Research on the Impact of Transportation on Greenery in the Urban Envıronment

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Abstract

The main purpose of this study is to scientifically analyze the impact of the development of transport systems on urban and peri-urban greenery against the background of the urbanization process, to determine the negative effects of transport activity on ecosystems, biodiversity, and the ecological sustainability of the urban environment, and to investigate the possibilities of forming an optimal transport-greenery balance in the context of sustainable urban development. Research method: The study used a systematic approach, comparative analysis, and content analysis methods. Official statistical data, scientific articles, and reports of the European Union and international organizations were analyzed to assess the relationship between transport and greenhouse gas emissions, air and noise pollution, land use, and the reduction of greenery. Research results: The study found that the expansion of the transport sector leads to the reduction of urban greenery, the fragmentation of ecosystems, and an increase in the ecological load. Despite technological advances, the increase in the overall intensity of transport limits the reduction of ecological impacts.

Keywords: transportation, greenery, civilization, technological progress

1. Introduction

The formation of human settlements and the historical stages of civilization development have been closely linked to the development of transport systems. Historically, settlements that arose around trade routes, ports, caravan routes, and later railways have become economic and social centers. Rapid advances in transport technologies, especially after the industrial revolution, have enabled the spatial expansion of cities and the intensification of urbanization. From the introduction of steam engines to modern urban transit systems, the development of transport has acted as one of the main driving forces for the growth of urban areas.

In modern cities, the development of buses, metros, light rail, regional railways, and other types of public transport has not only facilitated the daily mobility of the population but also created conditions for the economic and social integration of remote areas with centers. This process has led to the expansion of cities beyond their administrative borders, the formation of new residential areas, and industrial zones. As a result, the growing transport infrastructure has required the rapid expansion of street networks, bridges, and tunnels, which has led to the intensification of land use and the reduction of urban greenery.

Globally, industrialization and urbanization processes have significantly increased the demands on people's lifestyles, work schedules, and socio-travel behaviors. These changes have had a direct impact on land use structures, transport planning, and infrastructure provision. The increase in land and real estate prices, especially in urban centers, has forced a part of the population to move to the outskirts of cities. Settlement in peri-urban areas has led to increased distances between residences and workplaces, increased daily transport demand, and increased dependence on private cars.

The expansion towards the outskirts of cities has created additional pressure on transport systems, leading to increased traffic jams and a decrease in the efficiency of public transport. This process has also been accompanied by the encroachment of urban and suburban green spaces by transport infrastructure, the fragmentation of ecosystems, and the disruption of green spaces. The reduction of green spaces as a result of the expansion of roads and parking areas has strengthened the "heat island" effect in cities, creating conditions for worsening air quality and reducing biodiversity (Fig. 1).

Thus, while the important role of transport in urbanization and economic development is undeniable, its uncontrolled development has posed serious challenges for urban ecosystems and greenery. In this regard, ensuring a balance between the development of transport systems and the protection of greenery in modern urban planning is one of the main conditions for sustainable development.

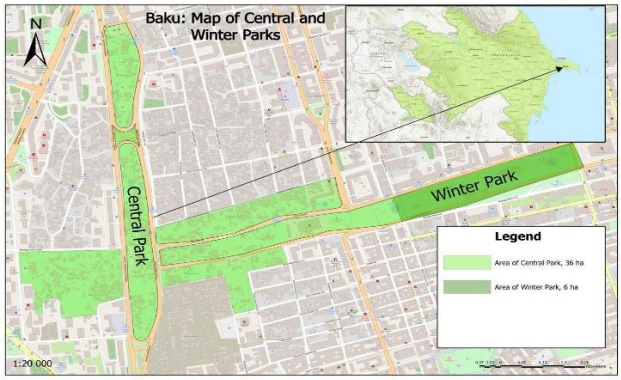

Figure 1. *Baku City Central Park*

The relevance of the research is precisely related to the scientific analysis of the impact of transport activities on urban greenery and the identification of effective approaches to reducing these impacts.

2. Materials and methods

The methodological structure of the study is formed by a systematic approach and multidisciplinary analysis methods that allow us to assess the impact of urbanization processes on urban ecosystems in terms of quantity and quality. To form the material base of the study, international fiscal and environmental organizations, including the European Environment Agency (EEA), transport and emission reports, the European Commission's "Green Deal" strategic documents, Eurostat, and the European Automobile Manufacturers' Association (ACEA), dynamic statistical data covering the years 1990–2024 were used as empirical sources. Also, modern scientific literature studying the impact of transport infrastructure on the urban landscape and biodiversity, including the official methodologies of the World Health Organization (WHO) on acoustic pollution, was involved in the study.

The systematic approach applied in the research process made it possible to consider transport infrastructure, urban green zones, and urbanization dynamics as interdependent components of a single system. A comparative analysis method was used to compare the emission indicators of the transport sector with other economic sectors (industry and energy), and a qualitative content analysis method was used to measure the effectiveness of existing regulatory and legal acts and decarbonization strategies. The impact of transport on greenery was assessed by grouping four main indicators - emission load (CO_2 and nitrogen oxides), physical space loss (hardening of the soil cover), acoustic pressure, and thermal effect ("heat island" effect). This methodological approach serves to reveal the contradictions between technological progress and increasing transport intensity and to identify optimal solution models for the ecological sustainability of the urban environment.

3. Research results and discussion

The transport system plays a crucial role in shaping the socio-economic structure of modern society. Transport infrastructure, which ensures the integration of people, cultures, cities, and regions with each other, creates conditions for the continuity of production and trade chains, the expansion of labor markets, and increased access to services. The expansion of road and rail networks, especially in remote and peripheral areas, contributes to increased economic activity, the introduction of agricultural products to markets, and the reduction of interregional inequality (Banister, 2011; Rodrigue, Comtois & Slack, 2020). At the same time, the expansion of transport infrastructure is accompanied by a decrease in urban and peri-urban greenery, soil sealing, and the fragmentation of ecosystems, which pose serious risks to the ecological balance.

Current transport models, especially car-oriented development strategies, have a significant negative impact on the environment and human health. According to the European Environment Agency (EEA), the transport sector is responsible for around a quarter of total greenhouse gas emissions in the European Union and is also one of the main sources of air pollution in urban environments (EEA, 2023a). Nitrogen oxides (NOx), particulate matter (PM2.5 and PM10), and volatile organic compounds (VOCs) from road transport have a negative impact not only on human health but also on the photosynthetic capacity of urban green spaces, plant growth rates, and biodiversity (Nowak et al., 2014).

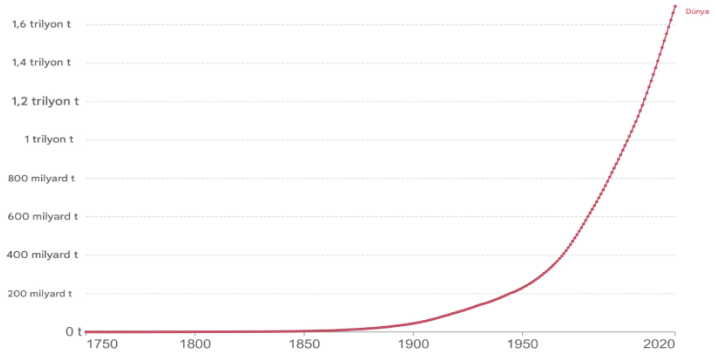

Figure 2: *Growth dynamics of European greenhouse gas emissions*

It is particularly noteworthy that the transport sector is the only major economic sector in Europe where greenhouse gas emissions have increased since 1990. While other sectors – energy production and industry – have made some progress in decarbonisation, the increasing motorisation of transport and the intensification of freight transport make it difficult to reduce emissions (European Commission, 2022). This process weakens the ecological functions of urban green spaces, as high concentrations of pollutants accumulate on the leaf surfaces of plants, reducing their filtration and climate-regulating potential (Fig. 2).

Although technological improvements and increased energy efficiency of transport vehicles are considered important advances, these changes cannot compensate for the increase in overall transport activity. The increasing intensity of passenger cars, trucks, aviation, and maritime transport across Europe leads to persistently high greenhouse gas emissions (IEA, 2023). Increasing traffic density results in the replacement of greenery in the urban landscape with road networks and parking lots, which intensifies the “urban heat island” effect (see p. 1).

Table 1. The rate of decarbonization of the transport sector and its impact on urban ecosystems

Indicator / Sector	Trend (Compared to 1990)	Environmental Impact Mechanism	Impact on Urban Green Areas
Total Transport Emissions	+26% increase	Growth in greenhouse gas (CO_2) emissions	Exceeding carbon sequestration capacity
Energy and Industrial Sector	Decreasing trend	Transition to renewable energy sources	Relative reduction of ecological pressure
Road Transport (NOx, PM)	Local decrease	Implementation of the "Euro" emission standards	Increased filtration load on leaf surfaces
Infrastructure Expansion	Rapid increase	Soil sealing and surface hardening	Fragmentation of green corridors
Noise Pollution	High (60+ dB)	Acoustic disturbance	Disruption of biodiversity (bird migration patterns)

Statistics show that in 2022, greenhouse gas emissions from the transport sector in the European Union increased by about 26% compared to 1990 and accounted for 29% of total greenhouse gas emissions (EEA, 2023b). These figures reveal that the transport sector, unlike other major economic sectors, has shown weaker progress in the decarbonization process. While there has been an increase in the share of renewable energy sources and a decrease in emissions due to technological modernization in the energy production and industrial sectors, this positive trend is offset by the increasing level of motorization in transport, the intensification of freight transport and increased intercity mobility. Against the background of the increasing rate of decarbonization of other sectors, the relative share of transport in the total emissions structure is projected to increase further, which creates additional risks for urban ecosystems. In particular, urban and peri-urban green spaces will have to bear a greater burden in terms of compensating for increased carbon emissions. However, the limited area of existing green spaces and the fragmentation of ecosystems significantly limit their carbon absorption potential. As a result, a mismatch is formed between the increase in emissions from transport and the ecological functions of greenery, which weakens the climate regulation capacity of cities and leads to a decrease in the level of ecological sustainability. Despite existing and planned policy measures, greenhouse gas emissions from transport in the European Union are projected to decrease by only 14% by 2030 and by about 37% by 2050. These indicators reveal that current policy mechanisms applied in the transport sector are not sufficiently effective in achieving climate goals. However, the "European Greening Policy" Agreement has set an ambitious strategic target of reducing greenhouse gas emissions in the transport sector by 90% by 2050 (European Commission, 2019). The significant gap between current projections and this target indicates the need for structural and systemic changes in the transport sector. To achieve this goal, technological improvements in transport vehicles and the introduction of alternative fuels alone are not enough. At the same time, environmental priorities at the level of urban and regional spatial planning are required to be strengthened. The protection and expansion of greenery, the formation of green corridors within and between cities, as well as the integrated planning of green spaces with transport infrastructure, can play an important role in reducing emissions. This approach allows for partial compensation of the environmental burden caused by transport by strengthening the carbon absorption and microclimate regulation functions of urban greenery and forms a more realistic basis for the goals of sustainable urban development.

According to preliminary data from the European Automobile Manufacturers' Association, average CO_2 emissions from newly registered cars continued to decline in 2023. The increasing share of electric vehicles is considered to be the main reason for this positive trend (ACEA, 2024). However, as the expansion of electric vehicle infrastructure also creates additional land use and landscape changes, a long-term balanced approach to urban greening is required.

The movement restrictions, border closures, and economic slowdown imposed during the COVID-19 pandemic have led to a sharp decline in transport activity, leading to a temporary drop in greenhouse gas emissions. According to the European Environment Agency, greenhouse gas emissions from the transport

sector in the European Union fell by around 12–15% in 2020 compared to the previous year, the steepest decline recorded in recent decades (EEA, 2023c). The decline in air transport and international passenger transport in particular was one of the main reasons for this decline. However, with the gradual resumption of economic activity and mobility since 2021, emissions from the transport sector have increased again. According to preliminary estimates, transport emissions increased by about 8.6% in 2021 compared to the previous year, and by a further 2.7% in 2022 (EEA, 2023c). This increase is mainly associated with increased private car use, reduced reliance on public transport, and increased freight transport. Thus, the emission reduction observed during the pandemic was not structural, but mainly the result of restrictions imposed by emergency conditions. This trend shows that short-term emission reductions achieved without big structural changes in the transport sector do not produce sustainable results. To achieve sustainable emission reductions, it is necessary not only to limit mobility but also to radically transform transport systems, switch to cleaner and more active modes of transport, and integrate transport planning with urban green spaces and ecological infrastructure. Otherwise, the environmental benefits achieved during temporary crises are rapidly lost during the recovery phase, and the negative impact of transport on urban ecosystems continues.

In recent decades, strict environmental standards applied to road transport, including "Euro" emission standards, the widespread use of catalytic converters and improved fuel quality, have led to some reductions in emissions of a number of key air pollutants – nitrogen oxides (NOx), sulphur dioxide (SO_2) and particulate matter (PM). According to the European Environment Agency, the levels of some air pollutants originating from road transport have decreased significantly compared to the 2000s. However, the opposite trend has emerged in the aviation and maritime transport sectors over the same period, with the increase in international flights and freight transport in particular leading to an increase in emissions in these sectors (UNEP, 2021).

The increase in emissions in the aviation and shipping sectors mainly negatively affects coastal and marine ecosystems, as well as green zones located in port cities. Sulfur compounds and nitrogen oxides emitted from ship engines worsen the quality of sea air and intensify acidification processes in soil and aquatic ecosystems. At the same time, greenery in port areas and coastal cities is directly affected by these pollutants and cannot fully fulfill its ecological functions. This leads to a decrease in biodiversity in these areas and a weakening of the ecological sustainability of the urban environment.

Although the increase in the share of renewable energy sources in the transport sector is considered an important positive trend, the current indicators are still not considered sufficient to achieve the climate neutrality goals. According to Eurostat, the share of renewable energy sources in transport in the European Union in 2022 was only 8.7% (Eurostat, 2023). Although the rapid spread of electric vehicles contributes to the reduction of noise levels in urban environments and the limitation of local air pollution, as long as the overall intensity and spatial expansion of transport continue, the environmental pressure on urban and peri-urban green spaces does not decrease. This shows that long-term environmental sustainability cannot be achieved without integrated planning measures that prioritize the protection of green spaces and the reduction of transport demand, along with technological transformation.

Traffic noise is also a serious problem for urban ecosystems. Long-term noise has a negative impact not only on human health, but also on bird behaviour, biodiversity, and the ecological functions of urban green spaces (WHO, 2018).

Thus, achieving climate neutrality for Europe by 2050 is possible not only through technological innovation, but also through sustainable spatial and ecological planning that takes into account the transport-green interaction. More active modes of transport, green infrastructure, and reduced transport demand should act as the main pillars of this process.

Based on the results of the study and the challenges of modern urbanization, the following list of strategic proposals has been developed to ensure the balanced development of transport systems with urban

green spaces. These proposals aim at both environmental sustainability and the efficiency of urban infrastructure:

1. Establishment of a network of "Green Corridors" - It is envisaged to create continuous green strips along the edges of transport highways within the city. This not only has an aesthetic purpose, but also plays the role of a "biological bridge" between ecosystems fragmented by transport infrastructure. Multi-level greening (trees, shrubs, grass) can reduce noise levels by 10-15 decibels and perform the function of a natural filter that prevents the spread of harmful solid particles (PM10, PM2.5) into residential areas.

2. Application of water-permeable infrastructure against "Soil Sealing" - Instead of traditional asphalt pavement on roads and parking areas, environmentally sustainable, porous materials and "grass stones" should be used. This approach does not interrupt the contact of areas allocated for transport with the soil, allows rainwater to integrate into groundwater, and extends the life of urban plants by maintaining the oxygen supply of the root system of trees.

3. Integrated planning of micro-mobility and green zones - Bicycle paths and pedestrian routes should be isolated from highways and run directly inside or outside existing parks and gardens. This encourages the population to move away from private cars and use active modes of transport. As a result, the need for new road expansion projects decreases, and the process of "absorption" of urban greenery by infrastructure stops.

4. Application of Vertical and Roof Greening Systems - In city centers with high traffic density and limited space for additional tree planting, building facades and roofs should be greened. This method neutralizes the "heat island" effect by absorbing heat emissions from traffic and, in addition to increasing the energy efficiency of buildings, improves air quality at the local level.

5. Transition of public transport hubs to the "Eco-Hub" model - Bus stops and metro exits should be designed as "mini-ecosystems" rather than just transport points. Greening the roofs of parking lots and creating small "pocket parks" around them ensures citizens' contact with the ecological environment while waiting for transportation and increases the city's overall "green index".

4. Conclusion

Transport systems have historically been one of the main driving forces of human settlement, urbanization, and economic development. However, in modern times, the development model of transport, especially the automobile-oriented one, has created serious environmental problems such as the reduction of greenery in urban and peri-urban areas, hardening of soil cover, fragmentation of ecosystems, and weakening of biodiversity. As a result of the spatial expansion of cities and the intensive development of transport infrastructure, the ecological functions of greenery – air purification, carbon absorption, microclimate regulation – have weakened, putting the ecological sustainability of the urban environment at risk.

The research results also prove that although technological innovations and increasing energy efficiency in the transport sector are of great importance, these measures cannot fully compensate for environmental pressures against the background of the increase in the total volume of transport activity. Although some progress has been made in reducing greenhouse gas emissions in the European Union, the transport sector still remains one of the main sources of emissions. This situation leads to the fact that urban greenery has to bear the increasing ecological burden alone and its protective potential is limited.

Thus, to achieve a sustainable urban environment, it is necessary to apply a systematic and integrated approach between the planning of transport systems and the protection of green spaces. Promoting cleaner and more active modes of transport, expanding green infrastructure, reducing transport demand, and strengthening environmental priorities in spatial planning should be key directions in terms of protecting urban ecosystems. These approaches can not only reduce the negative impact of transport on the

environment but also contribute to ensuring the sustainability of urban green spaces and improving the quality of human life.

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