

Impact of railway infrastructure on sustainable development of regions

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Abstract. The study of the impact of railway infrastructure development on the sustainable development of regions is relevant for many reasons and requires additional attention. Firstly, the railway infrastructure is a crucial element of the transport system, providing communication between different regions and contributing to economic development. Secondly, the development of the railway infrastructure can improve the accessibility of the regions, which can lead to an increase in the tourist flow and trade volumes. Thirdly, the development of railway infrastructure can contribute to reducing environmental pollution, as it is a more environmentally friendly form of transport than automobile or aviation. The scientific novelty lies in using PESTE analysis to study the impact of railway infrastructure on the sustainable development of regions and in the combination of PESTE-factors with identifying opportunities and threats to regional development for each factor. General scientific and unique methods are used: analysis, synthesis, tabular-graphic, theoretical generalization and abstract-logical. Carried-out research on the railway's infrastructure impact on the sustainable development of regions helps to determine the most effective strategies for transport system development, environmental management and regional economy.

1 Introduction

The features and prospects for sustainable development of regions and the world are complex and diverse, reflecting a wide range of economic, social, environmental, technical and political aspects [1]. Regional development contributes to increased economic activity and production and GDP growth. Regions with diverse and competitive economies can attract investment, create jobs, and increase incomes.

Regional development includes the development of infrastructure such as transport networks, communications, energy and others. This ensures more efficient use of resources and improves access to them.

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Improved infrastructure and access to resources contribute to economic growth and increased competitiveness of regions, which ultimately has a beneficial effect on GDP and state stability. For Ukraine and the world community as a whole, sustainable regional development represents both a challenge and an opportunity for creating prosperous and sustainable societies based on the principles of environmental responsibility, social justice and economic efficiency.

2 Analysis of recent research and publications

Research of the railway's infrastructure impact on the regions' sustainable development is relevant and important in today's world. Scientists from different fields, such as transport science, economics, ecology and sociology, study this issue from different perspectives. Problems of reforming and technical development of railway enterprises, renewal of rolling stock, development of railway infrastructure are highlighted in the works of many Ukrainian scientists [2-8].

The scientific papers of Ukrainian scientists, as: T. Porudieieva [9, 10], O. Soltysik [14], K. Redko [13], N. Kondratenko [5] are dedicated to the study of sustainable development processes and sustainable development of regions.

Questions of crises and their influence on sustainable development are discussed by L. Martseniuk and O. Galushko in [3, 7]. Aspects of infrastructure and real estate development, and its influence on sustainable development of regions, are discussed by O. Galushko and G. Ciobanu in [4]. Questions of sustainable production are discussed by D. Atstaja et al [1]. R. Kostiukevych, H. Mishchuk, U. Nikonenko, T. Shtets in [6, 8] discuss sustainable development from economic and investment point of view.

Research on the influence of railway infrastructure on the sustainable development of regions occupies an important place in the modern scientific community. Some researchers [3, 7, 11, 12] examine this issue from the standpoint of economic development. They believe that the development of railway infrastructure can significantly improve transport connections in the regions, which will contribute to the sustainable growth of the economy. Other researchers emphasize the social aspects of the influence of railways on the development of regions. They study the impact of the availability of transport services on the residents' quality of life, as well as the promotion of the development of public transport through the development of the railway network.

Kondratenko et al. [5] focus on the ecological aspects of railway development. They are investigating the possibilities of reducing emissions of CO₂ and other harmful substances into the atmosphere through the modernization of transport infrastructure. Some scientists investigate the effectiveness of investments in developing railway infrastructure for regional development. I. Chupryna, V. Stupnytskyi et al., discuss clean energy and environmental compliance issues and their impact on regional development [2, 15]. Kostiukevych et al. [6] analyze the impact of such investments on the economy of the region and the possibilities of attracting new business projects. Another group of researchers [6-8] examines innovations in rail transport and their impact on sustainable development. They analyze new technologies and approaches to rail industry management to improve productivity and efficiency.

In general, the current state of research shows a wide range of approaches to studying the of railway's infrastructure impact on the regions' sustainable development. The results of these studies will help to develop strategies to improve the infrastructure and transport system, and contribute to the sustainable economic, social and environmental development of the regions.

3 The purpose of the article

The purpose of the article is to carry out the research of the influence the railway's infrastructure development on the economic, ecological and social aspects of the sustainable development of regions. The article includes a theoretical and methodological justification and identification of practical advantages and potential opportunities for the development of railway infrastructure to create sustainable and prosperous regional socio-economic and environmental systems.

4 Results

Sustainable development of regions is closely related to the Sustainable Development Goals adopted by the United Nations. The Sustainable Development Goals (SDGs) are an international action plan to combat poverty, protect the planet, and ensure well-being for all people. Regions' sustainable development makes a significant impact and directly contributes to the achievement of these goals. The key links between regions' sustainable development and the SDGs include:

1) *Economic development*. Development of regional infrastructure, creation of jobs, stimulation of economic growth and improvement the standards of living for people, contribute to the achievement of the SDGs, such as reducing inequality, decent work and economic growth.

2) *Environmental sustainability*. Promoting clean technologies, reducing greenhouse gas emissions, protecting natural resources and combating climate change are important for achieving the SDGs related to environmental sustainability.

3) *Social justice and well-being*. The development of education, health care, social protection and infrastructure in the regions helps to reduce inequality, improve the situation of people and their quality of life, and provide all people with equal opportunities, which is a key aspect of the SDGs.

4) *Innovations and technologies*. Regions' sustainable development requires the introduction of innovations and new technologies in various industries, to lift up the efficiency of resources use and to reduce the negative impact on the environment.

5) *Global responsibility*. Sustainable development of regions is connected with global challenges, such as reducing inequality, fighting poverty and ensuring global security, which requires cooperation and coordination of actions at the international level.

The opportunities and problems of sustainable development of regions in Ukraine and in the world are complex and diverse, they reflect a wide range of economic, social, environmental and political aspects.

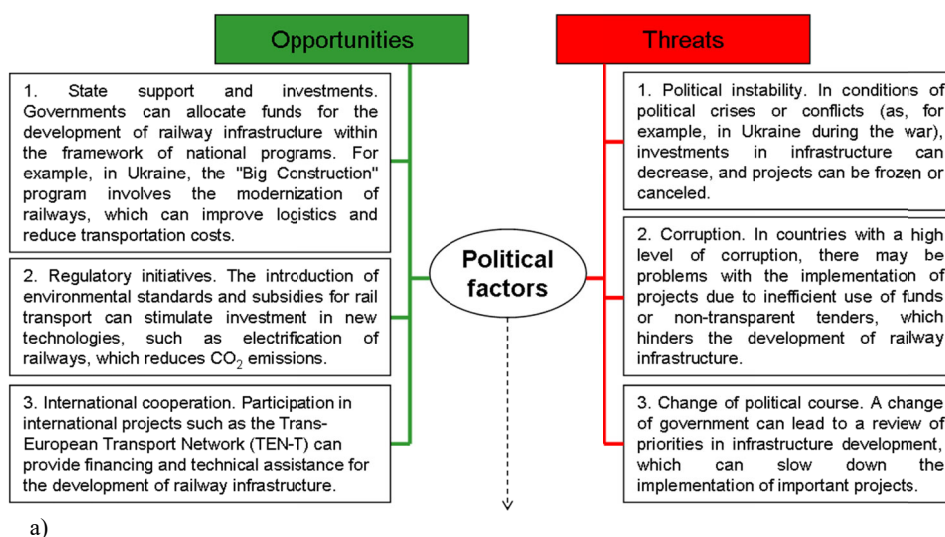
PESTE analysis is a strategic planning tool that helps assess external factors affecting the business environment. PESTE stands for Political, Economic, Social, Technological and Environmental Factors. The main purpose of the PESTE analysis is to identify external factors that can have a major impact on business / regional strategy and development. Analyzing each of these five aspects helps businesses and regions better understand their environment and predict opportunities and threats that may arise in the future. This tool helps to see the wider context and take into account external factors when formulating strategies for development and adaptation to changes in the environment. That is how each of the factors can be applied to the sustainable development of regions:

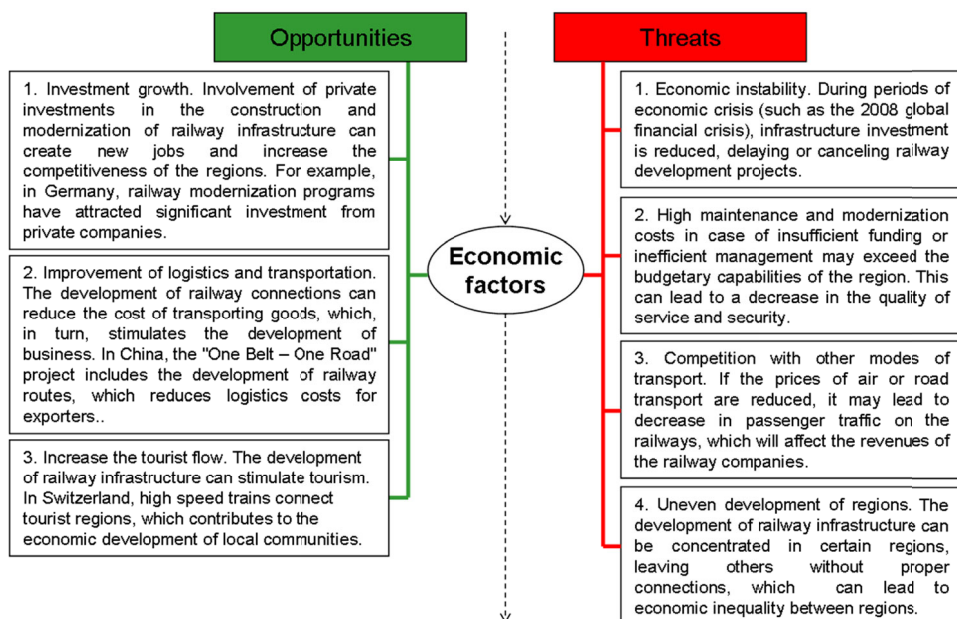
1. Political factors:

- Assessment of political stability and level of corruption in the region.
- Analysis of the legislative base supporting sustainable development.

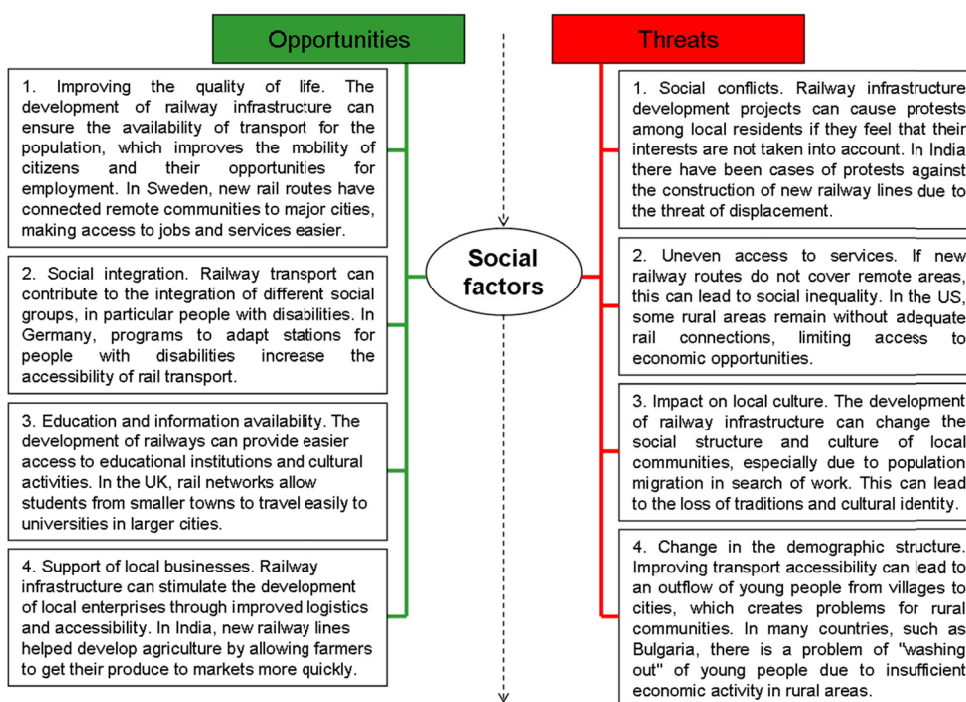
- Study of state programs and strategies aimed at sustainable development.
- 2. Economic factors:
 - Study of economic growth and investment climate in the region.
 - Assessment of the unemployment rate, income level and inequality.
 - Analysis of financial resources and opportunities for financing sustainable projects.
- 3. Social factors:
 - Study of demographic trends, educational level and access to healthcare.
 - Assessment of socio-cultural features and public opinion on issues of sustainable development.
 - Inclusion of the needs and interests of local residents in the planning of sustainable development programs.
- 4. Technological factors:
 - Analysis of innovative technologies capable of increasing the efficiency of sustainable projects.
 - Study of digitization and the possibilities of using information technologies to improve sustainable development.
 - Assessment of the regional technological potential for the implementation of environmentally friendly solutions.
- 5. Environmental factors:
 - Diagnostics of the natural environment and resources of the region.
 - Analysis of threats of climate change, environmental pollution and unsustainable use of natural resources.
 - Development of strategies for environmental protection and reduction of negative impact on ecosystems.

PESTE analysis with focus on opportunities and threats of sustainable development of regions, allows to get a more complete picture of external factors that can affect the success of sustainable initiatives, as well as to develop strategies for achieving sustainable development in the long term. Using PESTE to analyze the sustainable development of regions allows us to identify key factors that need to be taken into account when developing strategies and projects aimed at achieving sustainable economic, social and environmental development (Fig. 1a-e).

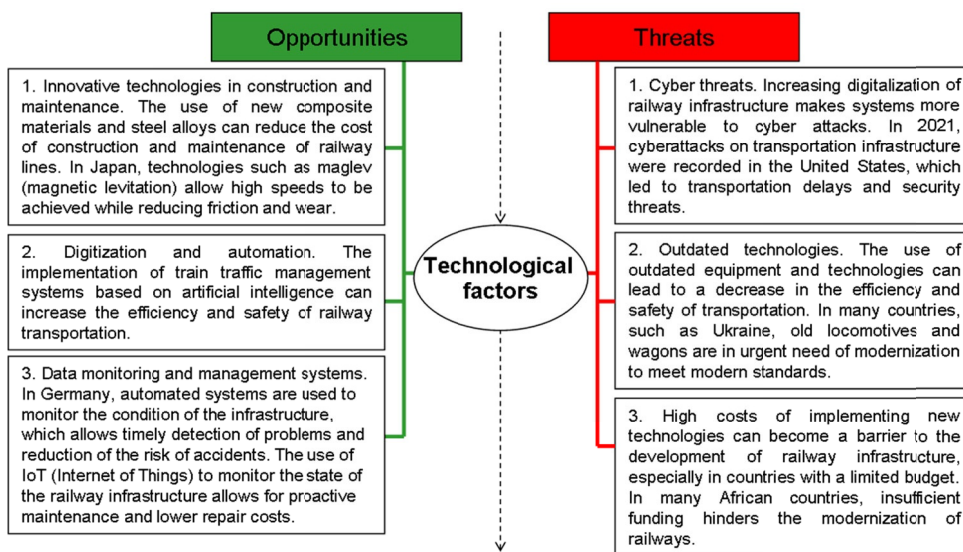




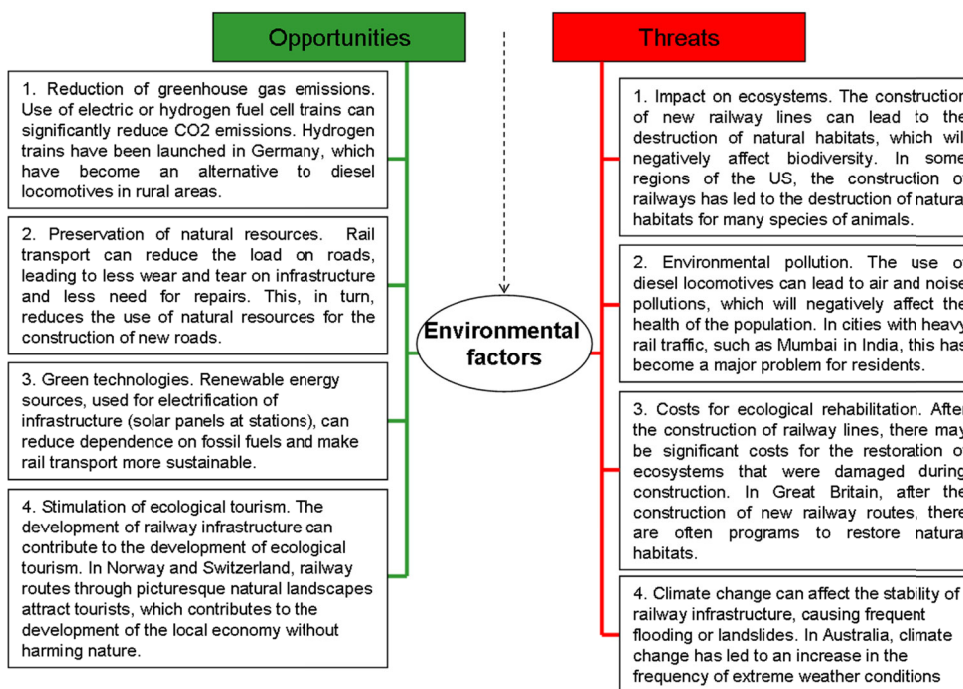
b)



c)



d)



e)

Fig. 1 (a-e). PESTE-factors, opportunities and threats of the railway infrastructure impact on the sustainable development of regions.

Thus, the development of railway infrastructure can pose both significant opportunities and potential threats to the sustainable development of regions, depending on how these factors are managed and taken into account when planning and implementing projects. Following examples (Table 1) demonstrate how the development of railway infrastructure can have a multifaceted positive impact on the sustainable development of regions, contributing to economic growth, social integration and environmental sustainability.

Table 1. Examples of railway infrastructure impact on regional development.

Railway infrastructure	Economic impact	Social impact	Environmental impact
Transcontinental Railroad, USA	Completion of the first transcontinental railroad in the US contributed to economic growth by connecting the East and West coasts. This facilitated the transportation of goods and people, contributing to the development of new markets and industrial centers.	The railroad contributed to the settlement of the Western territories, allowing people to move quickly and safely.	Although the initial impact on the environment was significant due to deforestation and changing landscapes, the railway later helped to reduce reliance on less environmentally friendly modes of transport such as horse-drawn carts.
Baikal-Amur Mainline (BAM), formed USSR	BAM contributed to the development of remote areas of Siberia and the Far East. This made it possible to discover new mineral deposits and develop industry in these regions.	The construction of BAM provided employment to thousands of people and contributed to the creation of new settlements. The railway also improved transport accessibility for local residents.	Although the construction of the highway had a certain negative impact on the environment, in particular on forest areas, in the long term it contributed to the reduction of the use of less ecological modes of transport.
European high speed rails (ICE in Germany; TGV in France)	High speed railway contributed to the economic integration of regions, providing fast and efficient connections between major cities. This supported the growth of entrepreneurship and the tourism industry, and also increased the competitive advantages of the regions.	High-speed trains have made travel more accessible to a wide range of people, promoting population mobility and social integration.	High-speed railways are more environmentally friendly compared to air and road transport, which allows to reduce greenhouse gas emissions and minimize environmental damage.
Railway network of China	The rapid development of railway infrastructure in China, including high speed railways, has contributed to the country's economic growth. It has made the transportation of goods and passengers more accessible, which promotes the development of the domestic economy and foreign trade	The rail network has improved transport accessibility for millions of people, providing fast and convenient connections between cities.	Investments in rail infrastructure have helped reduce dependence on road transport, resulting in lower greenhouse gas emissions and improved quality of air.

The railway infrastructure of Ukraine is one of the most important components of the country's transport system. Ukrainian railways have a significant impact on the economic, social and environmental development of the regions.

The Ukrainian railway network is one of the largest in Europe, with a total length about 20,000 kilometers. Only half of the railway network is electrified. The process of electrification helps reduce greenhouse gas pollution and reduce dependence on non-renewable resources. "Intercity+" high-speed trains operate in Ukraine, providing fast connections between major cities such as Kyiv, Kharkiv, Lviv, Odesa and Dnipro. Ukrainian railways play a key role in the transportation of goods, including agricultural products, manufactured goods and raw materials. This contributes to the development of domestic trade and exports. Having a developed railway infrastructure encourages business development, especially in remote regions where other modes of transport are less accessible or efficient.

Ukrainian railways provide affordable and convenient transportation for millions of people, especially for those residents, who live in remote corners or do not have access to vehicles. A developed railway network promotes social integration, improving communication between different regions of the country and facilitating access to educational, medical and cultural services. Despite the significant potential, the Ukrainian railway system faces a number of challenges:

- State of the infrastructure. Many sections of the railway network need modernization and repair;
- Funding. Insufficient funding limits opportunities for development and modernization of railway infrastructure;
- Competition with other modes of transport. Road and air transport are often more attractive due to speed and comfort.

The developed railway infrastructure of Ukraine has a significant positive impact on the sustainable development of the regions and on SDGs achievement. It contributes to economic growth, social integration and reduction of environmental burden. However, further development requires investments in infrastructure modernization, management efficiency improvement, and service quality improvement.

Railway transportation is one of the most energy-efficient and environmentally friendly types of transport, which allows to reduce the pollutions and to reduce the negative influence on the nature. Thanks to the development of the railway infrastructure, the regions can significantly improve their transport accessibility, which contributes to the increase in the volume of cargo and passenger transportation.

The economic impact of railway infrastructure is manifested through stimulation of local business development, investment attraction and creation of new jobs. The railway provides an efficient transport connection between different parts of the region, which contributes to the development of logistics centers, industrial zones and tourist facilities. This, in turn, increases the competitiveness of the region, including international level.

The social aspect of railway infrastructure development consists in improving the peoples' wellbeing and quality of life. The railway provides convenient and affordable transport for the residents of the regions, which contributes to their mobility and social integration. In addition, the development of the railway infrastructure contributes to the improvement of road traffic safety, as the load on the roads is reduced and the risk of traffic accidents is reduced.

From an ecological point of view, the development of railway infrastructure contributes to the preservation of natural resources and the reduction of environmental pollution. In addition, railway transportation contributes to the reduction of noise pollution, which has a positive effect on the health of the population.

Thus, the development of railway infrastructure is an important factor in the sustainable development of regions, as it ensures economic growth, improves life's quality of people and contributes to the preservation of the environment. Investing in railway infrastructure should become a priority area of regional development policy, which will ensure sustainable development in the long term. And, in turn, regional development significantly influences on GDP and the stability of the state as a whole. Here are some aspects of this influence:

1) *Economic growth*. The development of regions contributes to the increase in economic activity and production, which in turn contributes to GDP growth. Regions with a diverse and competitive economy can attract investments, create new jobs and increase the income of the population.

2) *Reduction of inequality*. Regional development can help reduce income inequality and social differences between different regions. A more even distribution of income contributes to social stability and the reduction of social tensions.

3) *Economic stability*. The development of different regions creates a more stable economic system at the national level. If the country's economy depends on one or several narrow sectors, then there is a risk of an economic crisis when the demand for these goods or services decreases. The development of different regions with various industries and sources of income helps mitigate such risks and ensure the stability of the economy as a whole.

4) *Political stability*. Regional development can contribute to political stability at the national level. Improving the economic situation and social conditions in the regions can reduce the level of discontent of the population and political conflicts. Same time, expanding of the regional institutions and increasing the level of citizens' participation in decision-making also contribute to political stability.

5) *Infrastructure and access to resources*. Regional development includes the development of infrastructure, such as transport networks, communications, energy, and others. This ensures more efficient use of resources and improves access to them. Improved infrastructure and access to resources contribute to economic growth and increased competitiveness of regions, which ultimately has a positive effect on GDP and the stability of the state.

Thus, regional development has a significant multifactor impact on GDP and the stability of the state as a whole, as it contributes to economic growth, economic stability, income distribution, political stability, and improved access to resources.

5 Conclusions

The development of railway infrastructure can have a significant impact on the sustainable development of regions, providing positive results for the economy, the environment and the social sphere. It contributes to the improvement of the transport accessibility of the regions and makes it possible to speed up the movement of people and goods, reduce logistics costs and increase the efficiency of economic activity.

Railway infrastructure can become a powerful catalyst for the economic growth of regions. The creation of new transport links contributes to the attraction of investments, the development of tourism, the expansion of sales markets and the increase of trade volumes. The development of railway infrastructure can contribute to the creation of new jobs in the regions. The construction and operation of railways require a large number of workers, which allows to increase the level of employment.

Railway transport is considered to be more environmentally friendly than automobile or air transport. The development of railway infrastructure can contribute to reducing the emissions of harmful substances and improving the quality of the environment in the regions as well as support the social development. The improvement of transport accessibility contributes to the increase in the level of education, the availability of medical services and cultural events, and also contributes to the strengthening of connections between different settlements.

For Ukraine and the world community as a whole, the sustainable development of regions is both a challenge and an opportunity to create prosperous and sustainable societies based on the principles of environmental responsibility, social justice and economic efficiency. Thus, modeling the influence of railway infrastructure development on the sustainable development of specific regions is a relevant and promising direction for further research.

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