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АНАЛІЗ ЗАРУБІЖНОГО ДОСВІДУ ВПРОВАДЖЕННЯ ІНТЕЛЕКТУАЛЬНИХ ТРАНСПОРТНИХ СИСТЕМ В УКРАЇНІ

ANALYSIS OF FOREIGN EXPERIENCE IN IMPLEMENTING INTELLIGENT TRANSPORT SYSTEMS IN UKRAINE

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Abstract. At the moment, the whole world is faced with the problem of providing quality transportation services with limited resources, so countries need to start actively investing in intelligent transportation systems. Smart implementation of intelligent transportation systems will make the existing transportation system more efficient and effective. The main goal of which is to improve transportation services, reduce congestion, accidents and air pollution in cities. Ukraine regularly hosts scientific and practical conferences dedicated to discussing this issue, and technical sports systems are actively developing and improving.

Keywords: intelligent transportation system, traffic management, traffic intensity, congestion.

Analysis of research and publications. The chronology of the development and study of the current state of intelligent transport systems were devoted to the works of scientists V. Danchuk, B. Vitruk, N. Bilichenko, V. Baranov, S. Tsymbal, A. Horiv, D. Bespalov and others.

The scientists noted the need and relevance of using intelligent transport systems in Ukraine.

Purpose of work: In conducting the analysis, the author used general scientific methods: comparison, generalization, historical hypothetical, and generalization.

- to achieve this goal, the following tasks were set;
- to define the essence of the concept of intelligent transport systems and its similarity to other concepts in this area;
- to analyze foreign experience in the implementation of intelligent transport systems;
- to analyze the Ukrainian experience of implementing intelligent transport systems.

Presentation of the main research material.

At the moment, the whole world is faced with the problem of providing decent transportation services with limited resources, so countries need to start actively investing in intelligent transportation systems. Reasonable use of intelligent transportation systems will allow us to make the existing transportation system more efficient and effective. The main goal is to improve transportation services, reduce congestion, accidents and air pollution in cities. It gives us the opportunity to:

- Reducing the level of congestion on streets and roads;
- Reduction of time spent on transportation;
- Improving road safety;
- Informing road users about the current traffic situation and optimal routes (for individual and public transport);
- Ensuring the smooth operation of public transport;
- Collection of fares;
- Improving the environmental situation.

In the last two decades, with the rapid development of intelligent transportation systems, the concept of «smart technologies» has gained great popularity, and many cities have begun to take a more holistic approach to improving the road situation using intelligent transportation system technologies.

Interest in intelligent transportation systems has emerged with the advent of traffic congestion problems as a result of the combination of modern modeling, real-time management, and communication technologies. Traffic congestion is occurring around the world as a result of increasing motorization, urbanization, and population growth and increasingly dense population. Traffic congestion reduces the efficiency of pre-transportation infrastructure, thus increasing travel time, fuel consumption, and environmental pollution.

The issue of introducing intelligent transport systems in the road industry is relevant and widely discussed in the world, as projects of this type are characterized by a quick payback, which attracts a lot of investors. Once built, a «smart» road operates practically free of charge, performing its functions autonomously, which is much cheaper and more efficient than constantly maintaining the existing infrastructure. At the moment, conferences are regularly held in our country to discuss this issue, and intelligent road control technologies are actively developing and improving. Also, the implementation of ITS has a great chance to become a solution to many environmental and social problems mentioned in the article [1]. ITS is the key to minimizing the effects of these impacts on the environment.

The term «Intelligent Transport Systems» characterizes a set of integrated transport infrastructure management tools, traffic management equipment used to solve traffic management problems based on modern information technologies, organization of information flows about the functioning of transport infrastructure in real time. A multi-level, complexly organized ITS is a hybrid system consisting of many

different systems, mainly those that interact with each other – managers that classify, forecast, make expert assessments and make decisions, or those that support these processes in order to achieve a single goal.

ITS are designed to collect, process and transmit information about the operation and condition of vehicles, as well as to exchange information between users and management structures in real time and manage ground transportation. The solution of transport problems is based on the use of modern information and telecommunication technologies and management methods. The implementation of ITS has almost unlimited scalability and integrates with existing information systems and databases of government agencies, including road patrol and law enforcement services [2].

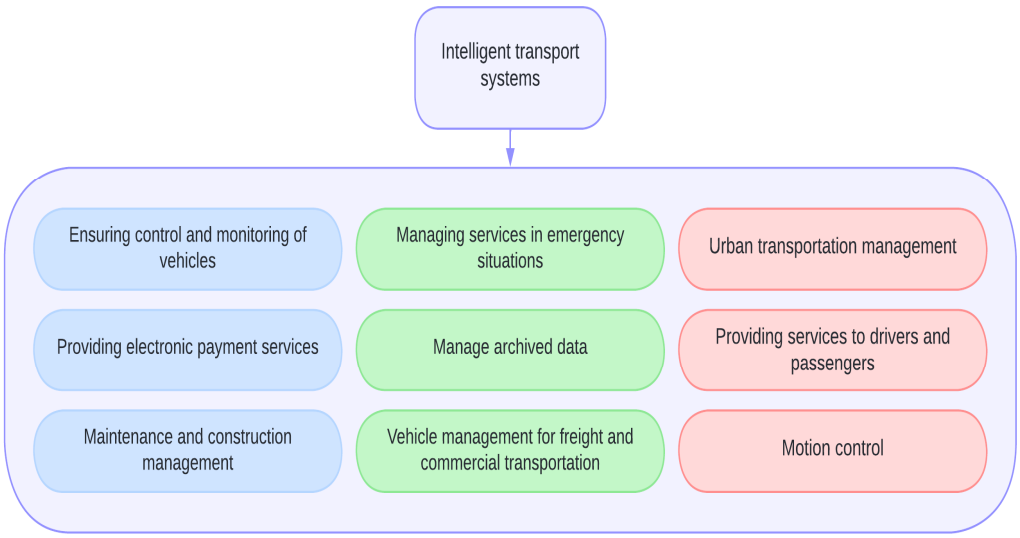

Figure 1 – Functions that can be performed by intelligent transportation systems
Рисунок 1 – Функції, які можуть виконувати інтелектуальні транспортні системи

Smart urban transport requires technologies that will enable data exchange between the central link of the system and all its components, as well as between individual elements of the entire communication system. An essential component of any modern transport-related solution is information subsystems, the main purpose of which is to increase the availability of information for public transport users.

The innovative way of development requires the creation of new methods of operation, management and control. The modern direction of restructuring and modernization of transport should be a qualitatively new approach, one of the basic principles of which is the use of intelligent transport systems (ITS). The use of intelligent transport systems in many countries is dictated by the modern technical development of society, the level of technology and the requirement for the quality development of transport systems.

In the process of analyzing foreign experience in implementing intelligent transport systems, we have encountered conceptual uncertainty and confusion regarding the terms «integrated transport systems» and «integrated transport systems». These two terms are often used synonymously, although they have different conceptual approaches and objectives.

The analysis of literature and international practices has shown that:

- Integrated Transport Systems are aimed at combining different modes of transport into a single, complementary system that allows optimizing logistics processes and increasing transportation efficiency.

- Integral Transport Systems focus on balancing traffic flows, strategic management and end-to-end control over all stages of passenger and cargo movement, ensuring the harmonious development of the transport network.

To analyze the features and differences of these concepts in more detail, it is worth considering the definitions given in Tables 1 and 2, which provide the relevant arguments and sources of information.

Traffic management system on highways

The vehicle management system consists of several subsystems, including: an alarm management subsystem, an information display subsystem, a real-time video surveillance subsystem, and an analysis subsystem. Using intelligent built-in traffic controllers, LED panel lights and warning systems, vehicle detectors, and surveillance cameras concentrated in one place, several road functional groups can be conventionally identified:

Vehicle detectors collect information about the traffic flow, including the number of vehicles, their speed, location, and then send this information to an intelligent embedded computer via a wireless transmission system.

The embedded computer, as part of the traffic controller, calculates and analyzes the data to determine the state of the traffic flow, and then sends signals to traffic lights and warning boards, thereby creating conditions for the traffic process to be continuous and avoid congestion on the highway.

The traffic controller can also send information to warning devices to inform drivers about traffic jams on the highway and alternative routes to avoid congestion [13].

Vehicle position control system

The GPS controller of the system determines the position of the object, registers the route and speed of movement. Fuel consumption, driving and parking time, and equipment operation are monitored using special sensors. The data from the on-board system of the object is transmitted to the server via GPRS and archived in the independent memory of the on-board system (in case of the absence of a GPRS channel). The transmitted data is processed on the server and displayed to end users in the form of interactive maps, text reports, and graphs.

The main features of the system:

- graphical display of the current position of the object on the map
- graphical display on the map of the route of the object
- control of fuel consumption and mileage
- control of travel time, parking
- control of compliance with the route
- registration of the work of the executive equipment (transfer case, body lifting, etc.).

Video surveillance system

The video surveillance system is designed to visually monitor and control the most dangerous sections of the road. It is possible to monitor both in real time and frame-by-frame with a certain frequency. In addition, the system has the ability to archive the received video data for further viewing if necessary.

If necessary, the system can transport images from cameras in real time to the surveillance center via digital data channels. Thanks to the use of the Streamlogic compression algorithm, the data takes up a small amount of space and can be transmitted over wireless data channels.

Traffic intensity accounting system

The system is designed to record the number, type (cars, buses, light trucks, medium trucks, etc.). and speed of vehicles passing control points. The system provides centralized storage of the received information and further output in the form of reports and graphs. The built-in statistical processing module allows solving tasks in the field of transport logistics.

Table 1 – Define the term «Intelligent Transport System»
Таблиця 1 - Визначення терміну «Інтелектуальна транспортна система»

№	Definition	Rationale (why this definition was chosen)	Literature and information source
1.	**An intelligent transportation system** (ITS) is a transportation system that uses innovative developments in modeling and regulating traffic flows, which provides end users with more information and safety, as well as qualitatively improves the level of interaction between traffic participants compared to conventional transportation systems [3].	Because: The traffic management system is designed to collect an array of information online, analyze it, and automatically make decisions on traffic optimization	Intelligent transportation system [Electronic resource]: https://en.wikipedia.org/wiki/Intelligent_transportation_system
2.	**An intelligent transportation system** is a blend of computer, information technology, and telecommunications developments, along with knowledge from the automotive and transportation sectors [4].	Because: ITS solves the following tasks: • Optimization of traffic light control algorithms; • Automatic recording of traffic violations; • Prioritization of public transport traffic; • Real-time monitoring of traffic conditions; • Informing road users about road conditions	Intelligent transport systems, a collection of materials for city policy makers, [Electronic resource]: https://city2030.org.ua/sites/default/files/documents/GIZ_SUTP_SB4e_Intelligent-Transport-Systems_UA.pdf
3.	**An intelligent transport system** is a system that analyzes camera data and adjusts traffic flows to relieve roads as efficiently as possible and organize public transport [5].	Because: ITS enables: • Reducing the level of congestion on streets and roads; • Reducing the time spent on transportation; • Improving road safety; • Informing road users about the current traffic situation and optimal routes	Intelligent transport system, the most difficult intersections in Kyiv are already analyzed by smart cameras: [Electronic resource] – Access mode: https://kyivcity.gov.ua/news/nayskladnishi_perekhrestya_v_kiyevi_vzhe_analizuyut sya_intelektualnoyu_transportnoyu_sistemoyu__petro_olenich/
4.	**Intelligent Transport System** (ITS, Intelligent Transport Management) is a system that combines computer, information and communication technologies to manage the movement of vehicles and goods in real time, and allows for improved road safety and the quality of transport services [6].	Because: The use of modern advances in information technology and communications in the management of transport systems can dramatically improve the efficiency and quality of their work.	Intelligent transportation system [Electronic resource]: https://apluss.ua/upravlinnya-transportnoyu-systemoyu/intelektualni-transportni-sistemi-its/
5.	**ITS** is a system that integrates modern control technologies with telematics and is designed to automatically search for and adopt the most effective scenarios for managing a vehicle and its elements to ensure mobility at a set level of service quality for vehicle users [7].	Today, the scope of ITS promotion in global practice ranges from solving public transport problems, significantly improving road safety, eliminating congestion in transport networks, increasing the productivity of the transport system to environmental and energy issues.	Intelligent transportation systems [Electronic resource]: https://stud.com.ua/120718/informatika/intelektualni_transportni_sistemi

Table 2 – Define the term «Integrated transportation system»
Таблиця 2 –Визначення терміну «інтегрована транспортна система»

№	Definition	Rationale (why this definition was chosen)	Literature and information source[2018-2022]
1.	An **INTEGRAL TRANSPORTATION SYSTEM** is a system of balanced management of the movement of material and related flows throughout the entire life cycle in order to optimize the system's target function – timely satisfaction of the needs of a particular consumer with minimal costs in the transport system [8].	Because: The need for a highly developed transport system is even more pronounced with integration into the European and global economy, and the transport system becomes the basis for Ukraine's effective entry into the global community and its place in it as a highly developed state.	**Integrated pharmaceutical logistics system,** [Electronic resource] – Access mode: https://www.pharmencyclopedia.com.ua/article/6974/integrovana-farmacevtichna-logistichna-sistema
2.	**Integral transport system –** coordination between transport modes and different transport systems [9].	Because: An integrated approach in the transport system requires combining different functional areas and their participants within a single logistics system in order to optimize it	**Integrated transport systems,** [Electronic resource] – Access mode: https://transportgeography.org/contents/chapter5/intermodal-transportation-containerization/integrated-transport-systems/
3.	**Integral transport system –** optimization of management processes in strategic planning to improve the quality of transport services [10].	Because: Transportation integration must take into account factors from origin to destination to ensure passenger safety and comfort throughout the journey.	Quality management of logistics processes at enterprises: an integral paradigm, [Electronic resource] – Access mode: http://www.economy.nayka.com.ua/?op=1&z=2494
4.	**Integral transport system –** synchronization of processes and end-to-end control over flow processes in transport systems [11].	Because: Public transport works best when it operates as a single integrated system	The concept of logistics, its functions and tasks, [Electronic resource] – Access mode: https://pidru4niki.com/72692/logistika/funktsiyi_integralnogo_logistichnogo_menedzher
5.	**Integral transport system –** management of main and related flows to ensure the most complete and high-quality passenger satisfaction in accordance with their specific needs and goals [12].	Because: The capacity of each mode of transport should be developed to meet its specific demand, which is considered within the overall demand for all modes of transport.	Concepts of logistics [Electronic resource] – Access mode: https://learn.ztu.edu.ua

GPS satellite navigation system

GPS is an abbreviation of the English name Global Positioning System, which means «global positioning system» or, in a more correct technical translation, «global positioning system». Its main interacting elements are 24 NavStar space satellites (launched and currently in operation by the United States) and millions of receivers on the Earth's surface. The GPS satellite navigation system was originally developed by the United States for military use. Another well-known name of the system is «NAVSTAR». The purpose of the system is to provide navigation throughout the globe. Not only on land, but also at sea and in the air.

The system works like this: the receiver picks up a signal from 3 or more satellites, measures the delay time of the signal from each of them and automatically calculates its location – geographical coordinates: latitude, longitude, and altitude. The device processor correlates this data with an electronic map loaded into the device's memory. thanks to this, the user sees an image of a geographic map on the display, where a «dot» is shown and moves – it is the user with his GPS receiver.

The GPS system is based on the principle of satellite trilateration. According to this principle, the coordinates of an object on the Earth's surface can be calculated by measuring the distances to satellites. Since the position in space is known and the satellites transmit the calculated values of their orbital parameters along with the range code, for an object on the Earth's surface, the satellites are points with known coordinates at any given time.

To simplify and secure the city's road system, it is necessary to think about parking. This is perfectly handled by parking machines, which are devices that are available in automated paid parking lots. With their help, a motorist can pay for parking independently in accordance with the set tariffs. The devices not only simplify the life of drivers, but also make parking more economical by reducing the cost of employees.

Automated lighting control

The lighting control system makes it possible to fully automate street and road lighting. It is able to independently make decisions on the need to turn on or off the lights in accordance with the situation on the road, time of day and other factors. The system operates according to a predefined algorithm, receiving information from various sensors that record the traffic and illumination of the road area.

Means of automatic recording of violations

One of the most important elements of the ITS, which is designed not so much to record traffic violations as to prevent such violations and accidents. Cameras are able to record any violation of the rules and make punishment for creating a dangerous situation on the road mandatory, so that drivers will be more responsible for following the rules.

ITS IN UKRAINE.

Attempts to introduce ITS in Ukraine began in 2008, when the mayor of Kyiv announced the creation of the Smart Traffic Lights system. To create the Smart Traffic Lights system, the city attracted a €30 million loan from the European Bank for Reconstruction and Development. In 2014-2015, the city administration plans to modernize most of the traffic lights, as there are currently 120 outdated traffic lights of this type in the center. They will be equipped with an automated control system that will be able to respond to the situation on the road. The essence of the system is to create a «green wave» for a group of cars moving at cruising speed. At the intersection, a permissive signal lights up for them. And such a corridor is created further along the road. The system is being modernized so that it will track traffic in real time and switch the traffic signal depending on the situation. Special sensors will read the number of vehicles and determine their type. Kharkiv is the furthest along the path to implementing an intelligent urban transport system in Ukraine. For the Euro 2012 championship, Kharkivpasstrans developed several programs to inform traffic management: a single travel card, a GPS navigation system, and a unified urban transport system. At the beginning of 2011, the Kharkiv city administration set a course to introduce GPS navigation systems on all types of transport as a crucial step towards creating a unified transport system in the city. By the middle of the same year, GPS navigators were operating on almost all of Miskelektrotrans' rolling stock. Thus, the transport infrastructure is gradually moving closer to creating a unified transport system of the city, which allows for efficient and prompt regulation of passenger flows and response to any traffic situations. ITS has many advantages, but a number

of system requirements – high accuracy of vehicle positioning for real-time control, navigation services for emergency vehicles, but the creation of a continuous sustainable navigation service in tunnels and multi-storey urban buildings – cannot be provided by the capabilities of modern satellite navigation systems. To fulfill these requirements, it is necessary to integrate positioning technologies with wireless communication technologies to create a continuous virtual transport management environment in any conditions. Other disadvantages of intelligent transport systems include:

- localization of sources (inability of cameras to cover 100% of the territory);
- difficulties with accumulating statistics based on existing databases;
- impossibility of realistic assessment of target efficiency – the ITS pilot zone is not scalable to the size of the city;
- increase in data error when ephemera change, which reaches 30 meters;
- the impact of terrain on data accuracy;
- periodic disruption of signal continuity, which is expressed in distortion and delay in signal detection.

Also, under certain conditions, the receiver does not receive a signal: due to heavy cloud cover from terrestrial radio sources. In this case, the operating frequency is in the decimeter range of radio waves. In addition, the signal reception is impaired by being inside a reinforced concrete building, in a basement, tunnel or apartment. Taking into account that the inclination of the orbit of the GPS monitoring system is 55, the signal in the circumpolar regions is poorly picked up. The main problem with satellite systems is their high cost, as they require large one-time investments to purchase photo and video cameras, modern traffic lights, information boards, and the creation of a unified electronic database for putting the system into operation. In addition, the condition of some roads is not ready for the implementation of this project. Also, the accuracy of the images is currently insufficient. But despite the shortcomings, this method of obtaining information about the Earth is the most promising [14].

In Ukraine, the formation of intelligent transport systems is at an early stage (standards, legislation, technologies and general principles of the system are being developed). The main financial risk of implementing an advanced ITS model is underfunding, which is minimized by phased financing, which requires sufficient investment for each stage of development. The main legal risk is the lack of a legislative framework for building the ITS and standardization in the field of interaction between executive authorities. The group of legal risks can be minimized by creating a legal environment, a methodological complex for the development of ITS, and conditions for coordinating the interaction of various executive authorities. Market and technical risks include the absence of a well-developed strategy and vision of ITS development. To minimize this risk, it is necessary to create a scientific community to develop its own ITS technologies and create a National ITS Development Strategy. It is necessary to develop national standards for the main indicators, interfaces and communication protocols of ITS components. For this purpose, it is advisable to create a Unit for ITS Systems and allocate it appropriate initial state funding [15].

In the future, the ITS Unit or an organization authorized by the government will conduct licensing in the field of ITS systems and certification of ITS systems of various levels and purposes on an ongoing basis, i.e., work on a partial self-supporting basis. The ITS unit will be responsible for: coordinating all activities in the country in the field of ITS systems; organizing the development of standards and regulations; conducting licensing and certification in the field of ITS systems; managing training in the field of ITS systems; and ensuring international cooperation. To train personnel in the field of ITS systems, it is necessary to create a Training and Research Center, which would not only train specialists, but also test standard equipment and conduct certification research in the field of ITS systems. Thus, the current stage of development of intelligent transport systems in Ukraine should become a stage of consolidation in which government agencies, industrial entrepreneurs and persons involved in the development, creation, supply, operation and use of ITS systems are interested. At this stage, it is advisable for government agencies to focus their efforts on ensuring:

- Streamlined and consistent regulatory framework relating to the main aspects of ITS activities;
- Coordination of scientific support for the development of ITS systems in Ukraine;
- Formation of a system of training and retraining of human resources in the field of ITS systems [16].

Conclusions and recommendations. To study the development of ITS in the world and in Ukraine as an instrument of economic growth in Ukraine. The results of the scientific research make it possible to note that there are problems of increasing traffic intensity, deteriorating accident rates, increasing traffic volumes, not always high quality of traffic flow management and service at the trans-port – there is a need to introduce ITS in transport.

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АНАЛІЗ ЗАРУБІЖНОГО ДОСВІДУ ВПРОВАДЖЕННЯ ІНТЕЛЕКТУАЛЬНИХ ТРАНСПОРТНИХ СИСТЕМ В УКРАЇНІ

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Висновоки: в Україні впровадження ІТС відбувається повільно через фінансові та технічні виклики, а також недосконале законодавче забезпечення. Проте міжнародний досвід підтверджує, що інтелектуальні транспортні системи можуть суттєво покращити ситуацію на дорогах, підвищити рівень безпеки та зменшити екологічний вплив транспорту. Результати дослідження вказують на необхідність розробки державної стратегії розвитку ІТС, впровадження єдиних стандартів та залучення інвестицій у модернізацію транспортної інфраструктури.

Ключові слова: інтелектуальна транспортна система, управління дорожнім рухом, інтенсивність руху, затори.

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