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Protection of the Environment in Terms of Functioning of Urban Transport. Literature Review

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Abstract: Environmental protection, as rational shaping of the environment, management of environmental resources following the principle of sustainable development, and counteracting pollution, is integrally related to the urban area. Therefore, most activities and initiatives are aimed at environmental protection in the cities, which are the living environment for half of the world's population. Therefore, the necessary action is to reduce the impact of urban transport on the environment. In particular, increased road traffic in urban areas is a constant increase in pollutants introduced into the environment in the form of solid, liquid and gaseous substances, harmful to people, the environment and spatial structures. One such negative impact of transport is the emission of CO_2 into the atmosphere. In the process of limiting it, actions are taken to shape urban transport systems and the mobility of city residents. In order to identify individual processes that are components of these activities, literature research was carried out, the results of which are presented in the article.

Keywords: environmental protection, emission, urban transport, transportation system, sustainable transport, mobility

1. Introduction

When analysing environmental protection issues, we often refer to waste management (Szymański et al. 2017) and energy recovery from waste (Sidełko 2021). Special activities are research aimed, for example, at the adsorption of odours emitted by waste (Piekarski et al. 2018) or the adsorption of leachates from municipal landfills (Piekarski et al. 2021). Nevertheless, it was the problem of climate warming that forced the reaction of many developed countries to look for solutions to reduce the emission of harmful substances by vehicles (Zajac et al. 2019), and in particular, to reduce carbon dioxide emissions. Almost 30% of total CO_2 emissions in the EU come from the transport sector, of which 72% are from

road transport. The significant impact of road transport is visible primarily in cities. Suspended dust or nitrogen dioxide generated from individual transportation harms human health and the environment.

Furthermore, transport contributes to climate change, air pollution and noise. It also covers a large area of land and contributes to urban sprawl, habitat fragmentation and congestion formation (Ejdys 2013). In addition, it generates significant noise, which is becoming more and more bothersome.

In this context, environmental protection includes activities undertaken by man to preserve the natural environment in the best possible condition, which leads to providing current and future generations with favourable living conditions with the possibility of using its resources without reducing their value. Of course, environmental protection is not only limited to caring for animate and inanimate elements of nature (soil, relief, inland waters, landscape and recreational values, greenery resources and air in cities). It also concerns protecting such aspects of human life as housing, and cultural and social conditions, which depend on the state of the natural environment and affect the quality of life. In addition, it refers to such activities as protection against noise and vibration, waste, chemical substances and threats arising from the broadly understood human transport activity.

This broad context of understanding environmental and nature protection indicates the need to consider its issues as a multifaceted idea. It combines the issues of coherent coexistence of social, environmental, legal and economic activities that will allow preserving the existing natural resources in at least an undeteriorated condition for future generations.

Undoubtedly, environmental issues in transport play an increasingly important role. All documents at the EU level, as well as national documents, are aimed at reducing transport emissions. As part of its efforts to reduce CO_2 emissions, the EU has set a target of reducing transport emissions by 60% by 2050 compared to 1990 levels. These efforts are already having an effect – air pollution is slowly decreasing – but much remains to be done, especially regarding the significant amount of freight transported by road.

The indicated problems related to ensuring environmental safety are at the centre of interest not only of scientists from various fields and disciplines of science but also of politicians, representatives of government and local government administration, local communities and non-governmental organisations. Scientific, social, economic and political debates are being conducted, which are becoming more and more intense along with the more and more severe effects of the disruption of the relationship between man and the natural environment, not only on a global but also local scale.

In this context, the article draws attention to activities that reduce CO_2 emissions in urban transport. Its purpose is to present selected research and activities

undertaken and implemented to reduce directly and indirectly CO_2 emissions by urban transport. The implementation of the goal is based on the literature analysis of the issue. The research used data available on the Scopus and Web of Science platforms.

2. Research Project

According to the Paris Agreement, CO_2 emissions in the area of transport are expected to be 240 g/km in 2031. However, in 2021, for Europe, CO_2 emissions in transport are already at the level of 250 g/km, i.e. exceeding the level that will be in force in ten years. When reducing emissions, it is necessary to take multi-stage actions to reduce the negative impact of transport on the environment. In transport, CO_2 emissions can be reduced by optimising the supply chain, in which planning orders in road transport (Woźniak et al. 2018, Woźniak et al. 2016) and optimising parking spaces (Kostrzewski & Varjan 2018) are important elements. An essential part is also shaping the pro-ecological transport system (Jacyna et al. 2018, Jacyna et al. 2017). Organisational and legal aspects of transport are also indicated as a factor of sustainable development (Filippova & Voronina 2021, Dmitriev & Plastunyak 2020, Chocholac et al. 2019). For the research, the $\boldsymbol{MCOT}$ model of the impact of urban transport on the environment was defined in the form of an ordered two, i.e.:

$$\boldsymbol{MCOT} = \langle \boldsymbol{ZT}, \boldsymbol{MM} \rangle \tag{1}$$

It is important that due to the objective of reducing the impact of transport on the environment, two areas were specified in this model: $\boldsymbol{ZT}$ – urban transport system, $\boldsymbol{MM}$ – mobility in urban areas. Each of these areas is an essential element of the adopted actions.

2.1. Research in the Area of the Urban Transport System

Cities are key centres of economic, social and cultural development with a strong impact on the surrounding regions. The city is the living environment for half the world's population, whose activity generates transportation needs. The adopted needs are reflected in the journeys carried out using individual and public transport. A significant number of these are means of road transport, which generate increased road traffic in cities. Research shows that road transport is responsible for 40% of CO_2 emissions in cities. Given the above problems, it has become necessary to look for solutions to limit this negative effect.

Research issues carried out in the field of the urban transport system include research in the area of shaping the transport system in the urban area st, research in the field of the intelligent transport system its and research on the implementation of zero-emission vehicles ev:

$$\boldsymbol{ZT} = \{st, its, ev\} \tag{2}$$

All these areas are interconnected, and the goal is to reduce the negative impact of urban transport on the environment. Therefore, an activity aimed at reducing the negative impact of urban transport on the environment was adopted to implement the concept of balancing transport in urban areas (Chamier-Gliszczyński 2011, Ejdys 2017). The main goal of reducing CO_2 emissions in cities.

Shaping the transport system in an urban area (Chamier-Gliszczyński 2012) takes into account environmental aspects (Kumar et al. 2021, Sidorchuk et al. 2021, de Almeida et al. 2021) and, in particular, the concept of sustainable development (Jacyna & Wasiak 2017, Ejdys 2009). Identification of research tasks carried out in the field of shaping the transport system in the urban area is presented in Table 1.

Table 1. Research tasks in the field of shaping the transport system in the urban area

Research area	Source
Optimisation of the location of P&R facilities as potential solution in shaping the urban transport system.	Manaswinee et al. 2023
Research on the intensity of CO_2 emissions in terms of individual means of transport and modes of movement in cities.	Vajjarapu et al. 2023
Studies of passenger flow in urban transport networks.	Weerasinghe & Bandara 2023
Study of air quality in urban space in terms of optimisation of transport tasks.	Li et al. 2023
The construction of transport models, in which traffic measurements supplemented with an analysis of the behaviour of travellers moving in urban areas, are important elements.	Kłos et al. 2020
Modelling of the transport network, considering individual transport subsystems and relations between them.	Soczówka et al. 2020
Identification and configuration of functional and operational tasks in urban transport projects. The research referred to various decision-making problems related to the shaping of transport systems, decisions of transport users, and traffic flows in the urban transport network.	Karoń & Mikulski 2020
Identification of methodologies for redesigning and evaluating public transport systems in urban areas.	Żak & Kiba-Janiak 2018

Table 1. cont.

Research area	Source
Identification of traffic parameters for sections of the transport network in highly urbanised areas.	Jacyna & Wasiak 2016
Modelling urban transport services, taking into account various means of transport.	Jacyna et al. 2015
Modelling transport preferences on the example of inhabitants of Polish cities.	Cheba et al. 2015
Modelling travel demand in dense street networks. An important element of these studies was the estimation of the travel schedule in terms of the urban street network.	Zochowska 2012

In turn, the research area of the intelligent transport systems its includes the following research areas: (1) research on the implementation of the intelligent transport system as a tool for managing traffic congestion in cities (Żochowska & Karoń 2016, Hamadeh et al. 2021), (2) research focused on the use of an intelligent transport system in the field of traffic management in urban areas (Bhatia et al. 2022), specifying the scope of traffic light control (Petrica et al. 2021), (3) analysis and study of the implemented ITS systems in urban areas (Żochowska et al. 2018, Karoń et al. 2018, Drop & Garlińska 2021, Xue & Xue 2020).

When analysing the aspect of environmental protection in terms of the functioning of urban transport, we must refer to the means of transport used in transport processes carried out in urban areas (Gedik et al. 2022). It should be emphasised that in the analysed transport structure, the means of road transport constitute an important link. Therefore, it is important to undertake research aimed at reducing the impact of road transport on the environment, i.e. zero CO_2 emissions from transport in cities. One of these activities is the implementation of zero-emission vehicles in urban traffic, where electric vehicles constitute an important group. Identification of research tasks carried out in introducing zero-emission vehicles into traffic is presented in Table 2.

Table 2. Research tasks in the implementation of zero-emission vehicles

Research area	Source
Construction of transport models for urban areas where electric vehicles are used.	Jacyna et al. 2021
Research aimed at developing a method enabling the identification of critical inter-stop sections that have the greatest impact on disruptions in the traffic of electric buses.	Barchański et al. 2022
Assessment of the environmental impact of activities aimed at replacing the fleet of classic buses with electric buses in urban traffic.	Leichter et al. 2022

Table 2. cont.

Research area	Source
Optimisation of the bus's ability to cover designated routes in city traffic.	Gairola & Nezamuddin 2022
Optimising the use of electric batteries and hydrogen fuel cells in zero-emission vehicle fleets.	Blades et al. 2022
Shaping financial and environmental needs in terms of using electric buses in collective public transport.	Lu et al. 2022
Shaping charging systems for electric and hybrid vehicles	Dižo et al. 2021
Research on the implementation of electric buses in cities and the development of the basis for intelligent transport, in which electric vehicles will be the link.	Janecki & Karoń 2014, Karoń 2022

2.2. Research in the Field of Mobility in Urban Areas

In the research issue of mobility in urban areas $\boldsymbol{MM}$, research is carried out that considers the aspect of a new approach to mobility in urban areas. This approach has been formulated in European documents as a new culture of mobility. It was emphasised that mobility enables the development of urban areas, ensures an appropriate standard of living for its inhabitants and protects the natural environment. The position adopted in this way generated research aimed at shaping the mobility of inhabitants of cities kmm and taking actions aimed at promoting pro-ecological urban mobility pem, i.e.

$$\boldsymbol{MM} = \{kmm, pem\} \tag{3}$$

Selected research areas in the field of mobility in urban areas are as follows:

- modelling mobility in urban areas (Suryani et al. 2021, Al. Maghraoui et al. 2019),
- assessment of the mobility of residents (Medina et al. 2021, Chamier-Gliszczyński & Bohdal 2016, Gudmundsson 2003),
- shaping transport systems and mobility in the area of smart cities (Ribeiro et al. 2021, Chamier-Gliszczyński 2012a),
- mobility in a sustainable environment (Medina-Sanchez et al. 2021, Can et al. 2020, Chamier-Gliszczyński & Bohdal 2016a),
- researching and analysing the mobility of city dwellers (Gorzelanczyk 2021),
- optimisation of shared mobility of city dwellers (Soppert et al. 2023),
- research into the elements of sustainable urban mobility (Kiviluoto et al. 2022),
- the research focused on the implementation of the green strategy in mobility planning in urban areas (Pamucar et al. 2022),
- optimisation of urban mobility in terms of the layout of streets in a given area (Tokuda et al. 2022).

3. Summary

A city is a place of man's life, activity and work in the modern world. Due to these aspects and the continuous development of cities, there is CO_2 emission generated by urban transport in their areas. Therefore, research and activities are undertaken in urban transport to reduce and counteract this emission. The article shows that these activities aim to shape transport systems in urban areas, research the field of intelligent transport systems and research the implementation of zero-emission vehicles. In addition, it was indicated that research is being undertaken in shaping the mobility of city residents as well as promoting and implementing pro-ecological urban mobility.

Literature analysis based on Scopus and Web of Science sources emphasised that research in environmental protection in urban transport is an essential element of global scientific research.

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