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CONTENT

блокуючи основний потік. Це робить Node.js ідеальним для серверних додатків з високою інтенсивністю вводу/виводу, таких як веб-сервери.

Отже, Event Loop є фундаментальним компонентом JavaScript, який дозволяє ефективно працювати з асинхронними завданнями в однопотоковому середовищі. Розуміння його механізму роботи — це ключ до написання ефективного коду, що дозволяє оптимізувати продуктивність додатків, забезпечуючи плавний та швидкий користувацький інтерфейс.

Список використаних джерел

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3. The Node.js Event Loop. URL: https://nodejs.org/en/learn/asynchronous-work/event-loop-timers-and-nexttick
4. What is the Event Loop in JavaScript and Why is it Essential to Understand? URL: https://medium.com/@burak.bburuk/what-is-the-event-loop-in-javascript-and-why-is-it-essential-to-understand-b11af520a28b

IoT IN THE TRANSPORTATION SECTOR: OPPORTUNITIES AND CHALLENGE

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The Internet of Things (IoT) is one of the most rapidly evolving areas in the field of information technology, attracting significant attention from researchers, practitioners, and the business community, particularly in the transportation sector. This technological paradigm involves connecting various vehicles, infrastructure objects, and logistics systems to the Internet and enabling their interaction through the network [1]. The core idea of IoT is to create «smart» transportation ecosystems (Figure 1), where objects can exchange data, coordinate their actions, and respond to changes in transport conditions.

Figure 1. An Example of IoT Usage in Transportation

In recent years, IoT has shown significant potential in the transportation sector, especially in logistics, passenger and freight transportation, and transportation infrastructure management. This technology facilitates process automation, increases transportation efficiency, lowers costs, and improves safety. The appeal of IoT in transportation lies in its ability to transform the way we manage transportation processes, improving service quality, accident response time, and route optimization. The use of sensors, actuators, data collection systems and software allow the creation of intelligent transport systems that can analyze large amounts of information, predict transport events and make informed decisions.

The issue of the use of IoT in transport was studied in works [2-4], and the development of logistics transport systems, including the use of information technologies, in works [5-8].

This study analyzes the potential applications of IoT in the transportation sector, focusing on the advantages, opportunities, and challenges that arise during its implementation. Further analysis will provide a better understanding of how IoT impacts transportation business processes and how it can be utilized to achieve strategic goals.

The purpose of the study is to systematize and summarize knowledge about the application of IoT in the transportation sector to examine its impact on the strategic aspects of transportation business.

It is important to thoroughly consider and analyze the advantages, opportunities, and challenges that arise from the implementation of IoT technologies in transportation systems. Accordingly, the analysis conducted in this study aims to reveal the impact of IoT on the optimization of transportation processes, the enhancement of service quality, and the creation of new business models and opportunities for innovative development in the transportation field.

The first stage of any IoT system in transportation is data collection. Various sensors installed on vehicles, infrastructure, or logistics objects transmit data to control centers. For instance, sensors on trucks can gather information about engine

status, speed, or position on the road, enabling route optimization and congestion avoidance.

Connectivity. Various types of wireless connections, such as Wi-Fi, Bluetooth, NFC, 4G/5G, or ZigBee, allow for the effective linking of vehicles and infrastructure objects into a single network. For example, 5G significantly enhances data transmission speeds, which is critical for autonomous vehicles and intelligent traffic management systems in urban areas.

The main challenges of IoT in transportation are related to issues of security, device compatibility, and network scalability. Specifically, vulnerabilities in security systems can allow unauthorized individuals to interfere with the operation of vehicles or infrastructure objects. Additionally, there are difficulties in integrating IoT solutions from different manufacturers due to various communication protocols and operating systems.

Analytics. The collected data can be used to analyze driver behavior, predict malfunctions, or optimize routes in real time. This enables transportation companies to reduce costs, enhance safety, and ensure high-quality service.

IoT enables the automation of processes in transportation, reducing the need for human intervention and increasing efficiency. In freight transport, IoT allows for route optimization, tracking the location of shipments, and monitoring the technical condition of vehicles. For passenger transport, IoT can enhance passenger convenience by providing accurate information about arrival times, transportation status, and more.

It is important to note that IoT is transforming traditional approaches to organizing transportation processes. Among the key advantages of using IoT in the transportation sector, several main benefits can be highlighted (Table 1).

Table 1. - Key Benefits of Using IoT in the Transportation Sector

№	Benefits	Characteristics of benefits
1	2	3
1	Enhancement of transportation operations efficiency	With the help of IoT sensors, traffic, road load, and the condition of vehicles can be monitored, allowing for route optimization, reduced delivery times, and minimized downtime.
2	Increased Safety	IoT-based smart transportation systems can alert drivers to hazardous road conditions, detect vehicle malfunctions in real time, and even automatically apply brakes in critical situations.
3	Environmental Efficiency	IoT allows for the reduction of harmful emissions through better engine performance monitoring, optimized fuel usage, and decreased unnecessary mileage.
4	Process Automation	IoT can assist in automating processes in transportation logistics, such as warehouse management, loading and unloading control, and fleet management

Let’s consider several examples of IoT applications in transportation.

1. Smart cities and transportation infrastructure. In many developed countries, IoT is used to manage road traffic. For example, in London, the «Smart Traffic Lights» system uses traffic sensors to optimize traffic light operation in real time. This helps reduce congestion and shorten travel times.

2. Autonomous vehicles. One of the most well-known examples of IoT in transportation is self-driving cars. Companies like Tesla use IoT to integrate their vehicles with intelligent management systems that enable cars to maneuver independently in urban traffic conditions.

3. Freight Monitoring Systems. In transportation logistics, IoT is widely used to monitor freight shipments. Sensors track temperature, humidity, and the condition of goods in real time, which is especially important for food and pharmaceuticals. IoT systems allow for more precise management of shipments, providing early warnings about potential risks, such as temperature increases in refrigerated containers.

4. Intelligent Transportation Monitoring Systems on Railways. Companies in the railway industry also use IoT to monitor the condition of tracks and railcars. This helps prevent potential accidents and infrastructure failures. For example, sensors can detect defects on rails or signal when train brakes are worn out.

IoT transportation networks require various technologies for connectivity, data exchange, and ensuring the stable operation of systems. Among the most commonly used technologies in transportation, the following can be highlighted in the Table 2.

Table 2. - IoT technologies in transport

№	Technologies	Scope of application
1	2	3
1	GPS	Vehicle location tracking.
2	4G/5G	High-speed data exchange between vehicles and infrastructure.
3	LoRaWAN	Long-distance data exchange between devices with low power consumption.
4	Machine learning and artificial intelligence	Analysis of collected data and prediction of potential situations on roads or within the transportation system.

The application of IoT in transportation logistics and vehicle optimization requires mathematical modeling to achieve maximum efficiency. Let’s consider a few examples of mathematical models used in the transportation sector:

- Vehicle Routing Problem (VRP). VRP is a classic problem used for planning optimal delivery routes. The mathematical model of VRP is based on minimizing total transportation costs, including distance, time, and fuel expenses. By using IoT sensor data on current road conditions, vehicle routes can be adjusted in real time to avoid traffic jams and accident-prone situations.
- Fuel Optimization. Using mathematical models and IoT analytical data, it is possible to predict the optimal operating mode for engines, which helps reduce fuel costs. For example, by employing regression models to analyze distance, speed, and road conditions, one can forecast how much fuel will be needed for a specific trip.
- Traffic Flow Modeling. These are complex models used for analyzing and predicting transportation flows in urban areas. With IoT sensors capturing vehicle movement on various road segments, mathematical models can be created to help city administrations manage traffic effectively. One example of such a model is the Lighthill–Whitham–Richardson (LWR) model, which describes the dynamics of traffic flow and allows for the assessment of traffic intensity on different sections of the road.

- Transportation Optimization Model. This model is used to determine the most efficient way to deliver goods from one location to another, taking into account constraints such as vehicle load capacity and delivery timelines. It may also consider factors such as fuel costs, travel time, routes, and CO_2 emissions.
- Traffic Congestion Forecasting Model. This model analyzes traffic data from various sources, such as surveillance cameras, road sensors, and mobile applications, to predict the likelihood of traffic congestion. This enables drivers to avoid overloaded sections of the road and plan alternative routes.

Also, in addition to all the positive aspects, it is necessary to take into account the main challenges, risks and threats [4] that the introduction of IoT in the transport sector may face (Figure 2).

The Internet of Things (IoT) holds immense potential in the transportation sector, enabling process automation, enhancing safety, and improving the efficiency of transportation operations. Specific examples of IoT applications, such as smart traffic lights, autonomous vehicles, and cargo monitoring systems, demonstrate the significant prospects of this technology. At the same time, it is crucial to address the challenges associated with security and the integration of IoT into existing transportation infrastructure, as well as to employ mathematical models.

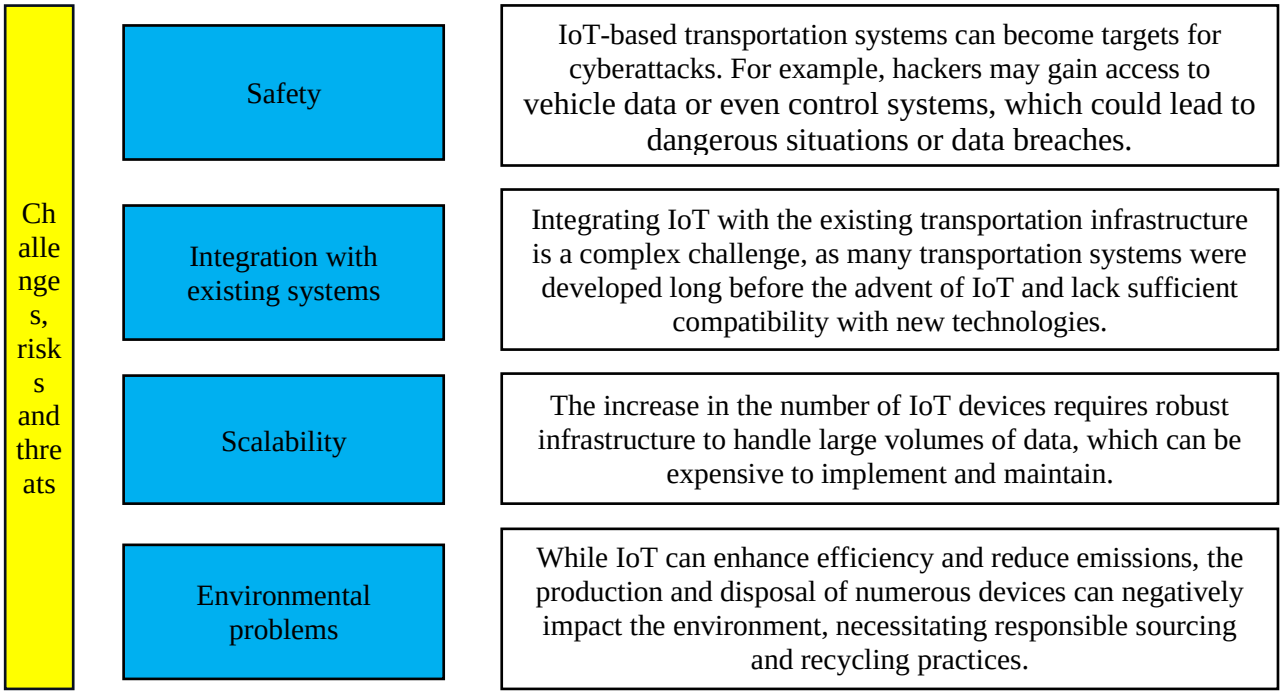

Figure 2. Challenges, risks and threats that the introduction of IoT in the transport sector

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АНАЛІЗ МОДЕЛЕЙ СТВОРЕННЯ ЯКІСНИХ ІНТЕРФЕЙСІВ ДЛЯ ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ

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Якісний інтерфейс є ключовим елементом для досягнення задоволення потреб користувачів та створення продукту найкращого рівня. Якісний інтерфейс для програмного забезпечення слугує каталізатором для залучення користувачів та збільшення конкурентоспроможності продукту. Поєднання