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Intelligent Transport Systems

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Abstract

An important strategic goal of the infrastructure development in the Czech Republic is the use of modern detection, diagnostic, information, control and security technologies based on intelligent transport systems (ITS), global navigation satellite systems and Earth observation systems. The modern transport system is based on a multimodal and intermodal approach. The individual modes of transport are being developed to form a coherent whole from the users' point of view. Transport infrastructure and vehicles must be in good technical condition and equipped with intelligent technologies. Managing the process of transporting people and goods requires reliable transmission of information in real time. The transport system must also be operated in a secure manner, be prepared for risk and emergencies and have the ability to deal with security threats arising from illegal behaviour. The paper briefly shows the process of building ITS, the possibilities of using modern intelligent information, diagnostic, control and safety technologies in transport until 2027 with a view to 2050.

KEY WORDS: *cooperative intelligent transport systems, human - machine interface, information and communication technologies, mobility as a service*

1. Introduction

Transport is the purposeful and intended movement of means of transport-on-transport routes. The product of transport is conveyance using transport technologies. Transport technologies include means of transport, infrastructure and transport organization. Information, communications and telecommunications are a separate part of the transport. The management of passenger and freight transport is conditioned by the reliable transmission of information, which is dealt with by transport telematics. It can be stated that transport has a global character; it is very closely linked to the territory of individual states. This interconnection is called interoperability, which is the ability of different systems to work together, provide services and achieve interoperability. Interoperability is usually achieved by complying with standards and by their compatibility, i.e. the compatibility of their technical equipment [1]. The transport infrastructure is built with parameters and modern technologies that provide quality services with minimal environmental impact and maximum safety. The requirements for traffic management are real-time activity, timeliness of the information on the location of vehicles, the state of the transport network and the detection of emergencies. The results of research and development are implemented in the transport, and the transport infrastructure is interconnected with elements of cooperative systems. Intelligent Transport Systems (ITS) are a tool of modern trends enabled by current technologies. They are sets of electronic devices, technical equipment, software and other tools that allow the search, collection, access, use and processing of data on roads, road traffic, travel, logistics and transport links, with the purpose to increase the safe and coordinated use of roads and reduce the negative impact of road traffic on the environment. The development of ITS is a modern trend in transport. It enables better transport planning, organization and management to be sustainable, accessible, interoperable, safe and economical. The field of transport has one of the highest innovation potentials as new applications of modern detection, diagnostic, information and control technologies are continuously being developed, based on global navigation satellite systems and Earth observation systems [2]. In ITS, both intelligent infrastructure and intelligent means of transport, as well as other active participants in transport or traffic, interact with each other. Through ITS, for example, intelligent infrastructure can provide reliable traffic or travel information.

Dispatchers of transport companies or integrated systems can give organizational and control instructions to vehicles, or vehicles can communicate with other means of transport as well as with infrastructure equipment in order to increase safety and traffic flow, reduce energy consumption or shorten travel times. The core of ITS is the

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use of information and communication technologies as well as digitization and automation. These could massively reduce human error in the transport system in the future. ITS make it possible to organize the process of relocating people and goods and further influence traffic in such a way that the existing transport network can be used more optimally. ITS technologies can provide data that can be used to reduce operating and maintenance costs of transport infrastructure. ITS allows traffic flows to be optimised in such a way that vehicles run smoothly without sudden stops and subsequent starts, thus eliminating excessive energy consumption. Currently, the massive development of large cities is evident. In addition to construction projects related to transport infrastructure, investments are needed in ITS systems for influencing and managing urban traffic, including urban public transport and city logistics [3], [4]. The ITS function is also applicable to rural areas. ITS can be used in cases of restrictions on the use of the road network, but also in cases of restrictions on the railway or waterway network. ITS is used in all modes of transport: road, rail, water, air, passenger and freight. Each mode of transport can use different components of the ITS system according to the needs and requirements. ITS is essential for ensuring intramodality (connectivity) and multimodality (combined transport), i.e. transport and transportation services across modes of transport. The individual parts of the ITS transport infrastructure, means of transport, instructions, information, and data structures must be interoperable at regional, national and international levels. The end user (passenger, carrier, shipper, consignor, consignee, etc.) expects continuous provision of certain service (traffic information, connection by public passenger transport, driving instruction for the railway vehicle, etc.) throughout the journey, regardless of where currently located, while it can use the transport infrastructure of different owners or travel on vehicles of different carriers, etc.

2. Trends in ITS Construction

The form of ITS is influenced by many parameters, trends, economic, technological, social and political directions. ITS is strongly influenced by technologies that support the strategy from simple construction of transport infrastructure to the efficient and safe operation of transport networks. Routine operations are being replaced by technology and automation. It is an ongoing process associated with the implementation of innovative products, services and optimization that are conditioned by economic factors. The most significant ITS trends and the overall form of the transport system mainly include safety, resilience, sustainable mobility, Single European Transport Area, education, awareness and ethics in society 4.0, multimodal approach, mass expansion of commercial value-added services, traffic management 2.0, mobility as a service and Door-to-Door Mobility, support for the transfer of research and development results into practice, big data, cyber security, cooperative C-ITS systems, etc.

Transport must be operated in a safe way, i.e. its operation must be ensured to avoid collisions of vehicles, collision situations that can be foreseen and resolved in advance, and that the transport infrastructure is in such a standard condition that it does not cause damage to the vehicle while driving on it (e.g. derailment). Furthermore, transport (traffic, infrastructure, etc.) must be designed and secured in such a way that the transport system does not fail in the event of emergencies and natural disasters such as floods, terrorist attacks, etc. Transport safety is a long-term priority and a constant trend in traffic organization and management [5], [6]. The company's well-known and accepted vision is "zero fatality". It means that no human life should be lost due to traffic. The application of modern technologies, including ITS and C-ITS, leads to the minimization of property damage or the risk of environmental accidents. Security also has the dimension of protecting road users or users of the transport system from criminal activities, including cyberspace.

The basic requirements for real-time traffic management include obtaining timely and correct (verified) information on the location of vehicles and the operation of the transport network by monitoring traffic and early detection of emergencies. ITS and C-ITS must successfully cope with emergencies where it is not possible for these systems to fail without any warning and in these extreme cases not to provide timely alternative procedures for organizing and managing traffic where ITS and C-ITS are not in action.

Sustainable mobility means organizing the transport of people and goods so that the needs of the served area are met according to its development in the short and long term. Innovative mobility systems can reflect changes in passenger behavior patterns. A necessary requirement is the use of digitization, automation and alternative sources for a gradual transition to clean, competitive and networked mobility. This transition requires new skills, adaptation and consideration of the needs of most key actors, in particular public administrations, passengers, carriers and users [7], [8].

Achieving the European goal of creating uniform conditions and technical rules in all EU countries to ensure the comparable quality of mobility services is a significant effort. A competitive and unified European transport system is expected. The application of harmonized ITS systems in all modes of transport, with support for interoperability at national, cross-border and European levels, tends to optimize transport and transportation processes with the main aim of substantially reducing Europe's dependence on imported oil and reducing carbon emissions by 60 % by 2050 (EC assumption).

The phenomenon of today is a digitization and related automation, which more or less affects not only the functioning of industrial production, the transport system, the functioning of cities, municipalities, or public institutions but also the everyday life of people. It is a large-scale and gradual societal change that not only changes the entire value chain and creates opportunities for new business models but also creates pressure on labor market flexibility. The success and development of ITS depend not only on technological progress but also on the ability to harness the potential of social diversity, the specific skills and experience of different social groups which will be reflected in the success of an economy capable of providing and serving their diverse needs. The public should be informed and educated about the use and application of modern (and constantly evolving) technologies in real life, as well as about the offer of new opportunities and benefits for society. However, informing and educating the public must be ensured in such a way that citizens' expectations of these breakthrough technologies are realistic and citizens are aware not only of the advantages but also of certain risks associated with these constantly evolving technologies. This education should be provided not only through lifelong learning but also through thematic training courses and awareness-raising campaigns, including opportunities to try out these technologies in practice in order to develop better habits and skills. Such an approach will help to create the necessary awareness and at the same time help to remove psychological barriers to the use of these new breakthrough technologies, as well as motivate users to use them (in the right way). In the context of the development of automation (for example, in transport in particular), routine human activities are being replaced which reduces human workload, corrects incorrect human interventions, eliminates errors and increases system performance. On the other hand, there is a loss of human habits and efficiency, especially in cases where the automatic system does not provide the required activities or it is necessary to operationally address non-standard or emergency situations. Sufficient ongoing training must be provided for persons operating or using automatic electronic systems to manage both operational situations in terms of operating and interacting with automatic electronic systems, as well as situations involving non-standard emergency and critical situations not addressed by the automatic system. Progressive automation could lead to a situation where people use the equipment, rely on it completely, and because of their lack of working with systems without automatic evaluation and decision-making, do not even recognize that there is a system failure or a critical situation they must understand and manage. Coping with such critical and dangerous situations can be trained in facilities that most realistically mimic emergencies arising in actual operation. This approach avoids a decline in the ability to handle critical situations due to a lack of practice [9].

A fundamental issue that relates to the possibilities of purely technological solutions is the ethics of automated operation. Academic and public discussions on ethical principles in the field of automated systems must go hand in hand with technical innovations in the field of automation. These include the effects of unforeseen emergencies, crises and accidents. Addressing ethical issues requires a general social consensus (principle of responsibility, correct decision-making in ethically ambivalent situations, etc.) and a legislative framework that regulates fully automated operations. Bearing in mind the basic standards of efficiency and profit on which the current private manufacturing sector is based, the state, or the public sector is ready to introduce such measures that regulate automated operation in the public interest, i.e. applying principles that ensure healthy development that is respectful of all heterogeneous parts of society.

The various modes of transport are gradually becoming better organized and coordinated in cooperation between the public and private sectors. The effort to create seamless information systems and the increasing need for cooperation and coordination between individual modes of transport contributes to the optimization of the transport system as a whole. Cities have specific transport problems and the consequent demands for appropriate policy decisions related to the organization and management of traffic, where measures may focus on the regulation of static traffic, restrictions on entry into cities, public transport preferences and the organization of city logistics. There are groups of key actors with different motivations and conflicting goals. The multimodal approach places high demands on the organization, management and coordination of transport in and out of town. A large amount of data is currently available. An important issue is the availability of data and its accessibility for different groups of users with specific needs. It is important to provide the end user (transport participant) with data relevant to them, which will increase their real-time awareness. Data sharing mechanisms and work on interoperability and standardization issues need to be further developed. Not only in passenger transport but also in freight transport, the trend is towards "seamless" transport. Especially for long-distance transport, it is rarely possible to transport goods from point A to point B directly by one means of transport without reloading. The introduction of new technologies, digitization and automation brings opportunities to make freight transport more efficient and, in some cases, to reduce transport time. This is especially possible in places where individual sections of the transport route are connected from one means of transport to another – logistics centers, combined transport terminals, ports, etc. In addition to automating logistics or transhipment operations, there is a long-standing desire to create a single and globally accepted electronic transport document (consignment note and accompanying documents required for transport), which will enable efficient information sharing not only between the supplying and receiving entities and the entities providing transport of goods, but also a data link with the supervisory authorities (for those transports that require professional supervision or supervision of compliance with the obligations imposed).

Today, business entities providing services to end users are significantly involved in the management and organization of transport. The private sector provides users, drivers and passengers with a wide range of transport, information, travel, navigation and other telematics services. These services are very popular, they are provided in high quality, in real time and their penetration is very high. Commercial services, therefore, have the potential to significantly affect transport (especially safety and the traffic flow). This poses both strength and threat to traffic organization and management.

It is possible to reduce the impacts of regular and irregular traffic congestion and increase the safety and condition of traffic solutions in critical parts of the transport network by applying appropriate traffic management and organization techniques. It is crucial to implement technological and organizational procedures based on the close cooperation of key entities, suppliers in the field of intelligent physical and digital infrastructure, vehicles (automotive industry) and services (manufacturers of map materials and navigation algorithms), who have so far cooperated only to a limited extent. The main goal is a wider range of products and services that will enable a new way of management and transport on roads usable not only from an individual user perspective but above all within the new Industry 4.0 concept of production management and organisation.

Mobility as a Service (MaaS) is a global trend today that aims to meet the needs of users through complex integrated services of the so-called "mobility operators". Drivers and passengers have access to public passenger transport, shared services, taxis, etc. through these operators at a pre-agreed quality. MaaS is a tool for implementing the trend of Door-to-Door mobility. An important element is the use of multimodal travel by users on the basis of "one electronic purchase of a ride". The principle based on the organization of the interchange route effectively manages the passenger's total time, if possible, without losses while waiting for the connection, and tends to suppress the need to own a vehicle. On a global scale, this has a positive impact on the efficient operation of the transport system [10].

Supporting the application of research and development results in practice, i.e. the commercialization of research and development results, is a trend that encourages the development of an intelligent mobility system. Cooperation in this area between academia and industry is crucial in terms of testing innovative solutions, mutual exchange of experience, as well as in terms of possible multi-source funding of development with subsequent implementation and deployment of already (in the pilot phase) proven ITS and C-ITS systems. Test sites or test polygons can be used to support this cooperation, but also to verify the ability to use new technologies and systems widely. The interoperability of new ITS and C-ITS technologies at the technical and organizational level needs to be ensured, thus ensuring that the installed solutions are not locked for technology open (neutral) and modular development. This approach will also reduce the cost of providing ITS services to end users.

Big data are data sets for which it is beyond the possibility to measure their size, store and process data at the required time by commonly used ICT means. With the digitization and automation of the transport system, more and more data will be created, which can be considered big data. The ability of key actors to work with this data will be increasingly needed. Processing large amounts of data from many data sources (from passengers, drivers, vehicles, goods, and infrastructure elements), information and real-time decision-making, processing historical data and their further use for optimization and strategic planning will be an integral part of a functioning modern transport system. Big data technologies will become a breakthrough tool to provide dynamic knowledge of mobility, enable the achievement of the goals of key actors (including political) and meet the expectations of users, including the vulnerable ones.

There is no doubt about the importance of cyber security (also known as information security in the ICT sector which can be seen as a set of legal, organizational, technical and educational means to ensure the protection of cyberspace). It plays a crucial role in all fields of human activity, where computer technology is used to a minimal extent. For ITS systems (or primarily in future C-ITS systems) and their future development and follow-up services (e.g. provided traffic information), cyber security is a key issue that needs to be addressed in order to guarantee the security (integrity, accessibility and confidentiality) of the systems and the data they contain.

New technologies have in the past provided and will continue to provide additional opportunities for the deployment of active traffic safety features, for the reliable and safe operation of ITS systems which the end-user perceives as trustworthy for ITS systems. The field of automated and autonomous vehicles is currently developing. Fully automated road vehicles are not yet normally used for live traffic. Until now, vehicles equipped with various levels of vehicle control automation are still being tested in a closed environment or in a test environment. But what is current and becoming a reality is the deployment of cooperative ITS (C-ITS) systems. C-ITS systems are based on communication (two-way data exchange) concerning the current situation in road traffic, both between the vehicles themselves and also between vehicles and road infrastructure equipment. C-ITS systems do not directly interfere with the vehicle control systems, the appropriate response depends on the decision of the (pre-warned) driver. Thanks to the warning message received, the driver can be informed in advance so that he can react to an unexpected road traffic situation as quickly and as best as possible (according to his abilities). Even in reduced visibility if he would otherwise react correctly and in time under better conditions. C-ITS systems have the potential to prevent major accidents. In this respect, it is necessary to deploy technology that is already proven and therefore safe. Otherwise, ordinary drivers could be exposed to dangerous road traffic situations to which the deployed system may not react according to the set conditions and assumptions. The basic philosophy of building C-ITS includes a simple but reliable solution, a unified solution (technical and organizational cross-border interoperability), and a safe solution (system users trust).

3. SWOT Analysis of ITS

SWOT (strengths, weaknesses, opportunities, and threats) analysis has the character of a strategic universal marketing tool to evaluate the information for generating alternatives for further development of the organization, process, technology, potential, risks, etc., based on the assessment of strengths and weaknesses, opportunities and threats.

a) The strengths of the current state of ITS in the Czech Republic include:

1. In general, the Czech Republic is a relatively developed EU country [11], in terms of research and development and national ITS implementations (an example is the participation in the international C-Roads project in the field of C-ITS, operation of the timetable information system, etc.).

2. Transport strategy papers shall comply with the European strategic framework and be adapted to national circumstances.

3. The current versions of the state strategic documents (Transport Policy of the Czech Republic) are the basic starting point for the development of ITS until 2027.

4. Key modal actors perceive ITS as an essential tool for the development of their activities and interconnections with other modes of transport.

5. The Ministry of Transport and the national ITS associations strive to support research and development, ensure interoperability, support standardization and also cooperation between individual public and private sector actors.

6. The National Traffic Information Center (NTIC) is a respected central access point for authorized traffic and travel information.

7. The strategic documents “Strategic plan for further development of the unified traffic information system (JSDI / NTIC) with a view to 10 years” and “Strategic plan for further development of the road database with a view to 10 years” are an important element of the conceptual development of ITS.

8. The number of devices in the transport system that provide processable data is constantly growing. The Directorate of Roads and Motorways operates a comprehensive source of open traffic information on road traffic. This information can be a valuable source of information for new ITS applications and services.

9. Spatial data sets, reference localization network of roads and map works covering the Czech Republic in the basic level of accuracy and completeness.

b) Weaknesses of the current state of ITS include:

1. The speed of implementation of ITS systems and services on the part of public sector clients is hampered by the lack of own professional capacities for project preparation, project management and their operation. The pace of public procurement is slow. The use of existing standards and norms by customers and suppliers is insufficient, which slows down the achievement of interoperability.

2. Systematic preparation of ITS projects and their management throughout the life cycle is absent. Similarly, ongoing assessment of benefits, cost-effectiveness, and timely planning of modernization and renewal is not an established standard.

3. The process of digitization of state administration and introduction of eGovernment in transport is not a sufficient priority, some public administration information systems are completely missing. Representatives of public administration and the professional public sometimes mistake ITS systems and services as a sub-component of telecommunications, ICT, or eGovernment solutions.

4. Cooperation between entities at different levels of government in different modes of transport is insufficient, e.g. in the field of planning and implementation of transport measures, coordination of management scenarios, or mutual exchange of traffic information.

5. There is still a shortage of professional staff or insufficient human resources in public administration for ITS. For this reason, there are delays in the implementation of ITS projects. There are also insufficient opportunities for lifelong learning and skills development.

6. Public support for the transfer of knowledge and innovation into operational practice is weak. The capacities for testing innovative technologies in both closed and open test environments, such as living labs, demonstrators, simulators, polygons, and dedicated sections of roads with real traffic, are insufficient.

7. The willingness of key actors to share and provide static and dynamic data on the transport system is not the rule, even in cases where the data were acquired by the public sector.

8. Access to reliable and comprehensive multimodal ITS information is still insufficient. The conditions for meeting the mandatory requirements in the EU-wide Regulation on the provision of multimodal travel information services are not sufficiently prepared. The provision of some ITS services targeted at specific user groups (carriers, lorry drivers, vulnerable road users) is lagging behind.

9. In contrast to roads, the application of the concept of an intelligent vehicle on the railway lags behind for the purposes of organizing and managing traffic on all railway lines, incl. regional.

c) Opportunities to strengthen the position of ITS in the Czech Republic include:

1. Make full use of the potential of Czech know-how, research, development and production capacity in ITS, road, rail and water transport, in the transport of people and goods. Consistently apply the concept of intelligent automated vehicles running on the intelligent infrastructure.

2. Create a professional organization with cross-sectoral overlap and motivation for a positive effect on the management and organization of transport. The scope of this organization should be the coordination and development of intelligent mobility in the Czech Republic across different modes of transport, development of international cooperation, preparation and coordination of national and international projects, project management, support for knowledge development in public and private sectors, specialized expert consultations, support for stakeholders in ITS implementation at all stages of the life cycle.

3. Intensively develop international cooperation and exchange of experience within international ITS research, development and implementation projects.

4. Create conditions (legislative, organizational, economic) for the use of new trends (MaaS, Big Data, etc.) and gradually contribute to increasing the share of safe and environmentally friendly transport.

5. Use ITS to integrate modes of transport and improve their interconnections, increase care for the transport of people and goods requiring special care or supervision.

6. Use the ever-increasing penetration of the number of "data-connected" equipment and vehicles to increase the safety and fluidity of traffic and its management in real time on the basis of relevant traffic information.

7. Prepare transport infrastructure managers for new transport trends, thus creating an environment for the development of intelligent infrastructure communicating with vehicles, the application of automation in vehicle management, the use of alternative propulsion and new energies in transport.

8. Develop the concept of the digital layer of transport infrastructure, including the existence of its digital virtual image. Ensure access to static and dynamic information throughout the transport sector across all public administrations.

9. Create a unified data platform providing open and machine-readable data to all key actors in the transport system and beyond.

d) Threats in further development of ITS in the Czech Republic include:

1. With the change in the structure of the economy, the change in the habits and behavior of users and their generational change, there will be more and more undescribed patterns of transport behavior, to which the transport system will not be able to respond adequately and in a timely manner.

2. The strategic and regulatory framework will not be kept up to date. Implementing new trends and practices will become difficult and very slow. The ITS industry will start to lag behind and cease to play its role as a driver of innovation and digitization of the transport system.

3. ITS development will slow down due to a lack of transport system financing strategy, lack of financial resources, lack of qualified human resources, or insufficient conditions of public sector clients to plan, acquire, implement and operate ITS systems. The Czech Republic's participation in international ITS activities will be limited.

4. Insufficient preparation of project evaluation indicators and missing or inaccurate impact assessment will cast doubt on the effectiveness of ITS implementations. This will significantly reduce confidence in their use.

5. Poorly prepared public procurement of ITS clients from the public sector will cause the implemented ITS systems and services to not perform the required functions.

6. The private and public sectors will not work together to put innovation into practice, thus reducing the competitiveness of the private sector. The public sector will not have a modern transport system.

7. Insufficient coordination between road and rail transport, passenger and freight transport, suburban and urban transport will worsen the safety and fluidity of transport on a national scale.

8. Business entities providing commercial services to end users without system restrictions, e.g. for traffic management, will start to enter the transport organization even more in an uncoordinated manner, and the state will no longer have control over influencing and planning traffic using traffic information.

9. Operators of ITS systems and services underestimate the cyber threat; do not ensure sufficient resilience and robustness of ITS systems in the event of emergencies or high protection of personal data. The consequences of crime, emergencies, or natural disasters will have serious repercussions on the operability and credibility of the whole transport system.

4. Vision of Building ITS

We anticipate that ITS will become a crucial tool for the integration of individual modes of transport in the Czech Republic, for ensuring the continuity of transport between cities and regions with neighboring countries, for managing transport infrastructure and related services, and for transport solutions in general. Transport will form a comprehensive interconnected system consisting of intelligent transport infrastructure, safer and more environmentally friendly vehicles and better-informed users. The public and private sectors will have guaranteed information on the current state and outlook for the behavior of transport networks. ITS will be a concrete measurable benefit for the economy. The Czech Republic can become an advanced country in the field of "Door-to-Door" mobility. The comprehensive logistics service will use electronic data transmission in freight transport, based on the interconnection of information systems in all modes of transport. For effective planning and deployment of means of transport, information systems will be used to a greater extent to improve the use of the vehicle fleet. New business opportunities will arise for the Czech ITS branch abroad.

The global goal is trouble-free safe and efficient travel and transportation, meeting the demands of the 21st century. This will be achieved, inter alia, through the digitization of the transport system in the broad sense, in particular the application of ITS systems and services, by creating a so-called "digital transport infrastructure layer". Developed ITS and C-ITS systems will be an integral part of safety measures in transport infrastructure, where there will be almost zero deaths due to accidents, minimal delays in the transport system, environmental impacts will be close to zero and the transport system will use fully informed transport system users. These goals will be achieved through

the development of a fully integrated multimodal transportation network that will ensure the efficient and safe movement of people and things.

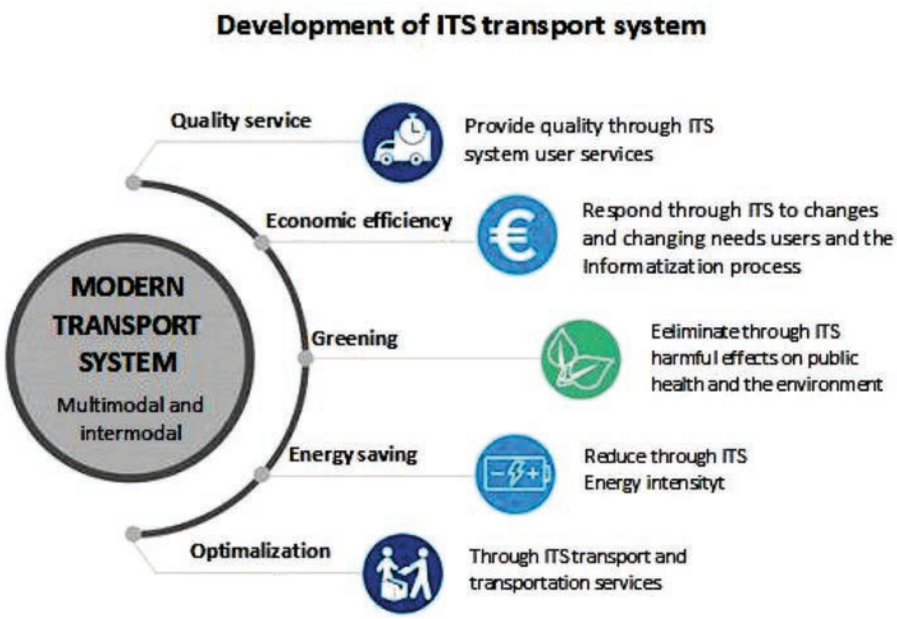

Fig.1. Development of ITS transport system [4]

5. Conclusions

The interconnection of the transport system and related information through ITS improves the safety and the flow of traffic, increases the efficiency of the transport process and makes it more environmentally friendly. Thanks to the devices that collect and create data, it is possible to create new information sources and provide new information services. The main challenge of ITS is to be a tool for the provision of quality traffic information services, the conditions of which and information on the operational situation are passed on to the user in a predictable and comprehensible form. This will make it easier for users to use more modes of transport without being a major barrier to multimodal access. The gradual transition to electronic transport documentation and related electronic communication brings both a reduction in time losses and a reduction in the administrative burden within the logistics chain. Recognition of electronic communication is an important role of the state, establishing uniform standards and interfaces between different applications. In terms of conceptual approach in transport, technological development supports the strategic shift from the simple construction of transport infrastructure to the operation of transport networks and to the organization/management of the process of relocation of people and goods on these networks. Increasingly, traffic and related operations management is being replaced by technology and is being automated. This is a never-ending process, due to the availability of technological solutions not only from a technical point of view but especially from an economic point of view and the related acquisition and operating costs. The benefits of ITS need to be assessed from the perspective of the stakeholders in the transport system and in relation to a specific system, or ITS service. In particular, the private sector will implement ITS solutions that are based on profit from the services provided. In certain cases, the public sector acts as an investor and operator of ITS, while public sector projects are not prepared as a commercial alternative to private sector projects (this is to ensure the public interest). In addition, the operation, or provision of some ITS services requires cooperation between the private and public sectors. This is, for example, a situation where data sources are created by ITS facilities built and operated by the public sector, are publicly published in a uniform standardized format, and the private sector can continue to build on them and provide various commercial (and non-commercial) services. For this reason, it is necessary to define an appropriate interface between the private and public sectors to ensure the whole chain of ITS services, both technically and organizationally [4].

For most ITS systems and services, we find a business model in which the benefits cannot be expressed financially. The economic costs of the construction and operation of these systems are balanced by the socio-economic benefits. These are ITSs that reduce the risk of damage to health, reduce greenhouse gas emissions, and harmful emissions, increase the attractiveness of transport, optimize transport services, streamline the performance of public administration concerning the transport system or have other societal benefits, such as:

as a tool for attractive and integrated public passenger transport, ITS supports the development of economically and socially backward regions and also contributes to the protection of environmentally sensitive areas;

the role of ITS in increasing traffic safety, promoting the independent and safe movement of people with reduced mobility, orientation or communication is important, as well as in the barrier-free use of public passenger transport and publicly accessible space; ITS helps to increase the safety of road cyclists and non-motorized road users (especially pedestrians);

ITS can make driving smoother without sudden stops and subsequent starts, which increases safety, reduces energy consumption and increases the permeability of traffic routes; higher permeability of existing transport infrastructure also reduces the need to take additional land for transport;

information on the current state of traffic or the operational situation of public passenger transport, if available on the basis of open data, initiates the development of other ITS applications and services; these "commercial" ITS applications have additional benefits, for example in conurbations through smart parking services, smart stops, shared mobility and goods supply in city logistics concepts;

optimization of urban road traffic through ITS allows for better consideration of pedestrian traffic, e.g. encouraging

pedestrian traffic through "smart traffic lights", and longer green light at traffic lights, which is crucial especially for seniors, prams and carers of children under 3 years of age or for people with disabilities.

The construction and operation of ITS systems without direct profit is usually initiated by the public sector in the form of projects implemented through public procurement and public subsidy programs. The impetus for implementation on the part of the private sector, vehicle manufacturers, hauliers and others is usually the regulatory framework and the resulting legal obligation.

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7. **European Commission Decision** of 11 December 2018 updating the Work Program in relation to activities under Article 6 (3) of Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on a framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.
8. Commission Implementing Regulation (EU) 2019/1213 of 12 July 2019 laying down detailed provisions ensuring uniform conditions for the implementation of the interoperability and compatibility of on-board mass measuring devices pursuant to Council Directive 96/53/EC.
9. **Directive** (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and re-use of public sector information.
10. **Commission Regulation** (EU) No 1273/2013 of 6 December 2013 amending Regulation (EU) No 454/2011 concerning the technical specification for interoperability relating to the subsystem 'telematics applications for passenger services' of the trans-European rail system.
11. **Commission Regulation** (EU) No 1305/2014 of 11 December 2014 concerning the technical specification for interoperability relating to the telematics applications for freight subsystem of the European Union rail system and repealing Regulation (EC) No 62/2006.