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INTELLIGENT TRANSPORT SYSTEM: THE PROBLEM OF DEFINITION AND FORMATION OF CLASSIFICATION SYSTEM

Abstract

Introduction. The experience of developing the economies of the developed countries of the world suggests that it is directly related to the evolution of transport and infrastructure. In most of countries, intelligent transport systems (ITS) are under investigation as one of the scientific directions of the symbiosis of the economy - technology – telematics, and considered as the most effective tool for solving transport problems. The efforts of international organizations, state representatives in the field of transport, scientists, entrepreneurs and the public are aimed at such key areas as: significant increase in both the safety of transport on all modes of transport and capacity grows of the transport system of the country.

Purpose. The goal of the article is to develop a single integrated approach to the definition of the term ITS and to provide a general classification system with details on the management objects.

Methods. To achieve the goal methods have been used based on the systems approach, management theory and decision-making theory. The system analysis has been used to determine the scientific task.

Results. In order to implement the tasks of transport management in terms of ITS, the system analysis of the field of research has been carried out in the article, including the systematization of the definition and the construction of a general classification system with details on the management objects. The analysis of the subject area of ITS usage has allowed establishing the main classes of the analyzed objects, to classify the tasks of monitoring characteristics, organization of management of transport flows and transportation process, information support for participants, organization of transport infrastructure management. Research of the literature sources allowed to form an integrated approach to the ITS classification system, which includes both systems introduced in the objects of transport infrastructure and in the management of transport flows. In the addition to the above, the main thing in the infrastructure objects is the terminal monitoring and management system, as well as the security management system.

Conclusion. ITS is a new type of transport management systems that are gradually replaced by automated control systems. They are focused on modeling various cases and forecasting of dangerous situations and be used for decision-making tool in the condition of great complexity and large amounts of data. ITC can be considered as an important component of the modern integrated approach to improving the efficiency of the functioning of the country's transport system by expanding their information infrastructure: automated data collection on state of the system in real time, modeling direct and indirect operational impact on the formation and change of transport flows.

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Ольга Катерна (Україна)

ІНТЕЛЕКТУАЛЬНІ ТРАНСПОРТНІ СИСТЕМИ: ПРОБЛЕМА ТЕРМІНОЛОГІЇ ТА ФОРМУВАННЯ СИСТЕМИ КЛАСИФІКАЦІЇ

Анотація

Вступ. Досвід розвитку економік розвинених держав світу показує прямий зв'язок його із розвитком транспорту та інфраструктурою. У більшості країн світу інтелектуальні транспортні системи (ІТС) досліджуються як один із наукових напрямків симбіозу економіки – техніки – телематики, і розглядаються як найбільш ефективний інструмент для вирішення транспортних проблем. Зусилля міжнародних організацій, державних представників у сфері транспорту, науковців, підприємців та громадськості спрямовані на такі ключові напрямки, як істотне підвищення безпеки перевезень на всіх видах транспорту і підвищення пропускної здатності транспортної системи країни.

Мета. Метою статті є формування єдиного комплексного підходу до дефініції визначення ІТС та наведення загальної системи класифікації з деталізацією за об'єктами управління.

Метод (методологія). Для досягнення мети були використані методи на основі системного підходу, теорії управління та теорії прийняття рішень. Системний аналіз – для визначення наукового завдання.

Результати. З метою реалізації завдань управління транспортом на основі ІТС у статті проведено системний аналіз галузі дослідження, що містить систематизацію визначення і побудову загальної системи класифікації з деталізацією за об'єктами управління. Аналіз предметної області використання ІТС дозволив виокремити основні класи аналізованих об'єктів, класифікувати завдання моніторингу характеристик, організації управління транспортними потоками та перевізним процесом, інформаційним забезпеченням учасників, організації управління транспортною інфраструктурою. Дослідження фахових джерел дозволило сформувати комплексний підхід до системи класифікації ІТС, який містить як системи, що впроваджуються в об'єктах транспортної інфраструктури, так і при управлінні транспортними потоками. При цьому основним в об'єктах інфраструктури є система моніторингу та управління терміналом, а також система управління безпекою.

Висновки. ІТС є новим типом систем управління на транспорті, що поступово заміщують автоматизовані системи управління. Вони орієнтовані на моделювання різних подій та прогнозування небезпечних ситуацій і служать інструментом ухвалення рішень в умовах великої складності і великих обсягів даних. ІТС можна розглядати як важливу складову сучасного комплексного підходу до підвищення ефективності функціонування транспортної системи країни за рахунок розширення їх інформаційної інфраструктури: автоматизованого збору даних про стан системи в масштабі реального часу, моделювання та прямого й опосередкованого оперативного впливу на формування і зміну транспортних потоків.

Катерна О. Інтелектуальні транспортні системи: проблема термінології та формування системи класифікації. *Економічний аналіз*. Тернопіль. 2019. Том 29. № 2. С. 33-43.

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Ключові слова: види транспорту; інтелектуальні транспортні системи; інформаційне забезпечення; об'єкти інфраструктури; транспортні потоки.

1. Introduction

Transport, as one of the most important sectors of the national economy, is grounds for accelerating development by integrating Ukraine into the world transport system. Modern transport management is based on the use of information systems and technologies that are able to independently analyze information and make decisions in accordance with the established model of behavior.

Necessity for intellectual management in transport is a question of present interest and is the latest approach to managing the country's transport system.

The solution of the problem of efficient management of transport flows and infrastructure objects necessitates the research of information technologies of transport management, including the management of mobile objects and elements of transport infrastructure.

Necessity to improve existing information systems and technologies requires constant analysis that becomes possible during the study of practice and management experience in the transport sector of the world's leading countries. The experience of ITS using by leading countries shows that it is an important mechanism for effective management of the country's transport system. Thus, the innovative way of transport development requires the development of new methods of management and control, based on scientific - theoretical insights and expanding the scientific and conceptual basis of ITS.

2. Brief Literature Review

Internationally during management of transport flows and infrastructure objects technologies of intelligent transport systems are increasingly being used. The sustained tendency of further improvement and introduction of such systems is being strengthened. In the field of theory and practice of using ITS a significant positive experience has been accumulated, which is confirmed by researches of such scientists as Panamareva O.M. (2012) [16], Merenkov A. O. (2015) [14], Markelov V. M, Soloviev I. V., Tsvetkov V. Ya. (2014) [12], Dmitriev I. I., Kirillov A. M. (2017) [3], Osik V. E., Gorshchar R. S., Kozak A. M. (2016) [15], Komarov V. V., Garagan S. A. (2012) [11], Ivanov F. F. (2014) [7], Kocherga V. G. (2001) [10], Zhankaseev S.V. (2016) [23], Franke S. (2001) [6], L. Figueiredo; I. Jesus; J. A. T. Machado; J. R. Ferreira; J. L. Martins de Carvalho (2001) [5], Aldona Jarasuniene (2006) [8], Przhibyl P., Svitek M. (2003) [18], Mikheeva T.I. (2007) [13], Perego, A., Perotti, S., and Mangiaracina, R. (2011) [17] and others.

In recent decades in the native practice of ITS management considerable experience has accumulated, the scientific and methodological foundations of which have been generalized in researches by Skalozub V. V., Soloviev V. P., Zhukovitsky I. V., Goncharov K. V. (2013) [22], Rudzinsky V. V., Melnichuk S. V. (2012) [20], Rudzinska A. V., Bezzub Ya. V., Shumlyakivsky V. P. (2016) [21] and others.

The theoretical analysis that has been made gives grounds to state the insufficient terminological development of the problem and the deficiency of a unified approach to the definition of the term ITS. Current approaches to the classification system under draw about a comprehensive idea of the integrated application of ITS on all mode of transport and objects of infrastructure.

Thus, the problem of developing scientific and theoretical concepts and expanding the scientific and conceptual basis of the ITS is important.

3. Purpose

The goal of this scientific research is to substantiate the importance and necessity of forming an integrated approach to the definition of the term of ITS and the presentation of a general ITS classification system by modes of transport and objects of infrastructure.

4. Results

Today, as well as in the scientific literature [12, 14, 19, 22], and in many strategic, political and program-target documents of leading countries [1, 4], the term “Intelligent Transport Systems” is commonly used. The experience of using of ITS shows that they are effective in solving problems ranging from the management of public transport, improving of road safety innovation, optimizing transport flows, increasing the productivity of the intermodal transport system of the country (including road, rail, air and sea transport) to environmental and energy problems [7, 9, 15, 16, 23].

Taking into account the world experience, it is advisable to speak about ITS as a general transporting ideology of integrating the achievements of the economy - technology - telematics (satellite-based monitoring of transport) in all types of transport activities. The problem of ITS implementing is strategic; its solution determines the overall competitiveness of each country in the world market. Relative to significant capital intensiveness, ITS can’t be implemented without the direct involvement of the state, the relevant state program and support.

Panamarova O. M. notes that as a result of the annual growth in the volumes of international relations, the development of society and the economies of states, the services quality of the transport system of the country must comply with the higher requirements that have been applied. For this, it is necessary to carry out the solution of the problems presented in Fig. 1 (two possible directions for their solution are also presented here) [16, P. 97].

Investigating the question of the essence of ITS it is necessary to consider in detail the points of view of scientists regarding the interpretation of this definition and to disclose the content of this definition (Table 1).

The general characteristics of existing approaches to the definition of ITS is that they represent a modern system of telecommunication technologies that are used to manage traffic flows, ensure traffic safety and the efficiency of transport operation, and create a single database of "transport information".

Thus, the term "ITS" refers to the system integration of telecommunications, information and communication technologies, as well as automation facilities with transport infrastructure facilities that are designed for automated search and decision-making aimed at ensuring population mobility, improving safety, efficiency and improving the quality of the transport process.

The term "Intelligent Transport Systems" is more used for the countries of North America, Asia and Australia. In Europe, along with ITS, there is also the concept of "Transport Telematics", which covers the area of using the capabilities of telecommunication technologies and informatics in solving technological problems in transport. This term appeared through the compilation of the words "Telecommunications" and "Informatics" and shows a close connection between the two branches.

Transport telematics combines information and telecommunication technologies with the organization of traffic flow to increase capacity of transport infrastructure, to further traffic safety and psychological comfort of passengers [18, P. 13].

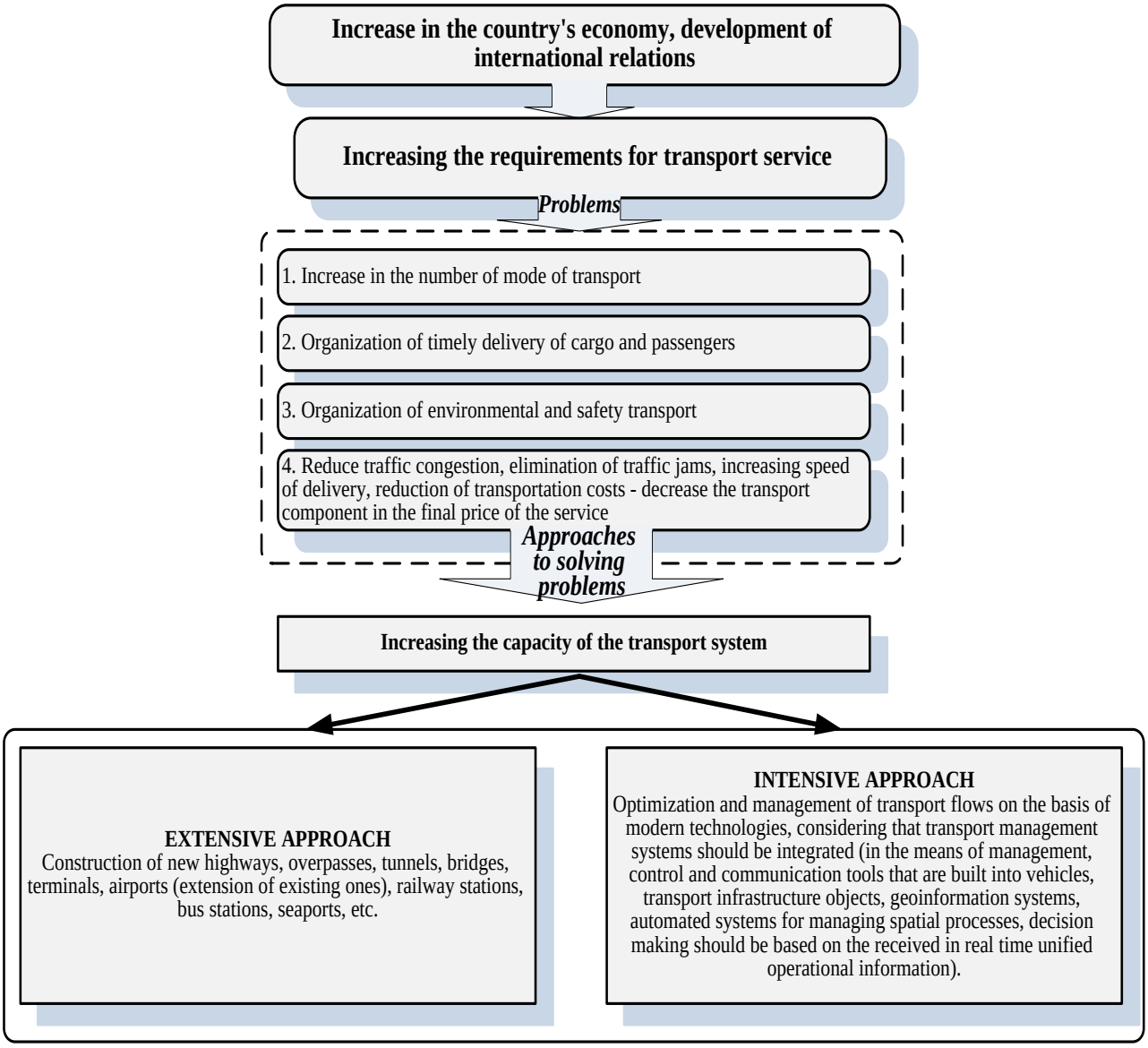

Fig. 1. Problems solved within the framework of the transport system with the growth of public relations and the development of the country's economy

Source [16, P. 97]

Table 1. Definitions of the term "Intelligent Transport Systems"

№	Author	Definition	Source
1	Merenkov A. O.	ITS is a complex engineering design that can reduce accident and hazard on the road by implementing complex information systems that provide traffic management and allow you to rapidly apply for emergency medical care in the cases of road accidents. In addition, ITS plays a critical influence in terms of ensuring national security.	[14, P. 100]
2	Markelov V. M., Solovyov I. V., Tsvetkov V. Ya.	ITS - systems created on the basis of integration of means of automating transport control and management, information and communication technologies, dynamic geodata and a unified information environment in the transport infrastructure, vehicles that are aimed at improving the safety and efficiency of traffic flows and transport users.	[12, P. 43]
3	Skalozub V. V., Solovyov V. P., Zhukovitsky I. V., Goncharov K. V.	ITS is a large range of services that are provided to users for comfort of use and to achieve the maximum capacity of transport networks. Intellectual properties are essential to the functioning of telematic systems.	[22, P. 9-10]
4	Dmitriev I. I., Kirillov A. M.	ITS is a telematic transport system that provides the implementation of functions of high complexity in processing information and developing optimal (rational) solutions and control actions.	[3, P. 7]
5	Osyka V. E., Gorshary R. S., Kozak A. M.	ITS is an intelligent system that are used innovative developments in the modeling of transport systems and the regulation of traffic flows, provides end customers with greater informative value and safety, and also qualitatively increases the level of interaction between the participants of the movement in comparison with conventional transport systems.	[15]
6	Rudzinsky V. V., Melnichuk S. V.	ITS is a collective term when using electronics, communications, information processing technology, etc. ITS is the integration of information and communication technologies between the main components of transport processes: a person - vehicle - transport infrastructure.	[20, P. 165]
7	Rudzinska O. V., Bezzub Ya. V., Shumlyakivsky V. P.	ITS is a system integration of modern information and communication technologies and automation facilities with transport infrastructure, vehicles and users, focused on improving the safety and efficiency of the transport process, the comfort for drivers and transport users.	[21, P. 230]
8	Komarov V. V., Garagan S. A.	An intelligent transport system is a telematic transport system that provides the implementation of functions of high complexity in processing information and developing optimal (rational) solutions and control actions. ITS is a system that uses the most advanced progressions in information technology to provide convenient and efficient transportation of people and goods.	[11, P. 5] [11, P. 11]
9	Ivanov F. F.	ITS means the system integration of modern information and communication technologies and automation tools with transport infrastructure, vehicles and users, focused on improving the safety and efficiency of the transport process, the comfort for drivers and transport users.	[7, P. 90]
10	Kocherga V. G.	Defines ITS as a set of control systems: traffic, transportation and planning of individual trips, management in emergency situations, information support for traffic participants.	[10]
11	Zhankaziev S. V.	The system integrating modern information, communication and telematic technologies, management technologies and is intended for automated search and adoption of the most effective scenarios for the management of the transport system of a region (city, road), a specific vehicle or a group of vehicles for the purpose of providing a given mobility of the population, maximizing the use of the road network, improving the safety and efficiency of the transport process, and for drivers and transport users	[23, P. 19]
12	Franke S.	ITS - an advanced application that is a means of providing innovative services related to various modes of transport and traffic management, allows road users to be informed, and the transportation process becomes more safety. This is achieved through the coordinated "smart" use of transport networks.	[6]
13	L. Figueiredo; I. Jesus; J. A. T. Machado; J. R. Ferreira; J. L. Martins de Carvalho	Intelligent transport systems are based on the use of advanced communications, information, electronic technologies to solve transport problems, such as: traffic jams, road safety, improving the efficiency of transport and protecting the environment.	[5]
14	Jarasuniene A.	ITCs can be designed to intelligently and adaptively manage the flow of vehicles (cars, commercial vehicles, public transport vehicles and trains) through physical infrastructure, often in different jurisdictions and regimes.	[8, P. 54]

Source: [Compiled by the authors]

English word “intelligent” has one of the meanings “to have artificial intelligence; self-regulating (about the program and device)”. In this case we are talking about understanding not the presence of intelligence in the general sense, but directly the presence of artificial intelligence. This means the ability of a technical system to perform rather complex actions on information that are not confined to simple operations, such as data collection, grouping, reflection, obtaining some results by performing simple mathematical actions, for example, summation, definition of shares, etc. [18, P. 14].

In most scientific researches, the concept of “intelligent transport system” refers to the highway or railway transport, sometimes including the multimodal transport [3, 10, 11, 18, 21]. At the same time, according to the “Action Plan for the Deployment of Intelligent Transport Systems in Europe” [1], along with the ITS, a number of information systems were created (Table 2).

Table 2. Intelligent information systems (by mode of transport)

№	Mode of transport	Name (abbreviations)	Explanation
1	Aviation	Single European Sky Air Traffic Management Research (SESAR)	air traffic control in a single airspace of Europe
2	Inland water	River Information Services (RIS)	River transport information services - for inland waterway transport
3	Railway	European Rail Traffic Management System (ERTMS)	Rail Traffic Management System in Europe
		Telematics Applications for Freight (TAF-TSI)	Telematic applications for cargo transportation
4	Maritime	SafeSeaNet	Safety network in the maritime space
		Vessel Traffic Monitoring and Information Systems (VTMIS)	Vessel monitoring and information systems
		Long-Range Identification and Tracking (LRIT)	Long-distance identification and tracking
		Automatic Identification System (AIS)	Navigable Automatic Identification System
5	Highway	Electronic Vehicle Identification (EVI)	Electronic Vehicle Identification (EVI)
		Electronic Stability Control (ESC),	Electronic Stability Control (ESC),
		Intelligent Speed Adaptation (ISA),	Intelligent Speed Adaptation (ISA),
		Collision Avoidance System (CAS), lateral control/support, blind spot detection, side collision avoidance, driver monitoring,	Collision Avoidance System (CAS), lateral control/support, blind spot detection, side collision avoidance, driver monitoring,
		Adaptive Cruise Control (ACC), route guidance and navigation, vision enhancement,	Adaptive Cruise Control (ACC), route guidance and navigation, vision enhancement,
		Anti Blocking System (ABS), alcohol interlocks, seat belt reminder and post-crash systems (black box and eCall).	Anti Blocking System (ABS), alcohol interlocks, seat belt reminder and post-crash systems (black box and eCall).

Source: [Compiled by the authors according to 1].

Immediacy of the problem of using ITS today for Ukraine is more important than ever - because the economic integration of Ukraine with the EU depends on the successful implementation of the “Association Agreement”, advances of Ukraine in providing common values and rapprochement with the EU in the political, economic and legal spheres. The purpose of this agreement in the economic and industry-specific cooperation in the field of transport is to promote the using of ITS.

Also for the transport system in Ukraine is important the issue of managing and monitoring transport flows and objects of infrastructure and make transportation as efficient and safety as possible.

Besides the general development of Ukraine's transport corridors in the framework of cooperation with the EU, intermodality is a main issue (Possibility of freight international transportation by various modes of transport using one supporting document) taking into account the implementation of satellite-based monitoring systems GPS \ EGNOS \ Galileo \ GLONASS. In such a manner we can expect the introduction in Ukraine of already developed commercial solutions that facilitate transportation, videlicet in intelligent transport systems that have

already functioned in the EU (in Ukraine they are just beginning to be developed and implemented in separate infrastructure objects).

In leading countries there is a tendency to synchronize the management of both traffic flows and objects of infrastructure. Using innovative developments in the modeling and management of transport flows and infrastructure elements, it becomes possible:

- to increase the country's transit potential;
- to develop intermodal transport and international transport corridors;
- to create a favorable investment climate;
- to improve traffic safety and efficiency in managing and decisions-making;
- to improve the quality and competitiveness of transport services;
- to provide high-quality information support to operators of logistics services for passenger transportation and so on.

It should be noted that ITS can use forecasts based on information that was stored in the system before. Indicated factors empower to form the main goals of ITS development, which are presented in Fig. 2.

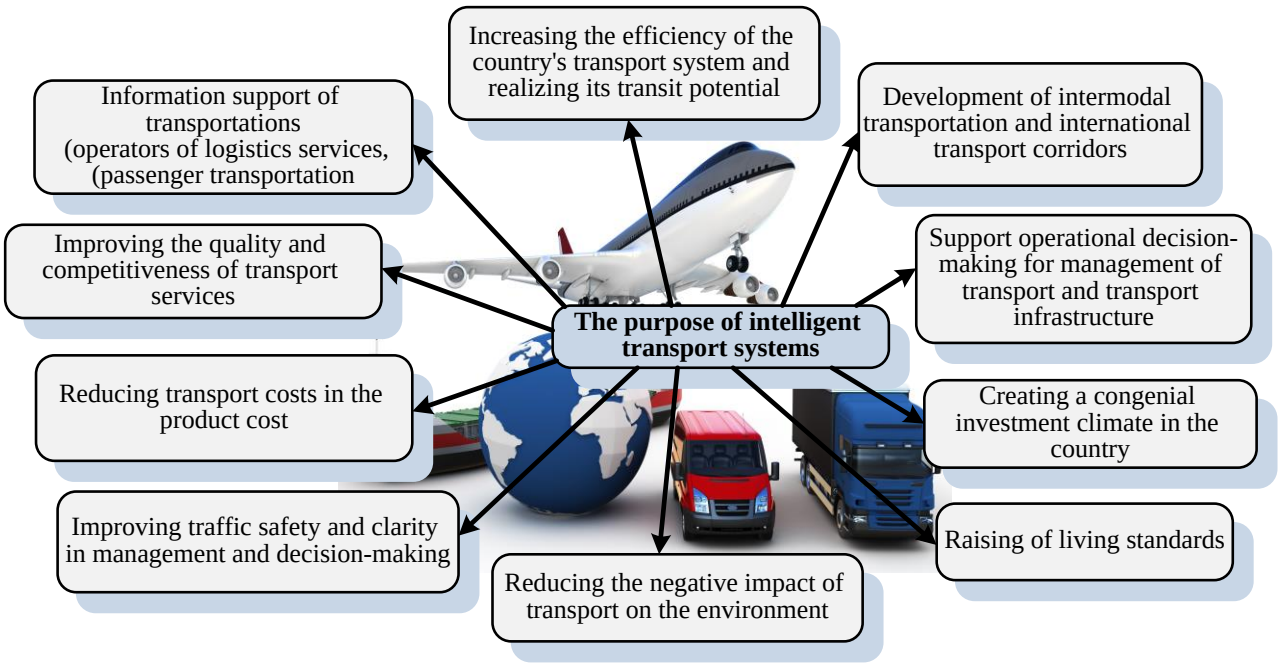

Fig. 2. Purposes of ITS development

Source: [Compiled by the authors].

ITS is a canonical example of a complex system that is characterized by: purposefulness, integrity, hierarchy, multidimensionality, emergence, multifunctionality of system elements; multicriteria, caused by the immanence (divergence) of the goals of individual elements of the system; complex (probabilistic and dynamic) behavior is in the interconnection of subsystems and requires feedback in the management etc.

The object of management for ITS is external traffic flows and internal flows in infrastructure elements (passenger and cargo flows). The sources of information about the control object are various sensors and detectors, identification technologies, contiguous information systems. And as for the analysis of information about the control object, it is necessary to program into the system some idea about this object, which is called a model. The detail and accuracy of the model is determined solely by the tasks that to be faced with the ITS.

Intelligent transport systems provide decision-making support under: optimization of traffic distribution in the network in time and space; increase the capacity of the existing transport network; provision of transportation priorities of a certain type of transport; transport management in case of accidents, disasters or events affecting the traffic; improvement of road safety, which leads to increased capacity; reduction of negative environmental impact; providing information on traffic situations to all stakeholders.

In consequence of ITS using, it is expressly understood that the factors affect the technology development that are stipulated by the political and economic situation in the country. Therefore, the private sector can very rapidly develop ITS technology.

Mikheeva T. I. in her research [13, P. 10] shares the classification of ITS tasks with the distribution on characteristics monitoring, management of transport flows, management of the transportation process, information support for the movement participants.

However, this classification concerns more road transport and management of the transport flow by external ones, excluding management tasks in the objects of infrastructure. The informatization infrastructure provides the conditions for the vital activity of the information environment and, first of all, its physical support and technical tracking.

ITS connects in a single whole new high-tech and science-intensive methods of managing various modes of transport with information environment and informatization infrastructure. Thus, we give the following classification of problems of ITS (Fig. 3).

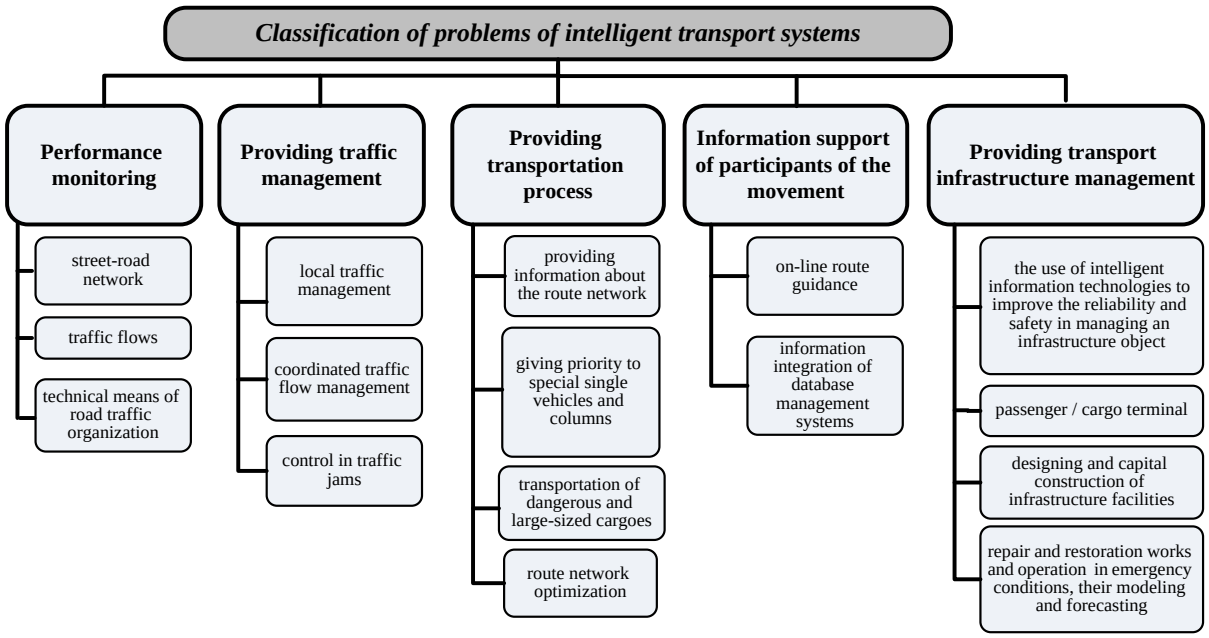

Fig. 3. Classification of problems of intelligent transport systems

Source: [Improved by authors]

Analysis of literature sources showed that there is up to now a unified approach to the classification of ITS does not exist. Thus, Jarasuniene A. in her research paper [9] offers a classification dividing into two main groups: ITS are in vehicles (such as communication systems and technologies inside them, so-called "intelligent vehicles"); and ITS located in the infrastructure or in the transport mode (such as dynamic signals, disturbance management systems etc.). In both categories, great efforts and work have been made to improve efficiency, based on the development of models of hardware, software and programs to optimize routes and traffic.

According to Jarasuniene A. [9], these systems are integrated through an information network, which includes the accumulation of information, communication, processing, dissemination and information using by users (for management and decision-making). These users can be subjects of regulation (as route managers), or they can be drivers transported passengers or goods.

Perego, A., Perotti, S. and Mangiaracina R. [17] classify basic information and communication technologies for logistics and freight transport using four groups:

1. Transport management applications. TM programs are tools that allow you to plan, optimize and perform transport operations. These systems store information about cargo, route, planning, tracking, audit system.

2. Supply chain execution. SCE applications manage real-time transport processes.

3. Field Force Automation. FFA applications are supported on mobile technologies and allow you to remotely manage your business processes.

4. Fleet and Freight Management. The FFM program is the manager of creating various reports. Also they allow you to make a decision in real-time.

Agre P. E. and Harbs C. A. [2] classified information systems into six groups (they used the classification only for highway transport): traffic management and travel systems; public transport management systems; electronic payment systems; systems for commercial vehicles; emergency management systems; extended systems for vehicles.

In our opinion, it is advisable to propose the following classification of ITS (Fig. 4). According to the developed classification system, intelligent systems are divided into two classes: in the management of objects of transport infrastructure and in the management of traffic. In this case, the main in

infrastructure objects are terminal monitoring and management system, safety management system.

It is proposed to classified ITS into two main groups: by mode of transport and traffic management and by transportation and traffic control. It should be noted that technological innovation and ITS using is the whole set of procedures, systems and devices that allow: to improve the mobility of people and the transportation of passengers and goods by collecting, transmitting, processing and disseminating information; get feedback and quantify the results. Recommendations of the ITS using should be based on assessments related to the impact they have on the quality of transport services, energy consumption, transport efficiency, safety, cost-effectiveness and environmental compatibility.

5. Conclusions

ITS using in the world is considered as one of the most effective tools for solving transport problems and is a source of creating for new industries.

In the scientific paper, various approaches of scientists to determine ITS have been analyzed, under which it is proposed to understand the system integration of telecommunication, information and communication technologies, as well as automation facilities with transport infrastructure objects, which are designed for automated search and decision-making aimed at mobility of the population, efficiency and improvement of the quality of the transport process.

The global goal of ITS design is the creation of a real-time monitoring and management system for the transport system in order to improve the quality of transport services, reduce transportation costs, improve environmental and safety [24].The study of the literature sources allowed to form an integrated approach to the ITS classification system, which includes both systems introduced in the objects of transport infrastructure and in the management of transport flows.

Further research is focused on analyzing the development of ITS in the world as a mechanism for ensuring the country's social and economic growth, revealing the essence and role of the management structure of intelligent systems in different countries, and defining common features of their implementation.

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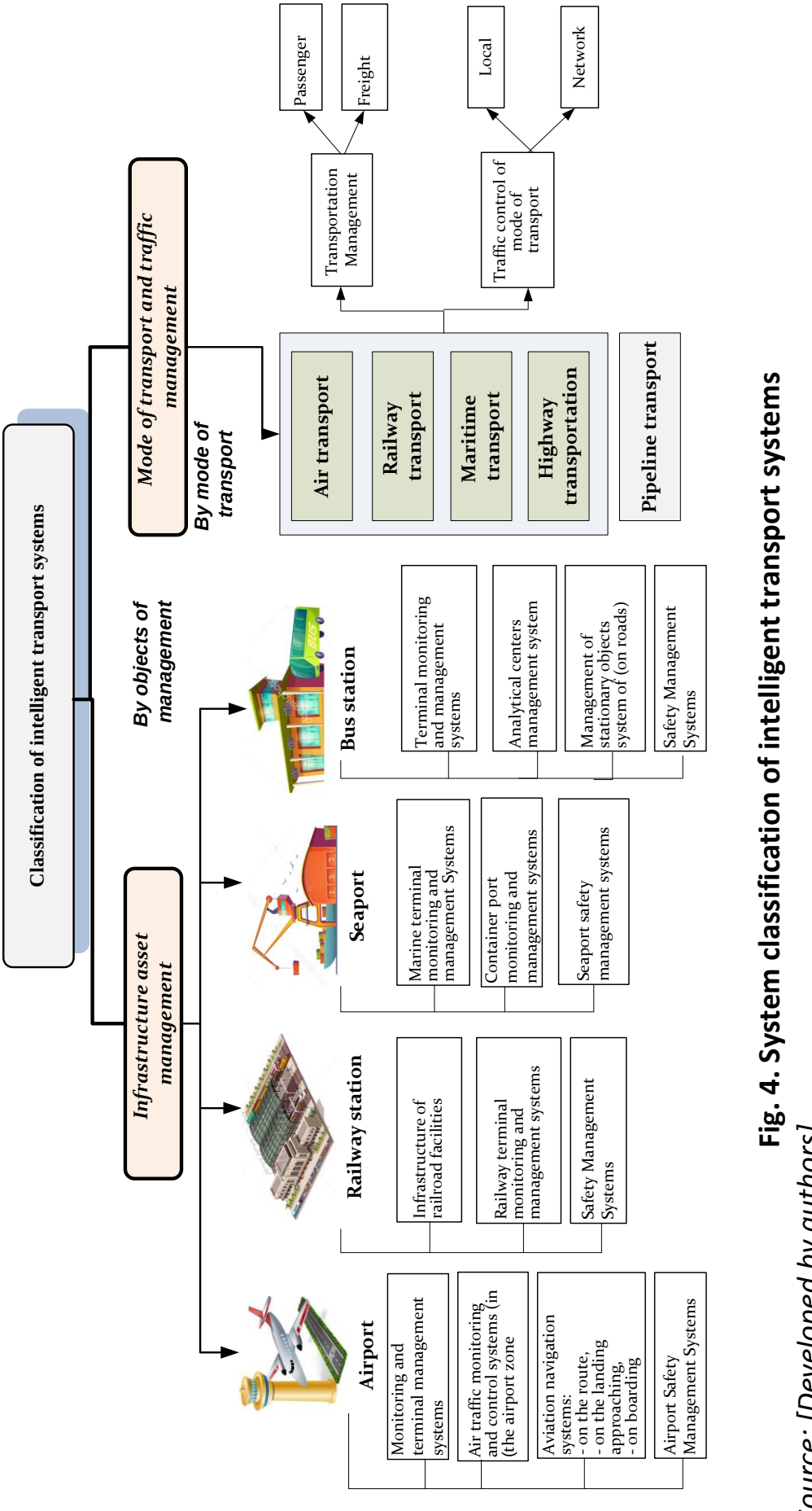

Fig. 4. System classification of intelligent transport systems

Source: [Developed by authors]

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