LOGISTICS INNOVATIONS: THE WAY TO SUSTAINABLE DEVELOPMENT OF THE OIL AND GAS INDUSTRY

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Abstract. The oil and gas industry, being a key element of the global economy, simultaneously represents a significant source of environmental and social challenges. In the context of global aspirations for sustainable development, the transformation of logistics processes in this sphere becomes not just desirable, but critically necessary.

Keywords: ecology, oil and gas industry, logistics, green technologies.

Annotatsiya. Jahon iqtisodiyotining asosiy elementi bo'lgan neft va gaz sanoati bir vaqtning o'zida ekologik va ijtimoiy muammolarning muhim manbai hisoblanadi. Barqaror rivojlanishga bo'lgan global intilishlar sharoitida ushbu sohadagi logistika jarayonlarini o'zgartirish nafaqat kerakli, balki o'ta zarur bo'lib qolmoqda.

Kalit so'zlar: ekologiya, neft va gaz sanoati, logistika, yashil texnologiyalar.

Аннотация. Нефтегазовая отрасль, являясь ключевым элементом мировой экономики, одновременно представляет собой значительный источник экологических и социальных проблем. В контексте глобальных устремлений к устойчивому развитию трансформация логистических процессов в этой сфере становится не просто желательной, но и критически необходимой.

Ключевые слова: экология, нефтегазовая отрасль, логистика, "зеленые" технологии.

Introduction

The challenges of sustainability in oil and gas logistics are multifaceted. Conventional methods of transporting, storing and distributing hydrocarbons carry a high risk of accidents and spills leading to environmental pollution. Greenhouse gas emissions from vehicles and energy plants contribute significantly to climate change. In addition, infrastructure projects often have a negative impact on biodiversity and local communities. The economic inefficiency of outdated supply chains also challenges the long-term competitiveness of the industry in the face of increasing attention to environmental standards.

The relevance of this issue can hardly be overestimated, which is confirmed by disappointing statistics. According to various studies, oil and gas logistics contributes significantly to global greenhouse gas emissions. Although exact figures may vary by region and methodology, the transport component of the oil and gas industry may be responsible for 10-15% of total industrial CO2 emissions [1].

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Moreover, the problem is exacerbated by the high risk of accidents and spills. Despite efforts to improve safety, incidents resulting in serious environmental pollution are recorded every year. For example, in 2023, the volume of oil spilled by tankers in the world was about 2 thousand tonnes [1]. Onshore, numerous accidents at pipelines and storage facilities are also recorded. According to Rostechnadzor data for 2022, 42 accidents occurred in the Russian oil and gas complex [2], which demonstrates the constant need to improve safety systems and logistics processes.

In March 2023, in the port of Poole (Dorset), about 200 barrels of formation fluid, including oil, leaked due to a failure of a Perenco (UK) pipeline. The incident caused pollution of coastal waters and required the intervention of environmental services.

In September 2023, a larger spill from a tanker owned by Thai Oil (a subsidiary of PTT) occurred offshore Thailand, which also caused severe marine pollution.

And given that the average monthly number of active oil and gas rigs has increased to 1,814 in 2023 (up from 1,747 in 2022), we can fear high accident risks due to increased activity in the industry.

The economic impact of unsustainable logistics is also significant. Inefficient routes, transport losses and accident management result in significant financial costs for companies and states. In 2020, the damage from accidents at hazardous production facilities in the Russian oil and gas complex totalled more than 5.4 billion roubles [3], which demonstrates a direct link between environmental risks and economic losses.

The UK also faces logistical challenges due to outdated infrastructure of pipelines and port terminals. For example, transporting oil and gas in the North Sea is complicated by the wear and tear of equipment, which increases maintenance costs (about 10-15% of companies' annual operating costs). Transport losses due to leaks and inefficient routes account for up to 2-3% of the total volume of oil products, which is equivalent to hundreds of thousands of pounds annually [6].

Logistical problems in Thailand are related to insufficient modernisation of port infrastructure and lack of effective pipeline monitoring systems. Transport losses account for up to 3-5% of oil volumes, equivalent to $50-100 million annually for the national economy. Delays in port operations due to outdated systems increase costs by 10-12% for companies.

Thus, in Thailand, economic losses from accidents and logistics losses reach $100-150 million in 2022-2023, with additional social costs due to damage to fisheries and tourism [7].

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Economic losses in Nigeria from accidents and unsustainable logistics reach $1.5-2.5 billion in 2022-2023, representing a significant share of the country's GDP (about 1-2%). It also increases social instability due to reduced income for local communities.

METHODS

This article uses statistical and factor analysis techniques to quantify data and identify trends and patterns in environmental policymaking. Factor analysis, in turn, helps to identify hidden variables that influence pricing in the oil and gas industry and to group related factors to simplify the interpretation of results. In addition, the article considers the international experience of leading companies on this issue, which emphasises the importance of integrating sustainability in the implementation of environmental initiatives.

RESULTS

One of the key areas of focus is the optimisation of transport routes and delivery methods. The introduction of intelligent planning systems using big data and machine learning can minimise vehicle miles travelled, reduce journey times and, as a result, reduce fuel consumption and emissions. Switching to more environmentally friendly modes of transport, such as rail and water, where possible, also helps to reduce carbon footprints. A promising direction is the development of alternative fuels and electric transport for short distance logistics operations.

Various modern approaches have been developed to address this issue. Leading companies worldwide have introduced numerous methods and innovative strategies to enhance the efficiency of sustainable logistics. An analysis of the practices of foreign companies engaged in environmentally focused logistics management demonstrates that integrating environmental and economic considerations yields positive outcomes. (Table 1).

Table 1

Experience of foreign companies in implementing eco-measures [4].

Enterprise, country	Eco-activities
Monoprix, France	Transporting goods by rail to a logistics platform. Delivery of goods by natural gas fuelled transport. Utilisation of transport using electric traction
Franprix, France	Delivery of goods by river transport
Amazon, USA.	Use of packaging consisting of 100% recyclable materials using a minimum of packaging material

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United Parcel Service (UPS), USA	Use of vehicles with hybrid engines that use 35% fewer gallons of fuel annually
Itella, Finland	Monitoring of resource consumption to find opportunities to reduce consumption (switching to LED bulbs). Separate collection of waste by type. Control of vehicle emissions
Unilever, Netherlands, UK	Reduce emissions through multimodal transport. Reduction of road transport
Kawasaki Kisen Kaisha, Japan	Installation of a computer system on ships that optimises engine performance based on weather monitoring
Deutsche Bahn Schenker Rail, Germany	Obtaining electricity for electric locomotives from renewable energy sources through additional charges to the customer

For example, the introduction of eco-measures by the Japanese company K Line resulted in a 1% reduction in harmful emissions into the atmosphere. When the express delivery operator UPS uses hybrid-powered vehicles, gas emissions will be 671 tonnes less per year. Deutsche Bahn Schenker Rail, a German carrier, has proposed a way of transporting goods that completely eliminates carbon dioxide emissions [4]. The result of such effective activity was the application of green technologies in logistics, a systematic approach to solving the problems of green logistics in general.

Innovative solutions in the field of recycling and reuse of materials, wastewater treatment, energy saving, air pollution control, environmental protection, renewable energy sources are considered to be green technologies [8]. The use of resource-saving technologies in logistics allows to reduce stocks of materials (40-60%), accelerate the turnover of working capital (20-40%), reduce the cost of loading and unloading and warehousing (15-30%). On the other hand, it leads to an increase in transport costs (1.5-2 times). This is explained by the fact that the application of principles and rules of green logistics in companies is limited by a number of factors:

- high cost of implementing resource-saving technologies;
- delayed in time result of greening activities;
- lack of proven methods of applying green technologies at the enterprise;
- lack of practice of forming return logistics flows and established traditions of waste sorting, reuse of materials (tab. 2).

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Table 2

Green logistics technologies: opportunities and limitations [5].

Green logistics technologies	Opportunities	Limitations
Electric and hybrid transport	Reduced greenhouse gas and air pollutant emissions (especially when using renewable energy for charging). Reduced noise pollution. Reduced operating costs (due to cheaper electricity and fewer moving parts). Potential for use in urban areas and over short distances.	Limited range and charging time (especially for heavy vehicles). Insufficient charging infrastructure, especially in remote oil and gas producing regions. High initial cost of vehicles. Dependence of environmental friendliness on power and load capacity for some types of transport.
biofuelled transport (biodiesel, bioethanol)	Utilisation of renewable feedstock sources. Reduction of greenhouse gas emissions (depending on the type of biofuel and its life cycle). Compatibility with existing infrastructure and engines (for some biofuels). Support for the agricultural sector.	Sustainability issues of raw material production (risk of deforestation, competition with food crops). Potentially higher production costs. Lower energy intensity compared to conventional fuels. Storage and transport problems.
Route optimisation with AI and big data	Reduced transport mileage and journey times. Reduced fuel consumption and emissions. Improved planning and coordination of deliveries. Reduced traffic jams and congestion. Improved vehicle utilisation efficiency. Consideration of multiple factors (traffic, weather, availability).	Need to invest in software and infrastructure. Dependence on data quality and availability. Complexity of integration with existing systems. Need for qualified personnel to operate the systems. Possible data security issues.
Leakage monitoring systems	Early detection of leaks in pipelines and storage	High cost of implementation and

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(IoT, drones, sensors)	facilities. Prevention of environmental contamination and product loss. Improved operational safety. Reduced costs of accident response. Possibility of remote monitoring of hard-to-reach areas.	maintenance of sensor network and analytical platforms. Problems with communication and power supply to remote sites. Need to process and analyse large volumes of data. Potential vulnerability to cyberattacks. Dependence on equipment reliability in harsh environments.
Lean Inventory Management (Lean Logistics)	Reduction of excess inventory and associated transport. Reduced storage space and energy consumption. Reduction of waste and losses. Improved material turnover. Improved demand forecasting.	The complexity of implementing and maintaining lean manufacturing principles in complex and distributed oil and gas logistics. The need for a high degree of coordination between supply chain participants. Risks of shortages when demand fluctuates dramatically. Requires changes in corporate culture and processes.
Intermodal transport	Reducing dependence on road transport and associated emissions and congestion. Use of more environmentally friendly modes of transport over long distances (rail, water).	The need for a well-developed infrastructure for transshipment between different modes of transport. Difficulty in coordinating different stages of transport. Longer delivery time compared to direct road transport.

The international experience presented in Table 1 illustrates the successful application of environmentally oriented measures. For example, K Line (Japan) achieved a 1% reduction in emissions by installing computerised engine

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optimisation systems. Similarly, the use of hybrid vehicles by UPS (USA) reduced greenhouse gas emissions by 671 tonnes per year. Deutsche Bahn Schenker Rail (Germany) has implemented freight transport using electricity from renewable sources, which completely eliminates carbon dioxide emissions [4]. These examples confirm that the integration of green technologies into logistics not only reduces environmental damage, but also increases economic efficiency.

The use of green technologies, such as Internet of Things (IoT)-based leak monitoring systems, drones and sensors, contributes to the early detection of problems in pipelines and storage facilities, preventing environmental pollution and minimising financial losses. For example, the use of such systems can reduce the cost of accident response, which, according to data, totalled more than 5.4 billion rubles for the Russian oil and gas industry in 2020 [3].

However, the adoption of resource-efficient technologies, such as lean inventory management and intermodal transport, can reduce excess inventory, reduce energy consumption and optimise the use of warehouse space. However, limitations such as high implementation costs, insufficient infrastructure and the need for coordination between supply chain actors require further research and investment.

CONCLUSION

The analysis presented above confirms that innovative logistics solutions, including green technologies and process optimisation, have the potential to significantly reduce the environmental footprint of the oil and gas industry, improve its economic efficiency and meet global sustainability standards.

Although implementing these innovations presents challenges—such as high initial investment and the need for industry-wide cooperation—the long-term advantages in environmental protection, operational efficiency, and corporate reputation are clear and compelling.

Ultimately, continuous research and implementation of innovative logistics solutions will be paramount if the oil and gas industry is to responsibly meet the world's energy needs while minimizing its environmental footprint for future generations.

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