Verifying the Economic Potential of Low-Carbon Energy Using Artificial Intelligence in Transport

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Abstract

Integration of artificial intelligence in the transport networks plays a crucial role in the path towards green transport transition. Considering this, the article is devoted to developing methodology for verifying the economic potential of low-carbon energy using artificial intelligence in transport. To reach this goal, it was used the method of correlation-regression analysis, which allowed to identify key factors, characterize their influence on the resulting variable (gross value added), and established causal relationships between the factors and the resulting variable in an analytical form. It has been investigated that the use of natural energy sources by transport has an effect on the reduction of gross value added in transport. Conversely, the use of low-carbon energy sources (particularly biofuels) and electricity with the using artificial intelligence in transport is a factor that promotes an increase in gross value added, while also ensuring climate neutrality. It were base for the development of the substantive components of forming a digital communicative environment for providing eco-transport services. The obtained results are the basis for further research on the use of GIS technologies in the diversification of low-carbon energy sources in transport.

Keywords

Smart transport, smart urban mobility, green transport, artificial intelligence, low-carbon energy[1]

1. Introduction

1.1. Problem statement

Under the low-carbon energy and transport transition, the use of artificial intelligence is aimed at enhancing the efficiency of renewable energy sources in transport, mitigating risks associated with their integration into the energy grid, coordinating technological processes of energy production and supply for transport, conducting monitoring and verification of ecological and economic impacts of using low-carbon energy sources in transport. "Technologies (more precisely, "technological changes") are considered to be the main drivers of structural transformations of territorial economic development; the emergence and disappearance of new products and production technologies occur within specific territories and largely depend on their ability to generate specific innovations" [1].

Furthermore, the Fourth Industrial Revolution was characterized as the synergy of the physical, digital, and biological spheres in technologies. At this stage of innovation development, it should be noted that there is a rapid transition from Industry 4.0 technologies to Industry 5.0 and beyond.

To ensure the implementation of measures for prevention, mitigation, and adaptation to climate change through the use of "green" digital technologies in the European Union, the Declaration "Green and Digital Transformation of the EU" has been approved. This Declaration includes the development of green digital technologies for the achieve climate neutrality in

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priority sectors including transport. In turn, participants of the COP26, COP27, and COP28 Conferences in 2021-2023 also focused on climate change. This determines the need for verifying the effectiveness of low-carbon energy sources using artificial intelligence tools in transport.

1.2. Related work

In the context of developing a "smart" city and green urban mobility, "among the innovative solutions, the application of piezoelectric sensors is highlighted for converting deformations and vibrations on sidewalk layers into electrical energy" [2]. Moreover, it is greatly valuable to consider "European experience in forming "smart" cities and managing "smart" transport by developing various programs based on the Internet of Things (for example, "smart" traffic lights equipped based on artificial intelligence systems) [3, 4, 5].

The smart transition to managing urban transport infrastructure involves using artificial intelligence in the city to increase interactivity and efficiency of the urban transport infrastructure. At the same time, with the aim of saving the environment, ensuring economic growth, and social justice, significant importance is attributed to forming a culture of responsible consumption of available resources. Specifically, the formation of a smart city development system entails three pillars (citizen engagement, infrastructure based on digital technologies, and urban services) and six universally recognized dimensions (people, economy, governance, mobility, environment, and the level and quality of population life). "Intelligent transport system technologies include modern wireless, electronic, and automated technologies that can reduce emissions through optimize traffic flows" [6].

In the context of researching the introduction of low-carbon technologies in transport based on using green energy and the development of smart cities [7, 8, 9], the concept of the "energy network of the future" includes digital technologies that utilize renewable energy sources. The management of such a system is carried out using artificial intelligence tools" [10]. In [11] the smart interaction between producers of "green" thermal energy and consumers is based on solutions of the HEAT 4.0 project. The integration of digital technologies and artificial intelligence into the energy grid necessitates determining the economic potential of low-carbon energy using artificial intelligence. Under the "smart" sustainable mobility and municipal ecology, it is important to diagnose the role of low-carbon energy using artificial intelligence in transport. The functioning of web systems for environmental expertise is considered in the work [21]. Air pollution from the influence of motor vehicles is also given in the work [22]

The purpose of the article is to develop a methodology for verifying the economic potential of low-carbon energy using artificial intelligence in transport.

2. Materials and Methods

2.1. Methodology

Ensuring the transition of enterprises to a low-carbon energy management system using artificial intelligence is based on the results of previous research conducted by the authors. Specifically, it involves the algorithm of operation of "smart" energy networks based on omnichannel principles [4, 12], the interaction between consumers of "green" energy, companies producing "green" energy, and energy service companies in a virtual environment [4, 13], using environmentally friendly technologies by enterprises [14]. The conducted research serves as a basis for developing an algorithm for verifying the economic efficiency of low-carbon energy sources using artificial intelligence tools.

The Figure 1 demonstrates the algorithm used for "smart" energy networks based on omnichannel principles, which was used for research. In particular, this algorithm includes the creation of virtual corporate platforms, and mobile applications for synchronizing the requests of eco-transport users with information about operating electric filling stations. In our research, the use of various types of energy with the application of artificial intelligence is considered as a factorial space (factors of influence) for the formation of economic stability (gross value added) of economic entities based on principles of resource efficiency and low-carbon development.

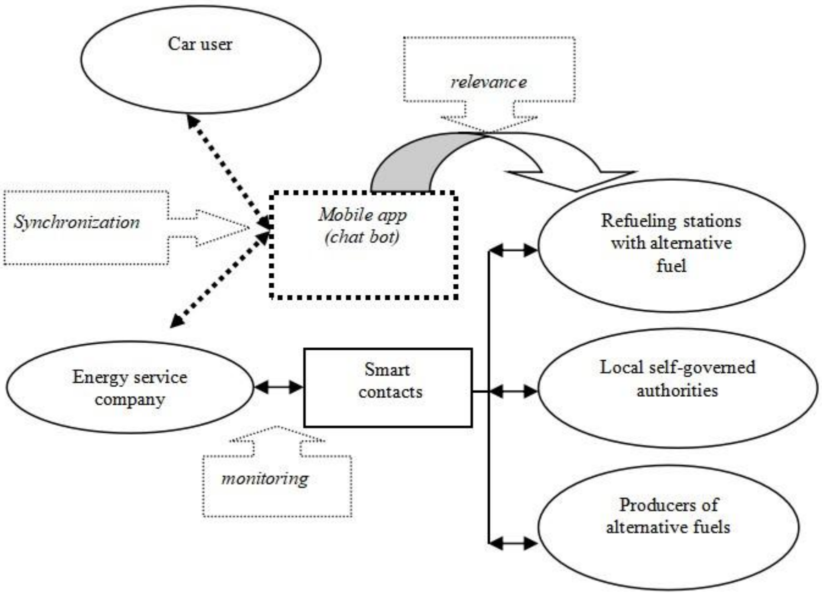

Figure 1: The algorithm used for "smart" energy networks based on omnichannel principles [4, 12]

To reach this goal, it was used the method of correlation-regression analysis, which allowed to identify key factors, characterize their influence on the resulting variable (gross value added), and established causal relationships between the factors and the resulting variable in an analytical form. This will enable us to verify the effectiveness of low-carbon energy sources using artificial intelligence tools. For the study, we will use statistical data on energy consumption relative to oil equivalent, as well as data on output and gross value added by types of economic activities [15, 16].

For factorial analysis, we use the correlation-regression analysis, which allows to identify the dependence of the economic potential of low-carbon energy sources using artificial intelligence tools on the types of energy used in production processes, such as petroleum (oil) products, natural gas, biofuels, and electricity. The procedure for searching for dependencies typically includes stages of establishing the presence and significance of the relationship between them, as well as the possibility of representing this dependency in the form of a nonlinear multiple regression which is presented with a following formula:

$$y(\vec{x}) \ = b_1 + b_2 \cdot x_1{}^{b_3} + b_4 \cdot x_2{}^{b_5} + b_6 \cdot x_3{}^{b_7} + b_8 \cdot x_4{}^{b_9} \qquad (1)$$

$y(\vec{x})$is the indicator of the economic potential of low-carbon energy sources using artificial intelligence tools in transport (added gross value);

$\vec{x}$is vector of values of impact factors corresponding to types of energy used in production processes. In particular, the types are:

x_1– petroleum products;

x_2 – natural gas;

x_3 – biofuels;

x_4 – electricity;

$b_1, \dots, b_9$ – parameters of nonlinear model.

To build the correlation field and regression equation, we used the Microsoft Excel spreadsheet software from the Microsoft Office 2019 suite of applications.

The analytical representation of the stochastic connection of energy consumption factors and the indicator of the economic potential of low-carbon energy sources using artificial intelligence tools in transport has the form of non-linear polynomial functions of the second degree and the third degree.

2.2. Case study

The first stage in the specified statistical analysis involves identifying the so-called correlation or correlation dependence. To do this, we will construct a correlation plot, where the x-axis will represent the value of the factor, and the y-axis will represent the value of the indicator of the economic potential of low-carbon energy sources using artificial intelligence tools. The second stage involves constructing the regression equation (1) for the investigated features. This is done using the method of least squares, where the coefficient of determination R^2 is used as a statistical measure of the dependency of the variation of the dependent variable on the variation of the independent variables.

The analytical representation of the stochastic interconnection between energy consumption factors and the indicator of the economic potential of low-carbon energy sources using artificial intelligence tools in transport takes the form of nonlinear polynomial functions of the second and third degree.

Based on the formed factors (types of energy used in the production process: petroleum products, natural gas, biofuels, electricity), we will construct an econometric model of the economic potential of low-carbon energy sources using artificial intelligence tools in transport. For this purpose, we will use the apparatus of regression analysis, specifically the method of least squares (MLS).

Taking into account the results obtained from the correlation-regression analysis of stochastic relationships between factors and the indicator of economic potential of low-carbon energy sources using artificial intelligence tools in transportation, we will build the econometric model in the form of a nonlinear multiple regression.

The model of the economic potential of low-carbon energy sources using artificial intelligence tools in transport looks as follows:

$$\hat{y}(\vec{x}) = 25597 + 539{,}1\, x_1^{-12.763} + 222{,}02 x_2^{1.0605} + \\ + 4{,}8476 \cdot 10^5 x_3^{0.13014} + 2127{,}3 x_4^{0.99234} \qquad (2)$$

To project the model, the MatLab software suit has been used. Precisely, the fitnlm function of NonLinearModel, which belongs to Statistics and Machine Learning Toolbox. This specific tool is designated to analyze and model data using statistics and machine learning.

The diagram in Figure 2 demonstrates that the factors of energy consumption, such as natural gas, biofuels, and electricity, have the greatest influence on the economic potential of low-carbon energy sources using artificial intelligence tools in transport.

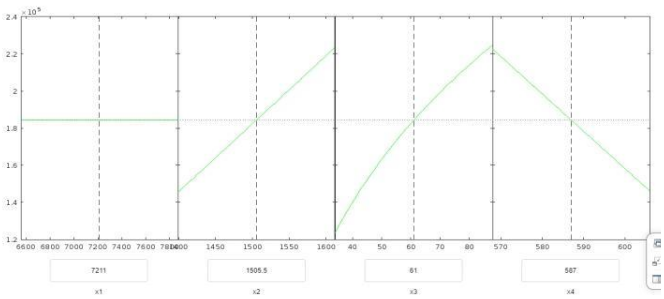

Figure 2: The diagram shows sections of the economic potential model of "green" energy consumption using artificial intelligence by enterprises in transport

It has been investigated that the use of natural energy sources by transport has an effect on the reduction of gross value added in transport. Conversely, the use of low-carbon energy sources (particularly biofuels) and electricity with the using artificial intelligence in transport is a factor that promotes an increase in gross value added, while also ensuring climate neutrality. It were base for the development of the substantive components of forming a digital communicative environment for providing eco-transport services.

3. Discussion

However, "the total volume of annual greenhouse gas emissions, including those from land-use changes, reached a record level of 55.3 Gt(gigatons) of CO_2e in 2018. CO_2 emissions from the combustion of fossil fuels in energy and industry, which dominate the total volume of GHG emissions, increased by 2% in 2018, reaching a record 37.5 Gt of CO_2e per year" [17].

This stimulates constant improvement of low-carbon activities of transport, and expansion of environmentally friendly processes. Particular importance lies in the verification of the economic potential of low-carbon energy using artificial intelligence in transport.

The trends in the development of artificial intelligence (smart technologies) influence the determination of the format of climate management in the using low-carbon energy by transport. The development of "smart" local energy networks based on the using Smart Grid system, which is aimed at automating the management process of production, transmission, and distribution of electrical energy [18, 19, 20].

"In the context of Internet of Things development, both Distributed Ledger Technologies (DLTs) and blockchain networks serve as the foundation for diversifying the directions of smart city development" [19]. Taking this into account, the formation of organizational support for integrating low-carbon innovations into the transport system involves using artificial intelligence to verify the effectiveness of low-carbon energy innovations in transport. Given this, the specifics of forming the architecture of the communicative environment in the context of climate-neutral development lie in considering the digital technologies development.

With this being noted and considering the obtained results of verifying the economic potential of low-carbon energy sources using artificial intelligence in transportation, it was presented the substantive component of forming a digital communicative environment for providing eco-transport services. This would involve establishing the following stages:

1. Direction of offering low-carbon transport services and requesting identification of transport users' needs based on the following indicators: level of adoption of climate-neutral technologies; level of business process digitization (input).
2. Synergy of needs with the economic potential of low-carbon energy sources using artificial intelligence in transport;
3. Prototype testing of the low-carbon transport services and concurrent monitoring feedback.
4. Refinement of the prototype for low-carbon transport services.
5. Provision of low-carbon transport services using artificial intelligence to transport users (output).

The introduction of such an algorithm for forming a digital communicative environment by transport companies is resource-oriented, which will contribute to achieving climate-neutrality of transport.

4. Conclusions

The formation of a green transport environment necessitates a focus on defining a methodological approach to verifying economic potential of low-carbon energy using artificial intelligence in transport. It has been investigated that the use of natural energy sources by transport has an effect on the reduction of gross value added in transport. Conversely, the use of low-carbon energy sources (particularly biofuels) and electricity with the using artificial intelligence in transport is a factor that promotes an increase in gross value added, while also ensuring climate neutrality. It were base for the development of the substantive components of forming a digital communicative environment for providing eco-transport services.

With this considering the obtained results of verifying the economic potential of low-carbon energy sources using artificial intelligence in transport, it were base for the development of the substantive components of forming a digital communicative environment for providing eco-transport services. The obtained results are the basis for further research on the use of GIS technologies in the diversification of low-carbon energy sources in transport.

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