

MODELING LOGISTICS FOR DISTRIBUTED PRODUCTION UNDER THE CONDITIONS OF THREAT

Popov I., Leshchenko O., Chubukina O.

National Aerospace University «Kharkiv Aviation Institute», Kharkiv, Ukraine

The growing turbulence in the modern world creates significant challenges to the operation of all supply chains, particularly for large enterprises with branches and representative offices across various regions and countries. Warfare, infrastructure destruction, trade restrictions, and economic conflicts exert substantial influence on production and exports.

During the period of military aggression, Ukraine experienced considerable reductions in both production volumes and road transportation, primarily due to the destruction of infrastructure and the disruption of established transport routes. In addition, the logistical situation was complicated by long queues at Ukraine's western border crossings. At the same time, regular shelling of Ukrainian ports, railway hubs, and warehouses disrupted export routes and damaged logistics facilities.

Many Ukrainian researchers are actively seeking solutions to the problem of adapting logistics to emergency conditions [1], increasingly turning to advanced information technologies such as robotics, artificial intelligence, and others [2]. However, the requirements for logistics management programs, reserve replenishment planning, and warehouse sizing during armed conflicts differ significantly from those in peacetime [3].

One promising solution, enabled by digitalization and the implementation of Industry 4.0 principles, involves the organization of distributed production with automated logistics that accounts for diverse threats – including military operations, infrastructure damage, and supply disruptions. This approach can significantly enhance the adaptability of production processes while minimize disruptions and costs.

The purpose of the report is to investigate the logistics processes of distributed production and supply chains within an industrial enterprise under the conditions of external threats.

The study examines methods and criteria for assessing the resilience of logistics systems to adverse external influences, as well as optimization and simulation models for supply planning in crisis scenarios.

During conflicts, even the most optimized supply chains are among the first to become vulnerable to systemic disruptions. In this context, a systems-based approach is proposed, that combines risk assessment, scenario modeling, route optimization, and simulation of various crisis impacts.

To address the outlined challenges, the following methods and technologies are employed:

- optimization methods – for selecting rational routes and resource configurations;

- simulation modeling – for analyzing system behavior under threat scenarios;
- risk and resilience analysis methods – for building risk maps, conducting scenario analysis, and defining indicators of system stability and adaptability;
- geographic information systems (GIS) – for route visualization, assessment of transport network disruptions, and construction of alternative routes;
- information platforms (Internet of things, cloud analytics) – for data integration and real-time decision support.

Agent-based modeling of logistics operations to assess supply system resilience under threat conditions was carried out using the AnyLogic simulation platform, which integrates agent-based and discrete-event modeling approaches. This enabled the simulation of interactions between production and transport nodes, as well as the evaluation of consequences arising from route disruptions and infrastructure damage.

Analytical processing and data optimization were performed using the Python environment (SciPy, Pandas); spatial analysis was carried out using open cartographic services such as OpenStreetMap and Google Maps API. Real-time monitoring of logistics processes was implemented via Node-RED, SQLite, AWS IoT platform and the AWS IoT Core cloud service. This approach aligns with the principles of Industry 4.0 and allows operations under possible threats.

The research results are presented as a set of criteria and indicators for logistics system resilience; an optimization model for selecting supply routes under threat conditions; and a scenario-based simulator of logistics processes with different levels of impact (military actions, disruptions, infrastructure damage). Based on these results, recommendations will be formulated for industrial enterprises to improve flexibility, reduce risks and costs, and a prototype of an information-analytical system that integrates models for optimization, simulation, and route visualization will be developed.

This approach is applicable not only to Ukraine but also to international corporations with distributed production facilities located in high-risk areas (geopolitical instability, natural disasters, sanctions, and cyberattacks). The application of logistics modeling methods that take threats into account allows such companies to develop flexible contingency scenarios, adapt supply chains, ensure production continuity, and reduce costs during emergency situations.

References

1. Sushchenko P., Ilchenko H. Adaptation of supply chains to the challenges of martial law. *Commodity science. Technologies. Engineering*, 2023, vol. 45, no. 1, pp. 4–16. DOI: 10.31617/2.2023(45)01.
2. Крамський С. О. Розвиток логістики в умовах воєнного впливу в Україні: проблеми та перспективи. *Проблеми сталого розвитку морської галузі (PSDMI – 2024) : зб. матеріалів 4 Міжнар. наук.-практ. конф. 2024*. С. 159–161.
3. Федорович О. Є., Поліщук Є. В., Чмихун Є. К., Соловйов В. С. Моделювання критичних вразливостей у логістиці постачання озброєння та військової техніки в умовах воєнних загроз. *Авіаційно-космічна техніка і технологія*. 2022. № 6. С. 40–49. DOI: 10.32620/akt.2022.6.05.