компанії. Отже, формування та постійне вдосконалення компетентностей менеджера з логістики є критично важливим для стабільного функціонування і успішного розвитку підприємства.

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ENHANCING ENVIRONMENTAL RESPONSIBILITY IN AGROLOGISTICS THROUGH TRANSPORT RISK MINIMIZATION

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Abstract. The article examines the theoretical and practical foundations for enhancing environmental responsibility in agrologistics by minimizing transport-related risks. The structure of agricultural transport flows and the factors contributing to environmental impacts are analyzed. The study explores current trends in the development of “green logistics” under EU integration, the influence of digitalization on transport efficiency, and the organizational and technical methods of reducing negative environmental effects from transportation.

An environmentally responsible agrologistics model integrating energy saving, emission reduction, and transport safety is proposed. The effect of implementing Idle

Shut-down and Start-Stop technologies is assessed, showing fuel savings of up to 9% and CO_2 emission reduction by 4–5%.

Keywords: agrologistics, environmental responsibility, transport risks, energy efficiency, digitalization, GPS monitoring, sustainable development.

Introduction. The sustainable development of Ukraine's agricultural sector is impossible without an effective agrologistics system that ensures not only continuous supply chains but also compliance with environmental standards (Pilipchuk, 2021; European Commission, 2019).

Within the context of European integration, the implementation of "green logistics" principles in accordance with the European Green Deal and EU directives on CO_2 emission reduction becomes especially important (European Commission, 2019).

According to the UNEP (2024), the transport sector accounts for more than 23% of global greenhouse gas emissions, with approximately 8% attributed to agriculture. In Ukraine, this figure is slightly lower, but the increasing intensity of freight vehicle use during harvest seasons highlights the need for systematic environmental risk management within agrologistical chains.

The purpose of this study is to generalize the theoretical foundations and practical approaches to enhancing environmental responsibility in agrologistics through the minimization of transport risks, to develop a model of "green agrologistics," and to evaluate the potential effects of its implementation.

Theoretical Framework. Environmental responsibility is defined as the readiness of enterprises to consciously reduce the negative impact of their activities on the environment (Porter & van der Linde, 1995; Elkington, 1997).

In agrologistics, this involves optimizing transport routes, minimizing idle runs, adopting eco-fuels, maintaining vehicles in good technical condition, and introducing digital monitoring systems (McKinnon, 2018; Gupta et al., 2023).

From a systems perspective, environmental responsibility in transport processes includes:

- consideration of ecological risks during route planning;
- monitoring actual fuel consumption and emissions;
- evaluating the product's ecological footprint (Zhang & Li, 2022).

For Ukrainian enterprises, combining energy efficiency with traffic safety is particularly relevant (Kuzmenko, 2023; Ovcharenko, 2024).

Regulatory and Policy Framework. The formation of environmentally responsible agrologistics in Ukraine is based on several legislative documents, including the Laws of Ukraine "On Environmental Protection," "On Transport," and "On Alternative Fuels" (Verkhovna Rada of Ukraine, 1991; 1994; 2000). Strategic documents such as the Environmental Security and Climate Adaptation Strategy until 2030 (Cabinet of Ministers of Ukraine, 2021), the National Transport Strategy until 2030 (Cabinet of Ministers of Ukraine, 2018), and the Agricultural Sector Decarbonization Program (2023) define national priorities in environmental policy.

Internationally, standards such as ISO 14001:2015 (Environmental Management Systems) and ISO 39001:2012 (Road Traffic Safety Management Systems) provide frameworks for integrating environmental and transport safety management (ISO, 2015; ISO, 2012). The Eco-Management and Audit Scheme (EMAS) further promotes environmental auditing across the EU (European Commission, 2021).

Environmental risks in agricultural transport. Agrologistics involves high-intensity transport operations, seasonal surges, and the use of specialised equipment, which in turn generate particular environmental risk factors. Key factors causing adverse environmental impacts in transport support include emissions of pollutants to the atmosphere, noise burden, contamination of soil and water by fuel and oil leaks, generation of maintenance waste, and degradation of road infrastructure due to overloading.

The major environmental risks in agrologistics derive from inefficient use of vehicles and machinery, especially when there are idle times at weighing stations, grain-elevators, or during inter-field movement, from overloading of vehicles, and from operating outdated diesel engines. These conditions increase fuel consumption and thus emissions of harmful pollutants such as nitrogen oxides (NO_x), carbon dioxide (CO_2), fine particulate matter ($PM_2.5$) and carbon monoxide (CO). Studies show that these inefficiencies can raise emission levels by 15–20%.

For example, one grain transport vehicle with its engine idling for one hour can emit up to 2 kg CO_2; when scaled to 100 machines this equals up to 200 kg of additional daily emissions.

In the case of Ukraine, the transport sector accounted for about 10 % of all greenhouse-gas (GHG) emissions, as the most recent data show. Between 1990 and 2017, GHG emissions from transport in Ukraine fell from 112 Mt CO_2-equivalent to about 35 Mt CO_2-equivalent, yet the proportion of transport emissions in the national total remained approximately constant. According to inventory data for 2021, Ukraine's total GHG emissions (excluding LULUCF) were around 327 Mt CO_2-eq; CO_2 alone represented about 65.7 % of that in 2021. Within the energy sector 2021 emissions were about 160 Mt CO_2-eq, while industry contributed ≈ 50 Mt CO_2-eq.

Moreover, a simulation-based study of grain transport from Ukraine via the Mykolaiv Commercial Port indicated that using a multimodal route (road + rail) reduced CO_2 emissions per tonne of grain to just about 1 kg, which was almost 90 % lower compared with the road-only alternative (~12.8 kg per tonne) in that study.

Beyond emissions, other environmental risks include fuel and lubricant spills during refuelling or field repairs, which can contaminate soil and infiltrate surface and groundwater. Also, maintenance waste such as used tyres, oils, filters and other consumables impose additional burdens on the environment, especially when no proper collection or disposal system is in place. Overloaded vehicles accelerate deterioration of road surfaces, increasing the frequency of repairs, which in turn entails additional resource use and emissions.

In sum, transport support in agrologistics poses substantial environmental risks, requiring a systemic mitigation approach. Priority actions include:

- Modernisation of the vehicle and equipment fleet (e.g., replacing old diesel engines, implementing cleaner technologies).
- Optimisation of routes and logistics processes to minimise idle times, waiting and unnecessary movement.

- Deployment of digital logistics platforms and monitoring systems to reduce downtime and improve utilization.
- Adoption of ecological monitoring (emission tracking, fuel consumption metrics) and implementation of reporting and targets within agricultural logistics operations.
- Promoting modal shift where feasible (e.g., increasing use of rail or inland water transport over road), since the Ukrainian grain-transport study showed large emission reductions for multimodal operations.
- Establishing waste-management protocols for maintenance by-products, spill control systems, and ensuring compliance with environmental regulations and best practices.

By integrating these measures, agrologistics operators can significantly reduce their environmental footprint, align with national and international climate goals, and contribute to sustainable agricultural supply-chain performance.

Organizational and Technical Measures. A comprehensive set of measures for minimizing transport risks includes:

1. Route and schedule optimization using artificial intelligence algorithms that consider traffic and weather conditions (McKinnon, 2018).
2. Implementation of Idle Shut-down and Start-Stop systems for automatic engine control during idling (Gupta et al., 2023).
3. GPS-based dispatching for tracking mileage, load capacity, and waiting times (Zhang & Li, 2022).
4. Periodic technical monitoring of emissions through OBD-II sensors.
5. Personnel training programs in eco-driving, which can reduce fuel consumption by 5–10% (Pilipchuk, 2021).

In EU countries, similar practices are supported through the EMAS environmental audit scheme, which could be adapted for Ukrainian conditions (European Commission, 2021).

Environmental and Economic Effect. For a mid-sized agricultural enterprise operating 80 trucks and transporting up to 40,000 tons of grain per season, the introduction of these measures resulted in:

- fuel consumption reduction from 32 to 29 L/100 km (–9%);
- specific CO_2 emissions reduction from 0.85 to 0.81 kg/t·km (–4.7%);
- a 33% decrease in accident frequency and 44% reduction in idle time.

With an average diesel price of 60 UAH/L and a total mileage of 1.2 million km per year, the fuel savings generate an economic benefit of approximately 2.1 million UAH per season, while reducing CO_2 emissions by 18–20 tons (Gupta et al., 2023; Ovcharenko, 2024).

Model of Environmentally Responsible Agrologistics. The proposed model includes three interrelated levels:

- Operational level – optimization of routes and schedules, reduction of idle time.
- Technological level – integration of energy-efficient engines, GPS systems, and automatic engine shut-off devices.

– Analytical level – digital emission monitoring, risk mapping, and environmental KPI evaluation (McKinnon, 2018; Zhang & Li, 2022).

This structure enables continuous monitoring of environmental indicators in real time and enhances the transparency of the agrologistics supply chain.

Conclusions. The conducted research substantiates both theoretical and practical principles for increasing environmental responsibility in agrologistics through transport risk minimization.

Implementation of a set of organizational, technical, and technological measures ensures:

- reduction of CO_2 emissions by 4–5%;
- decrease in fuel consumption by 9%;
- improvement of transport operation safety by over 30%;
- economic savings of approximately 2.1 million UAH per season.

Developing a national digital certification system for "green logistics" based on ISO and EMAS standards is a promising direction for Ukraine, enabling enterprises to verify their contribution to greenhouse gas reduction and sustainable development goals.

Further research should focus on life cycle assessment of transport processes, integration of AI-based risk management, and the creation of standardized environmental performance indicators for agrologistics systems.

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