UDC 378

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DESIGN AND TECHNICAL IMPLEMENTATION OF AN INTELLIGENT CONTROL SYSTEM FOR TRANSPORTED GOODS IN AGRICULTURE

Abstract. The Fourth Industrial Revolution introduces entirely new resources that fundamentally transform the operational paradigms of enterprises and supply chains. This article discusses one of the novel technologies recognized as the Internet of Things (IoT), which, alongside other technologies such as artificial intelligence, cloud computing, and big data, possesses unique potential to yield significant outcomes. IoT enables businesses to leverage innovative services with reduced risks in a more systematic manner. The Internet of Things guarantees a significant revolution in the logistics sector over the next decade. By minimizing the cost of device components, enhancing the speed of wireless networks, and expanding data reception capabilities, IoT creates new business benefits. This study focuses on the application of IoT in logistics, real-world examples of its use among transportation companies, and the prospects for the development of this new technology.

Keywords: *digital economy, logistics, Internet of Things, agricultural innovations.*

1. Introduction. The digitization process is a large-scale initiative aimed at creating a new network-information society driven by information and communication technologies that identify, collect, process, and distribute data through global telecommunication networks. When viewed through the lens of production, the digital economy's primary development trends include the adoption of new materials, the transition to advanced manufacturing technologies, the automation of production processes, and the implementation of innovations in logistics. The key distinction between the modern economy and the digital economy lies in the degree to which predictive analytics are utilized in economic processes.

Currently, there is a growing trend toward competent production planning to reduce costs and allocate existing resources as efficiently as possible. Alongside traditional logistics methods (such as postal services or courier deliveries), the development of delivery systems using drones, robots, and autonomous vehicles is advancing. These advancements have been made possible by the emergence of the Internet of Things (IoT) technology, which is elevating the world to a new level. Its impact extends across all facets of human life, from vehicle operation and shopping methods to the management and accounting of household electricity consumption. Every day, intelligent sensors and chips embedded in physical objects around us continuously exchange terabytes of data.

2. Methods. One of the primary challenges in the development of the Internet of Things is the lack of unified standards, which complicates the integration of wireless networks and objects into a single network. The ideal technology, combining three key characteristics—energy efficiency, stability, and security—is still in the developmental stage. Moreover, the risk of cyberattacks on IoT system data somewhat undermines confidence in this innovation. Therefore,

enhancing the security system for all devices participating in the network is one of the primary tasks of the IoT market. IoT technology finds applications not only in domestic settings, such as smart household appliances and personal digital devices, but also in commercial sectors, including agriculture, healthcare, real estate, and security, and it is rapidly gaining popularity in industries such as logistics.

Newly implemented technologies are distributed throughout the logistics value chain, encompassing warehouse operations, cargo transportation, and final deliveries. Additionally, innovations enhance production efficiency, customer service, and safety. The Internet of Things facilitates the resolution of operational challenges by utilizing the most optimal solutions.

The "physical" internet can be utilized in the form of directly connected devices (sensors, robots) or as a medium for data transmission between devices. This connectivity is supported by wireless technologies such as Bluetooth, RFID, and Wi-Fi, as well as mobile 3G (4G) and LTE networks that integrate numerous devices into a unified network. The application of IoT in logistics yields rapid and effective results. By leveraging this technology, it is possible to monitor the status of assets, packages, and environmental conditions (e.g., temperature, humidity) inside vehicles in real time across the entire value chain. IoT enables the automation of business processes to eliminate manual labor, improve quality and predictability, and reduce transportation costs. This innovative technology ensures improvements in the following areas:

- Optimization of utilized assets;
- Reduction of security issues such as fraud and theft;
- Precise monitoring of resources and workflows;
- Real-time tracking and timely responses to events;
- Analysis of real-time data flows for adequate and rapid decision-making;
- Reduction of manual data processing to enhance accuracy and save time;
- Identification of new opportunities based on studying consumer behavior patterns;
- Improvement of the quality of customer interactions.

Inventory management and warehouse storage are among the most critical components of the interconnected logistics ecosystem. The deployment of small, cost-effective sensors enables companies to easily track inventories, monitor their condition and location, and create intelligent warehouse systems. Thus, IoT technology effectively prevents losses, ensures the safe storage of goods, and facilitates the rapid retrieval of necessary products, minimizing human errors. Considering the current logistics conditions and opportunities, the development of an innovative system based on modern solutions is a highly essential process. When observing the real challenges encountered during the transportation of agricultural goods, it is possible to partially address these issues by employing IoT technology. An analysis of the damages sustained by transported goods (especially sensitive goods) inside trucks or containers, along with their impact on budgets, reveals the following sequence of factors:

- Temperature fluctuations;
- Terrain conditions;
- Uncertainty in transportation duration;
- Humidity levels in the environment and inside containers;
- Additional transportation costs;
- Supply chain management.

Additional factors also contribute to these issues. Primarily, two factors significantly impact the loss of product quality. When seeking solutions in this direction, it is possible to develop a new innovative product. Delivering products in high-quality condition is the greatest desire of customers, and providing customers with the ability to participate in the transportation process constitutes control, which is manageable. To address these challenges, it is feasible to create a manageable device based on artificial intelligence, accompanied by a mobile application to control it.

The proposed solution is designed to address the real challenges faced by individuals engaged in agriculture regarding the transportation of their products. Specifically, issues arising during transportation — such as product damage, lack of transparency in the process, improper time management, inventory management, and the detrimental effects of temperature, humidity, and carbon dioxide on products — are addressed through an IoT-based solution involving software and devices powered by artificial intelligence. Additionally, it is possible to partially mitigate the quality loss and spoilage of sensitive goods during prolonged waiting periods at customs. The proposed device will be installed inside the transportation vehicle. Temperature, humidity, pressure, and CO2 levels will be stabilized via a mobile application or server. The sensors used are connected to a central controller and managed through the network. Regarding energy, the device will initially draw power from the truck's battery. When changes occur inside the truck, control can be exercised automatically, by the driver, or by the customer through a mobile application (adhering to cybersecurity protocols and utilizing two-factor authentication). This enables real-time monitoring of the product and the resolution of the aforementioned issues.

Conclusion. Reports from reputable international organizations, analytical and consulting agencies, and IT companies unanimously provide optimistic forecasts for the global development of the Internet of Things. The potential of IoT is substantial, particularly in logistics, but it requires not only significant investments but also a shift in mindset. IoT guarantees a massive revolution in logistics over the next decade by minimizing the cost of device components (sensors, actuators, and semiconductors) and increasing the speed of wireless networks, thereby creating new business benefits. Specifically, in the transportation of agricultural goods, IoT fosters the development of highly innovative technology-based solutions. The advancement of these technologies is crucial in terms of both cost and accessibility.

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