaciers. A significant share of CO₂ emissions falls on the transport sector, which stimulates the search for new approaches to the development of transport infrastructure according to the principles of the green economy (Masson-Delmotte *et al.*, 2021; Shen *et al.*, 2020).

The impact of the transportation industry on the green economy is mostly considered in the paradigm of greenhouse gas emissions, but it is also important to consider the use of resources, namely fossil fuels, the impact of transportation infrastructure and different types of vehicles on the environment, etc (Shah *et al.*, 2021). Since the transport industry has a branched structure, investigating its complex impact on ecology is a complex process that requires a systematic approach through the definition of impact criteria and assessment of individual components that can reduce negative consequences for the development of the green economy (Zhao *et al.*, 2020). By

We discovered the lack of research on the impact of the transport industry on the environment due to the lack of availability of data on the use of personal transport. It is also difficult to estimate and calculate the amount of greenhouse gas emissions by individual transport companies. Therefore, it is practically impossible to determine the comprehensive impact of the transport industry on the environment (Zhao *et al.*, 2020). Hence, studies analyzing the relationship between greenhouse gas emissions and transport industry activity often use indirect relationships that do not allow for comprehensive impact analysis (Prus and Sikora, 2021). Such a factor as the state of air quality cannot, therefore, primarily indicate the impact of transport, instead, it also takes into account the activities of factories and enterprises that also pollute the environment

Thus, the present study contributes to the topic of green economy in scientific circles with its unresolved problems. The problems of low effectiveness of green economy development methods are caused by the lack of a single concept that requires the selection of the main criteria for the impact on the green economy. The increase in greenhouse gas emissions, related particularly to the transport industry, are crucial problem for a green economy. That is why in our study, we proposed to determine the impact of the activities of the transport industry by analyzing those criteria of the green economy that can be identified and linked to the activities of the industry, such as the use of fossil fuels, the impact of different types of transport for freight and passenger transport on the environment, based on the availability and reliability of such data.

To recognize the peculiarities of the transport system of Ukraine, the following objectives were formed:

- 1) to analyse the use of fossil fuels in the transport system,
- 2) to determine the types of transport for cargo and passenger transport,
- 3) to assess the transport industry from the point of view of compliance with the criteria of the efficiency of the green economy.

Literature Review

Today, scientists worldwide have come together to find ways to reduce the negative impact of human activity on the environment (Sołoducho-Pelc and Sulich, 2022). The green economy is implemented in all sectors based on state development strategies. For example, economists are working to develop efficient economic models to reduce carbon dioxide emissions (Roberts and Stalker, 2020). Policymakers introduce restrictive and incentive measures to encourage compliance with the principles of the green economy. Ecologists develop a plan for resource conservation and predict the future consequences of implementing specific environmentally friendly methods (Zhao *et al.*, 2022). For instance, studies have defined 5 problems that don't allow to achievement of carbon neutrality in China such as increasing CO₂ emissions, a short period for achieving carbon neutrality goals, high carbon fossil energy, low level of economic development and immature low-carbon technologies. International initiatives and conferences are being created to achieve the goals of environmental well-being. In 2015, at a conference on climate change in Paris, the international community agreed to reduce the global peak of carbon dioxide emissions in countries as quickly as possible to achieve a level of increase in the average global temperature of no more than 1.5° C compared to pre-industrial levels (Salvia *et al.*, 2021; Zhao *et al.*, 2022). Dai *et al.* (2023) describe the steady increase in carbon dioxide emissions, which as of 2019 reached 80% of 1990 levels. Although this level decreased by 12% during the COVID-19 outbreak, the authors predict it will continue to rise. Moreover, trucks and cars affect air quality through significant carbon dioxide emissions and deplete the earth's subsoil by using fossil fuels. However, according to the authors, European cities need to redouble their efforts to achieve the stated goals, as the analysis of carbon dioxide emission reduction plans showed the low efficiency of the proposed measures.

An important factor influencing the level of carbon footprint is the planning of infrastructure construction and development as the backbone of the economy, as today's

infrastructure investments determine whether countries can move towards sustainable development and achieve their goals (Chen *et al.*, 2022). Even though investments in green infrastructure are more costly, entrepreneurs, especially in advanced economies, choose this path mainly because of their reputation (An *et al.*, 2021). Green infrastructure, in turn, includes renewable energy, green logistics, and digitalisation (Chen *et al.*, 2022). Yedilbayev *et al.* (2023) explored the possibilities of ecological urban planning, which would include engineering planning of entire agglomerations in the city with the achievement of an ecological goal. Thus, transport infrastructure plays a vital role in achieving the principles of green infrastructure development.

Another aspect is the impact of green transport infrastructure development on the country's economy. This issue has been of concern to many scientists, who, in particular, have described the pattern of an inverse U-shaped curve, in which high economic development has a positive impact on the environment, thanks to the introduction of innovations, modern technologies and the political will to comply with Sustainable Development Goals 13 and 7 (Ali *et al.*, 2020; Caglar, Guloglu and Gedikli, 2022; Sinha, Sengupta and Alvarado, 2020). In contrast, developing countries with low levels of economic development have a more significant negative impact on the environment. The applicability of this curve to the transport industry is controversial, as developed economies increase the share of logistics operations for freight and passenger transport, which ultimately negatively impacts the environment.

Although most scientific works related to transport and the green economy are devoted to green programs based on the reduction of carbon dioxide emissions, the authors note the importance of greening transport planning as a promising direction for environmental protection, since globalization has left its mark on the growth of the level of urbanization, which cannot be stopped. With this in mind, all activities of the transport industry should be considered from the perspective of a sustainable development strategy (Shah *et al.*, 2021). Thus, the study of the impact of the transport industry on the green economy should include not only the analysis of greenhouse gas emissions but also the strategic planning of the development of the industry from the point of view of environmental sustainability, such as planning the construction of transport infrastructure, renewal of vehicles, use of resources, the availability of environmentally friendly modes of transport, etc. (Ali, Anufriev and Amfo, 2021).

In Ukraine, compliance with the principles of a green economy and environmental well-being is regulated by legislation, namely the Law of Ukraine on Environment, policy decisions and strategic plans in line with the international Sustainable Development Goals of 2015, which were the basis for the Presidential Decree on Sustainable Development Goals. As for transport, the requirements for its characteristics and infrastructure are set out in the Law of Ukraine on Transport. The transport industry, including vehicles and infrastructure, is required by law to meet environmental requirements, and transport companies are obliged to protect the environment and the land they use. Despite the legislative regulation of environmental issues in the transport system, the negative impact of transport on the environment continues to grow, prompting the search for new methods of regulating the industry. (Barvinska, 2023).

The analyzed literature revealed that the majority of works devoted to the green economy and transport are investigated in the context of greenhouse gas emissions. However, the importance of transport infrastructure and the use of fossil fuels is also debated. Moreover, scientific studies contain mostly theoretical content and do not recommend specific steps to achieve the goals of the green economy in the transport sector. Since proposals to reduce the amount of transport are not realistic at the time of globalization and the development of logistics, it is necessary to look for ways to reduce the negative impact of transport. Therefore the present study aimed to determine the specifics of the transport industry in Ukraine based on the study of the transport system's structure and its compliance with the criteria of green infrastructure efficiency.

Methodology

The analytical-bibliographic method was used to research the literature on the topic of green economy development in the transport industry. To achieve the goal, research was conducted on the structure of the transport system and evaluation criteria for green infrastructure, using the method of analysis, synthesis, induction and deduction. In this way, the information was systematized and the structure of the transport system of Ukraine was demonstrated based on the data of the Law of Ukraine on Transport. The main criteria for the efficiency of green infrastructure have been identified, which allows us to assess the comprehensive impact of transport infrastructure on the green economy. The systematized data of the structure of the transport system and criteria for the efficiency of green infrastructure are graphically demonstrated in Figures 1 and 2. The possibilities of a comprehensive assessment of the impact of the transport industry on the green economy by analyzing the criteria of green infrastructure are analyzed. The official statistical data of the Ministry of Finance of Ukraine regarding the dynamics of the use of fuel resources for the period 2014-2020 were analyzed, which were compared with each other using a quantitative graphic method and the method of trends method of changes in the use of fuel resources were determined with further forecasting of the dynamics of the use of fossil fuels for the next 5 years (Fig. 3-4). We used the quantitative trend method for analyzing fossil fuels. We analyzed the data of the State Statistics Service on the volume of cargo transportation from 2014 to 2021 (Fig. 5-6) and passenger transportation from 1995 to 2020 (Fig. 7-9), using a graphic, comparative and trend method to forecast trends for the next 5 years and calculation of probabilities. The quantitative trend method was used to analyse the volume of different types of vehicles. Graphs and calculations were made in Excel. The obtained results were summarized and conclusions were formulated, compared with the results of research by other authors and recommendations aimed at achieving the goals of the green economy in the transport industry, using logical methods. The limitation of the bias included the lack of availability of data on the use of personal transport and air quality in different parts of the city.

Results

Criteria for assessing the environmental performance of the transport industry

To analyse the development of transport infrastructure, we studied the structure of the Ukrainian transport system, which consists of public transport, industrial, departmental, pipeline transport and public roads. Figure 1 shows the scheme of the transport system

of Ukraine with the selection of key components and their constituents to understand the difference in factors affecting the transport industry on the environment.

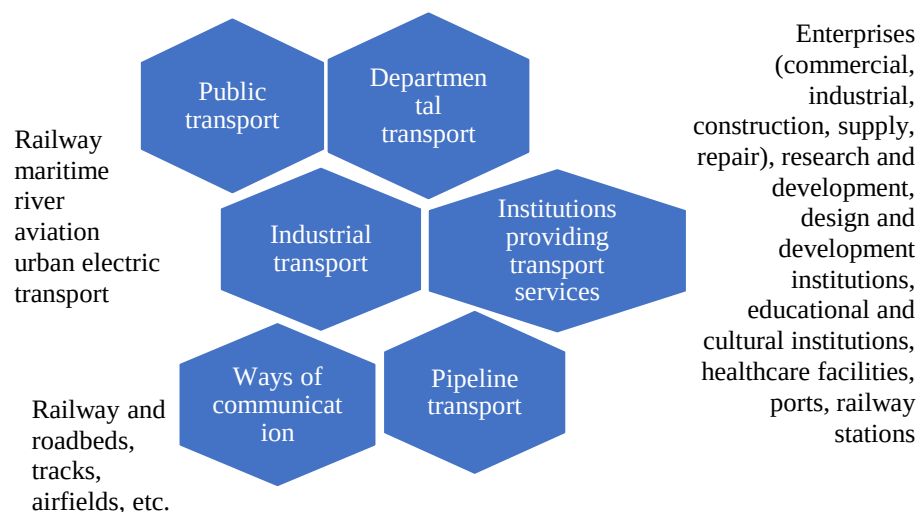


Figure 1: The structure of the transport system

As seen from the structure in Figure 1, the transport system comprises many diverse objects that impact the environment. Therefore, the environmental impact of transport infrastructure cannot be viewed only in terms of carbon dioxide emissions from vehicles but also in terms of the impact of the enterprises and institutions that support the transport industry. An important aspect is the condition of the land plots provided for use by transport companies, as the land must be maintained in a proper sanitary condition and used for its intended purpose. The land related to roads also includes roadside areas with landscaping, ditches, and forest belts. It is necessary to promote the planting of roadside areas and to preserve the natural flora of places where new roads or transport facilities are built to the maximum extent possible.

Thus, the development of Ukraine's transport infrastructure in terms of compliance with the principles of the green economy was considered based on green infrastructure criteria (Figure 2). These criteria allow us to assess the complex impact on the atmosphere and the condition of soils, water bodies, biodiversity, and public health.

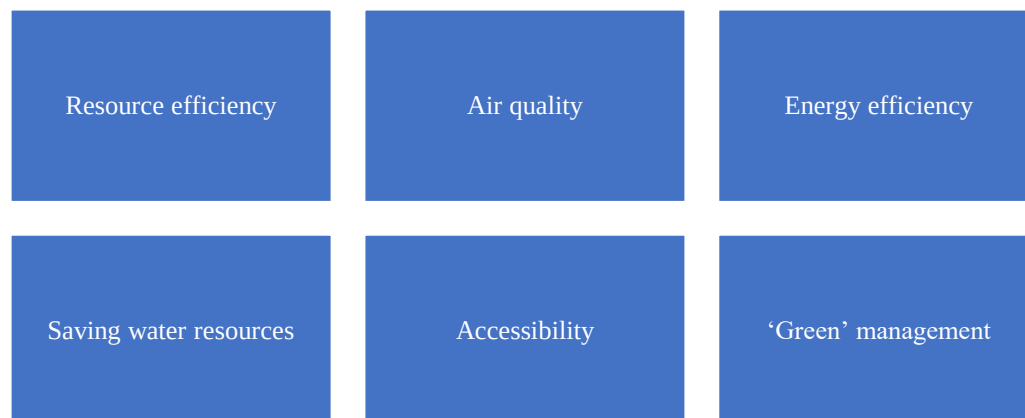


Figure 2: Criteria for Determining the Effectiveness of Green Infrastructure

Source: Khoshnava *et al.* (2020)

The above criteria consider such an essential aspect as resource efficiency, which is responsible for preserving resources for future generations. It is the assessment of the use of resources that makes it possible to analyze the activities of individual institutions in the paradigm of the green economy, because the assessment of air quality provides an understanding of the complex impact of various enterprises, factories, the consequences of fires on the level of air pollution, and does not provide information about the local impact of a company or industry. Thus, by analysing the dynamics of resource use, it becomes possible to conduct an internal audit of the company and use calculations to estimate the projected amount of carbon dioxide emissions by using the method of statistical forecasting and the effectiveness of energy efficiency innovations. The importance of assessing the use of resources, especially fossil fuels, is important for a green economy. For example, Zhao *et al.* (2020) identified the use of fossil fuels as a factor preventing the achievement of carbon neutrality.

As vehicles are only part of the transport system, which requires the operation of various institutions, including those that use much energy, energy efficiency is paramount. When constructing new facilities, it is necessary to consider using renewable energy and insulation to reduce energy consumption during the cold season. The introduction of innovative technologies will also be relevant to achieving this goal. New technologies, appliances, and machines are more optimised to reduce energy consumption.

Khoshnava *et al.* (2020) analysed recent publications and determined that the criteria for adequate green infrastructure have environmental, social and economic aspects. Socio-economic factors serve as motivators for the use of specific modes of transport. That is why the criteria include accessibility, which determines the behaviour and habits of the population and creates popularity among residents. It is this criterion that takes into account political will and public opinion and predicts their practical cooperation with each other.

The criterion of water conservation is relevant for water transport and includes requirements for vessels and the prohibition of polluting water bodies with oils. However, it is also important for other modes of transport to consider this criterion, especially when designing, building, and operating bridges. Transport service facilities

can also be located in coastal areas, which can impact water bodies by altering the coastline during construction (Kilkis *et al.*, 2020).

The criterion of green management is new and little understood by society, but regardless of the definition of this concept, it includes environmental protection and resource management (Carvajal, Nadeem and Zaman, 2022). Green management is a critical factor in achieving the seventh sustainable development goal by regulating the strategy and mitigating and preventing the negative environmental impacts of business operations. At the highest level, the government approves the environmental strategy and ensures its principles are legislated and adhered to. At the second level, individual industries approve their behavioural model based on the region's strategic environmental plan. The lowest level of green governance is the environmental rules of an individual enterprise or company (Sołoducho-Pelc and Sulich, 2022). From a global governmental perspective, this division of green governance positively impacts achieving critical strategic goals of a green economy and forming an environmentally friendly mindset among employees. After all, employees' involvement in the company's environmental activities allows them to feel their role in achieving the global goals of the green economy.

When assessing the sustainability of a transport system, it is essential to follow the criteria for the effectiveness of green infrastructure at different stages of its development. In particular, when planning road construction, avoid cutting down trees or draining small reservoirs, choose environmentally friendly and energy-efficient vehicle models when renewing transport fleets, and equip transport maintenance facilities with renewable energy sources. Considering their diverse environmental impact, the above criteria will allow for an effective environmental audit of companies and industries. We identified a trend towards an increase in demand for electric cars in Ukraine, which in 2021 exceeded the terms of sales growth in such developed countries as the USA and Japan.

Evaluation of Ukraine's transport infrastructure development according to green infrastructure criteria

The sustainability of the transport system was assessed using green infrastructure criteria. To determine the trends in resource use, we analysed the use of fuel materials from 2014 to 2021 in Ukraine. Figure 3 shows a graph of the dynamics of annual fuel use in Ukraine from 2014 to 2021. Based on the statistical data, we constructed trend lines shown in Figure 4 and estimated the probability of the trend. This analysis provides an understanding of the impact of the transport industry on the environment from the point of view of the efficiency criterion of the green economy, namely resource efficiency.

Based on the identification of trends, positive changes were identified in recent years, indicating a decrease in the use of hard coal with a polynomial dependence (non-linear) with a value of probability ($R^2 = 0.780$), which allows predicting a further decrease in the use of hard coal with a probability of more than 78%. A similar trend was identified for petrol, described by a linear relationship with a decrease in its use and the possibility of predicting a further decrease with a probability of $R^2 = 0.775$. The downward trend in using natural gas was characterised by a low probability level, with a value of $R^2 = 0.466$. On the contrary, the use of diesel fuel (gas oil) tended to increase with a probability of $R^2 = 0.706$.

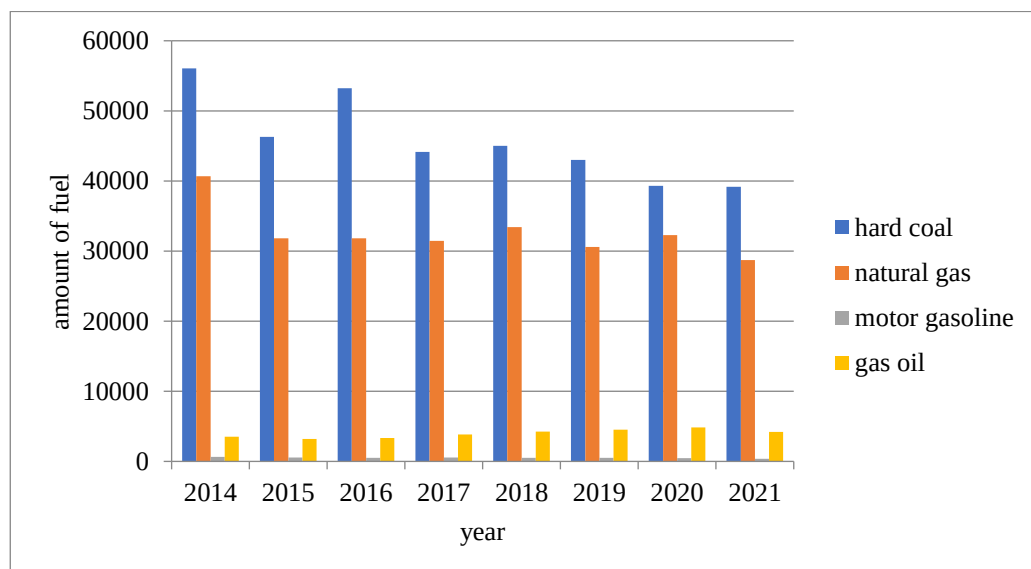
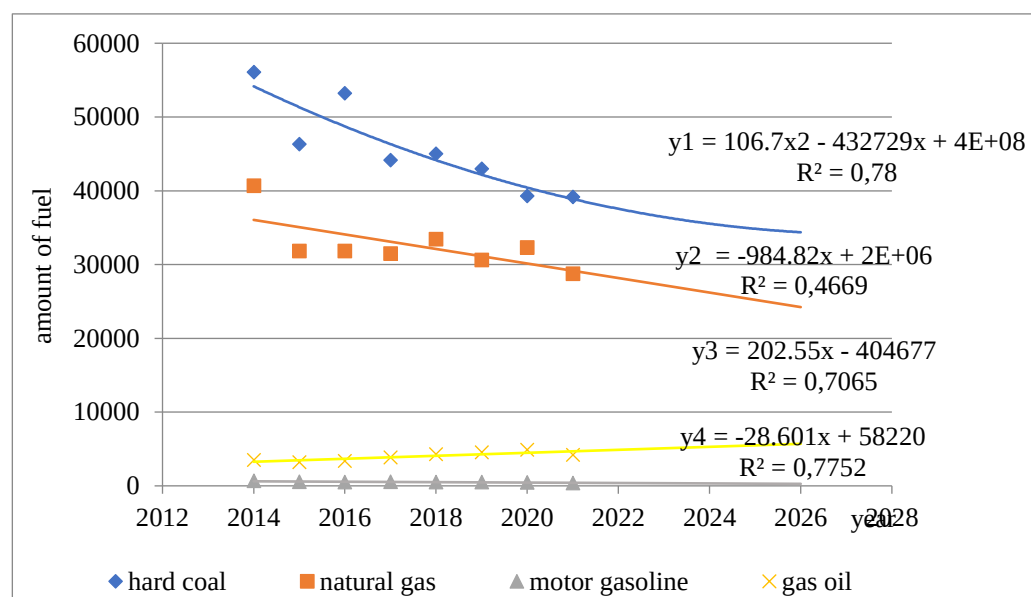


Figure 3: Graph of Fuel Materials Use [Source: Ministry of Finance of Ukraine]

Figure 4: Determining the Trend of Fuel Consumption (Coal γ_1 , Natural gas γ_2 , Gas oil γ_3 , Motor petrol γ_4) over the Last 8 Years, with Trend Lines and Forecasting

The decline in hard coal use and transport infrastructure development is indirect. It may indicate a decline in industrial production at metallurgical plants associated with machine building. Although not directly correlated, this trend can indicate vehicle-renewal with the participation of domestic production. As for gas, petrol, and gas oil, their use can be considered in terms of use by public, departmental, and industrial transport, as statistics do not consider fuel consumption by private vehicles.

We analysed the statistical data on freight and passenger traffic obtained from the open-source website of the State Statistics Service of Ukraine. This analysis makes it possible

to assess the impact of the transport system on the environment, taking into account the criterion of the green economy, namely green management, which determines the popularity of various types of transport for cargo and passenger transport. Based on the determination of indicators of the actual use of various types of transport for cargo and passenger transportation, the criteria of the green economy were evaluated, which determine the effectiveness of the implementation of green initiatives in the development of the transport industry. As can be seen from the graph in Figure 5, freight transportation is carried out mainly by rail and road. Therefore, we determined the trend of changes in freight traffic over the past eight years for road and rail transport (Figure 5).

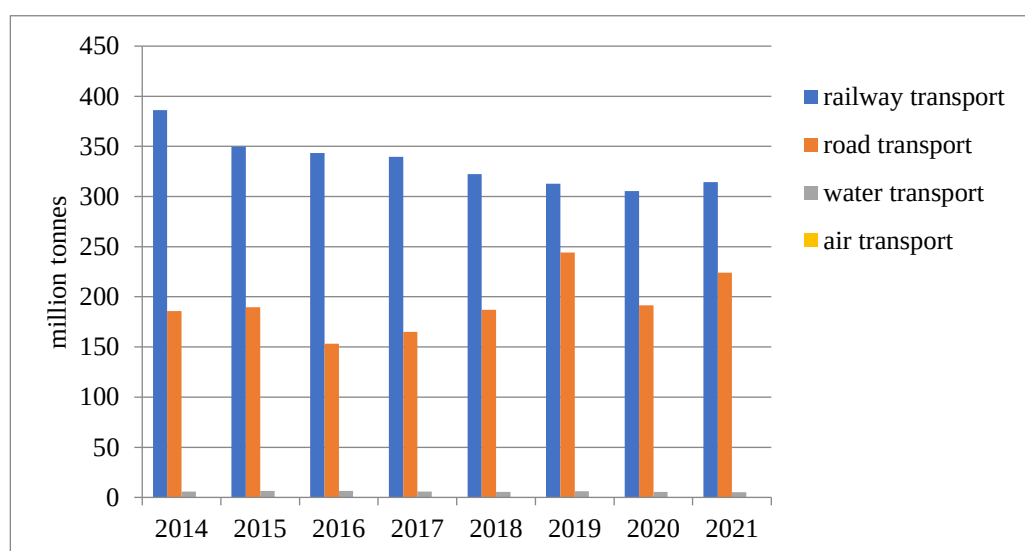


Figure 5: Volumes of Freight Transported by Different Modes of Transport in 2014–2021 [Source: State Statistics Service of Ukraine]

The assessment of the trend lines revealed a decrease in the use of rail transport for freight transport in recent years, which is predicted to decrease with a probability of $R^2 = 0.848$. The use of road transport for freight transport has not had a clear trend in recent years, which makes it impossible to predict further changes, but there is a probability of $R^2 = 0.408$ that the use of road transport for freight transport will increase.

We analysed the trend of passenger transport over the past 25 years. As seen in Figure 7, road transport prevails among all types of transport, mainly due to buses. A positive example is the high coverage of passenger traffic by electric transport, namely trolleybuses, trams and subways. In contrast, air, sea and waterways covered several passenger journeys.

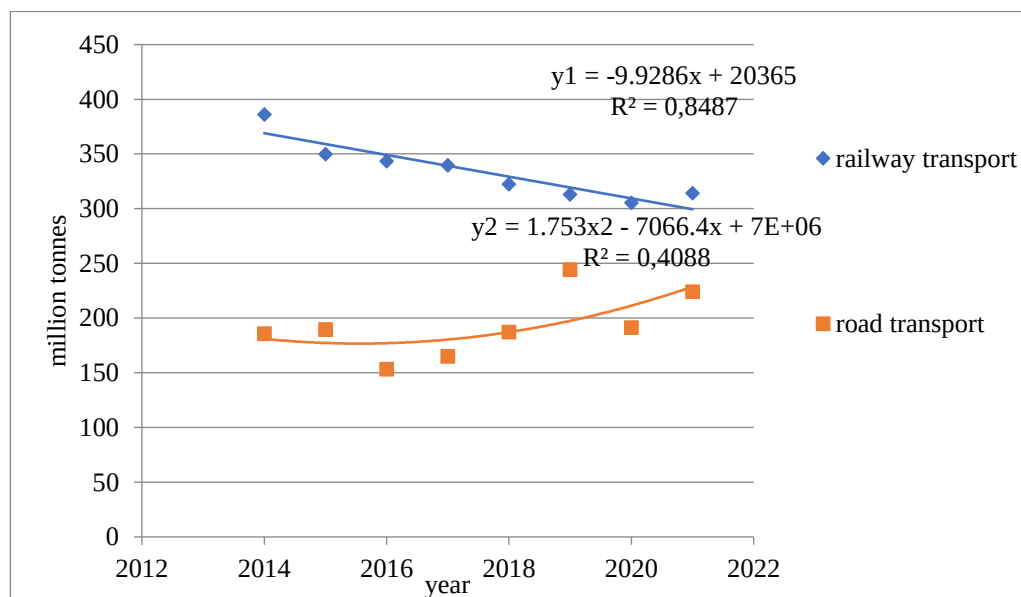


Figure 6: Graph of the Trends in the Volumes of Freight Transportation by Road (y_2) and Rail (y_1) in 2014–2021

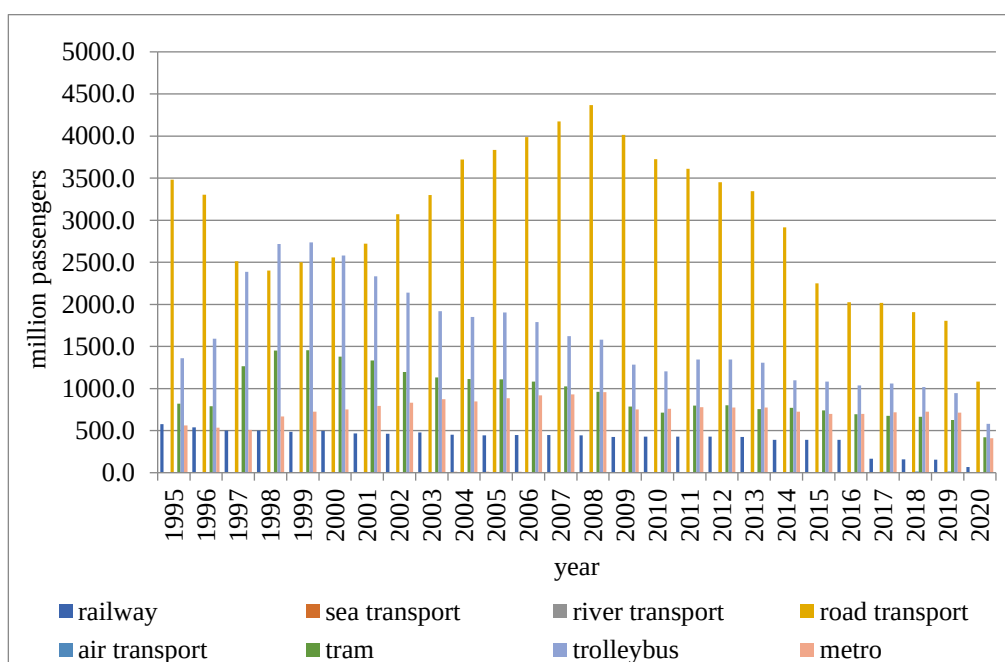


Figure 7: The Structure of Passenger Transport by Modes of Transport for 1995–2020
Source: State Statistics Service of Ukraine

Figures 8 and 9 show the analysis of trends in using different modes of transport for passenger transportation. As can be seen from the graph, the trends in road passenger traffic are described by a polynomial pattern with a probability of 0.673 for a slight decrease in road passenger traffic. A linear relationship describes rail passenger traffic and tends to decrease with a probability of more than 70%. Air, water and river

transport also tended to decline, with a probability of up to 77%. Tram and trolleybus use peaked in 1998–2004, and subway use in the 2010s, but there is a downward trend in the use of electric transport. The decline in passenger traffic in 2019 and 2020 was also due to restrictions related to the COVID-19 pandemic and the growth in the number of private cars.

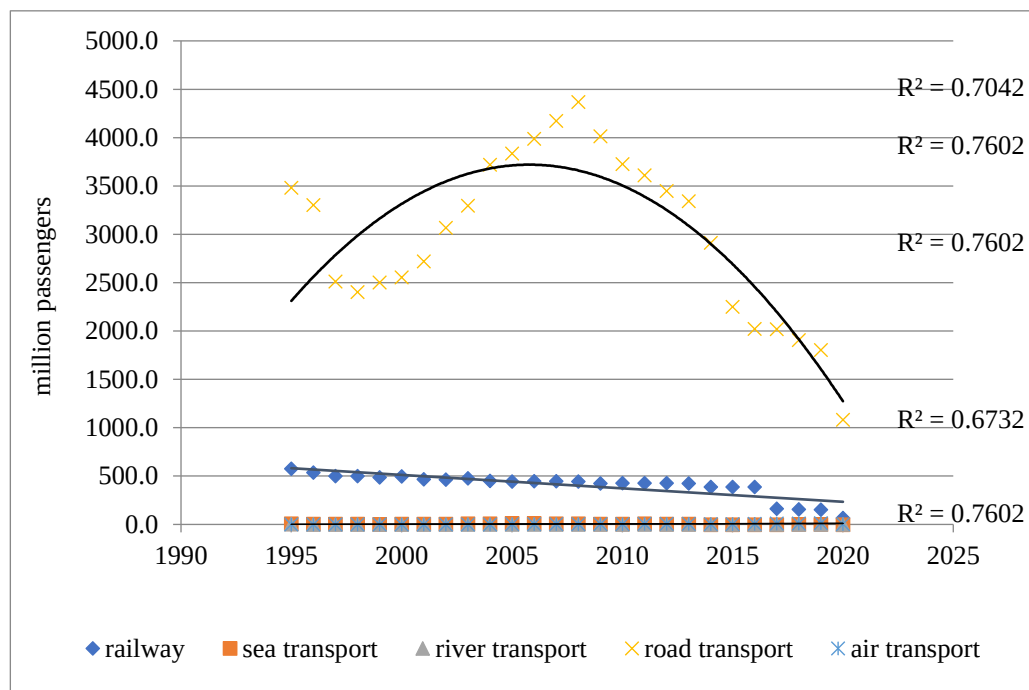


Figure 8. Graph of Trends in Passenger Transport by Different Modes of Transport in Ukraine for 1995–2020 [Source: State Statistics Service of Ukraine]

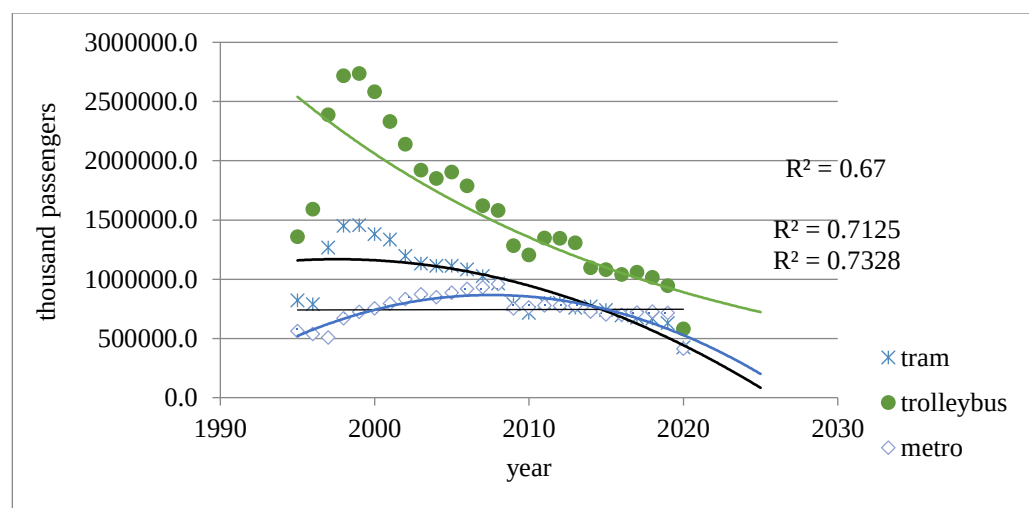


Figure 9: Graph of Trends in Passenger Transportation by Electric Urban Transport
Source: State Statistics Service of Ukraine

Thus, the freight and passenger transport statistics analysis indicated a trend towards a decrease in rail and electric transport for transporting goods and passengers and an increase in road transport, which explained the observed pattern of increased fuel consumption, namely gas oil. Trucks and passenger cars mainly use diesel fuel (gas oils) for travelling. Another pattern identified was the downward trend in passenger traffic on all modes of transport, which indirectly indicated an increase in private cars.

Assessing the impact of transport infrastructure on air quality is difficult because transport activities do not occur within a single local area. Moreover, determining greenhouse gas emissions from mobile sources is difficult. At the same time, in urban agglomerations, the impact of vehicles on air pollution can be assessed by the congestion level. The congestion level characterises the congestion of transport routes and is better than the number of registered cars to indicate the use of private cars. It is possible to prove the level of air pollution in places with traffic jams by conducting a quantitative comparative analysis of air quality based on the number of cars (Kusumaningtiar, Vionalita and Ardiansyah, 2020).

The accessibility criterion for the transport system is determined by the cost and convenience of transport services and explains the trends in freight turnover and passenger traffic. The identified trends in the decline in rail freight traffic are associated with a decrease in industrial cargo, including from the regions occupied since 2014. Instead, the increase in the share of road freight is due to the convenience of road transport for small businesses in providing logistics. After all, road logistics is characterised by faster delivery and greater mobility compared to rail transport. As for passenger transport, it is essential to note the positive impact of lower fares for electric transport compared to buses and minibuses. This step is also seen as effective green management, which shows its effectiveness through the financial promotion of electric transport. Although our study did not reveal a trend towards an increase in the use of electric transport in recent years, this does not negate the above-mentioned positive impact of the accessibility criterion. Instead, the reason for this finding is the lack of electric transport in many cities and villages, which affected the national statistics.

In urban agglomerations, there is an increase in freight and passenger transportation by road and the number of private cars. This creates a negative trend in the use of fuel resources and air pollution, especially in places where traffic congestion occurs. To reduce the negative impact of this trend in the transport sector, it is necessary to develop green management and infrastructure. Effective green management mechanisms include financial incentives for companies that use energy-saving technologies and environmentally friendly transport. It is essential to change the principle of cooperation between environmental regulatory institutions and companies by conducting audits of companies with consultations to encourage the use of energy-efficient technologies and demonstrate economic benefits. After all, the functions of environmental organisations to detect violations contribute to corruption and do not stimulate the development of environmental responsibility of entrepreneurs (Sundström, 2016). Local governments should also promote green policies among local businesses and help them obtain grants for implementing environmental technologies.

In densely populated cities, it is essential to combat congestion on roads by private vehicles, so it is vital to build transport infrastructure for the congestion of sections and traffic control planning to reduce the likelihood of congestion. Promoting electric transport, in particular, is necessary to ensure convenient timetables and public transport priorities. To reduce the number of cars owned by residents of suburban areas, secure car parks should be built at the entrance to the city, for example, near metro or light rail stations. Moreover, such car parks could have electric charging stations, encouraging people to use electric vehicles.

Discussion

After analysing the structure of the transport system and infrastructure, we found a sizeable branched network that includes vehicles, roads, and institutions for maintenance, which can have different environmental impacts. That is why it was proposed to assess the integrated environmental impact of transport by the criteria for green infrastructure performance. Such an integrated approach is used in many countries; for example, Broniewicz and Ogrodnik (2020) recommend using European environmental standards Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) and applying multi-criteria impact assessment methods (Multi-Criteria Decision Making/Multi-Criteria Decision Analysis) when planning and improving transport infrastructure. Churchill *et al.* (2021) emphasise the importance of analysing the impact of transport infrastructure on carbon dioxide emissions, which should include not only the effect of vehicles but also the production of materials, manufacturing and construction of transport infrastructure.

Globally, the impact of economic activity on the environment is an important topic, including transport infrastructure, with a 1% increase in its development leading to a 0.4% increase in greenhouse gas emissions (Churchill *et al.*, 2021). On the contrary, Zhang, Liu and Ding (2021) describe the positive impact of an extensive transport network on carbon monoxide pollution in cities, which reduces the accumulation of many cars in one place. China has a high carbon footprint due to its high population density, so its policies have focused on renewable energy sources and changes in transport infrastructure (Ding and Liu, 2023). Thus, as of 2020, 40% of all renewable energy is in China. Changes in the transport system in China included the development of the subway, high-speed rail transport, and the development of charging station infrastructure for electric vehicles. The authors describe such measures as practical, manifested by the growing popularity of electric vehicles among the population. At the same time, scientists in countries where electricity is mainly derived from fossil fuels wonder whether electric vehicles are more environmentally friendly if they need to use fossil fuel-based electricity to charge them (Petrovic *et al.*, 2020; Sobol and Dyjakon, 2020). Cary and Ahmed (2022) studied the impact of performance restrictions on cars and trucks in Europe and found a positive impact on public health due to reduced nitrogen oxide emissions. York *et al.* (2017) modelled changes in public transport to more environmentally friendly modes and the redistribution of freight logistics by rail. They identified positive results of changes in carbon dioxide emissions, namely a more than 17% reduction in the city of the study.

Ukrainian scientists have also studied the impact of transport on greenhouse gas emissions. Abuselidze *et al.* (2023) described the current policy of reducing the transport carbon footprint in Ukraine as ineffective and proposed scenarios for optimising transport as part of a transport sector decarbonisation programme, which redistributes traffic between road and rail. Dvigun *et al.* (2022) recommended the introduction of an environmental pollution tax that would encourage the search for more environmentally friendly modes of transport for logistics, which would reduce carbon dioxide emissions. Pivnyak *et al.* (2024) identified a trend towards an increase in demand for electric cars in Ukraine, which in 2021 exceeded the terms of sales growth in such developed countries as the USA and Japan. This trend is refreshing in favour of sustainable development in Ukraine, however, the infrastructure for electric vehicles is still not sufficiently developed. Another negative aspect is the war, which negatively affected not only the trend of buying electric cars but also the level of greenhouse gas emissions. During the first 18 months, emissions of carbon dioxide, methane and nitrogen oxide increased and amounted to 77 MtCO₂-eq (Bun *et al.*, 2024).

Conclusion

Based on the study of legislative documents, the structure of the transport system was identified, which included an extensive network of transport routes, means, and institutions that ensure their functioning. A multifactorial analysis of the transport sector's impact on the environment was proposed, and the positive role of assessing environmental consequences according to green infrastructure criteria – namely resource efficiency, air quality, energy efficiency, water resource conservation, accessibility, and “green” management – was demonstrated. However, according to the literature, an increased demand for electric vehicles in Ukraine was found, which stimulates the development of green infrastructure. However, the increased demand for electric vehicles did not show visible changes in the environmental friendliness of the transport system, since in general, the environmental friendliness is not only affected by the type of transport but also by the transport infrastructure, which requires energy efficiency. After all, in Ukraine electric cars are charged with electricity obtained from fossil fuels.

Analysing official statistical indicators on the use of fuel resources and the volumes of freight and passenger transportation, an increase in the use of diesel fuel and the predominance of road transport for both freight and passenger transportation were identified, indicating a negative trend in the development of the transport system from the perspective of the green economy, particularly in terms of resource efficiency and air pollution. However, a positive finding is the popularity of electric transport for passenger transportation and the availability of this type of transport, which forms an environmentally friendly habit among the population. However, in recent years there has been a tendency to decrease the use of public electric transport.

A list of organisational and managerial solutions was proposed to improve the environmental sustainability of the transport infrastructure, including the renewal of vehicles and equipment using environmentally-friendly models, the construction of transport infrastructure considering road load and reducing the likelihood of traffic congestion, advising companies on obtaining grants for the development of green technologies and training on environmental responsibility, introducing financial

incentives for implementing “green” initiatives and promoting electric transport, among other measures. Although, according to the literature, there have been attempts to stimulate the development of the green economy in Ukraine, which did not lead to significant improvement, our recommendations may have better results because they apply a comprehensive approach to the problem.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5
Conceived and designed the research or analysis	Yes	No	Yes	Yes	Yes
Collected the data	Yes	No	Yes	No	No
Contributed to data analysis & interpretation	Yes	Yes	No	Yes	No
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes
Supervision	No	Yes	No	Yes	Yes
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