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Architecture of intelligent transportation systems in the world and in Poland

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ABSTRACT
The main objectives of all the types of implementation in the field of ITS include facilitation of road traffic that results from efficient utilization of the network of roads, improving road safety and efficient services for travellers. The scope of activities within ITS systems includes road traffic management, demand management, support for management of public transportation, information for passengers, management of vehicles' fleet, management of incidents and support for rescue teams, advanced technologies inside vehicles and problems of electronic payments and collection of tolls. The ITS applications necessitates development of a strategic basis that regulates the principles of design, implementation and decision-making. Such a basis is provided by ITS architecture. This paper presents the standardization requirements and the structure of services in terms of ITS, discusses the organizational questions concerning architecture and presents current state in terms of development of the national ITS architecture

KEYWORDS: intelligent transportation systems, ITS architecture, road traffic engineering

1. Introduction

In many cases of thick development in the cities and municipalities, current state of road transportation infrastructure does not allow for further investments connected with extension of roads and streets. Therefore, one of the options in improvement of the conditions of traffic in road and street networks, reduction of costs of transportation and limitation of the negative effect of road transportation on natural environment is to implement intelligent transportation systems. Intelligent transportation systems (ITS) represent a wide collection of various telecommunication, information, automation and measurement technologies and management techniques used in transportation in order to protect lives of road traffic participants, improve the efficiency of transportation systems and protect the resources in the natural environment. Intelligent Transportation Systems derive from convergence of telecommunication and information technologies into telematics. The most important field of telematics is transportation, thus transportation telematics has emerged. Furthermore, individual solutions in telematics, which are interrelated with each other, often affected by an overriding factor e.g. human aided by dedicated software and specific methodologies of control and management of the systems and transportation networks, are offered by Intelligent Transportation Systems. It can be concluded that ITS represents a set of tools that allow for efficient and effective management of transportation infrastructure and efficient services for travellers. The basis for application of ITS that regulates the principles of design, implementation and decision-making is ITS architecture, which should determine technological, organizational, legal and business-related aspects. ITS architecture can be designed for the national, regional or urban needs. It might relate to specific sectors or services. The architecture ensures that the ITS system implemented is planned in a logical manner, meets the requirements concerning efficiency, is effectively integrated with other systems and operates, in any situation, in a manner demanded by a user. Furthermore, it is assumed that this system should be easy to be managed, maintained and extended as well as it should meet the expectations of the users.

2. Normalization and structure of Intelligent Transportation Systems

Normalization of ITS on a world scale is being implemented mainly by such organizations as [4, 10, 27]:

- ISO TC204 (Intelligent Transport Systems),which operates in the field of normalization of information, communication and control systems of urban and non-urban land transportation, including the aspects of intermodality and multimodality, information for travellers, traffic management, public transportation, rescue services and commercial ITS services.
- CEN/TC278 (Road Transport and Traffic Telematics), which strives for development of European standards and technical specifications in order to ensure interoperability and harmonization of technical solutions in such areas as cooperation of individual systems, information for travellers and traffic, determination of routes and navigation, public transportation, rescue vehicles and toll collection.
- ETSI TC ITS, which develops standards, specifications and other products to support development of ITS services in the network in terms of more specific problems concerning communication of the interrelated systems with consideration for vehicles, users, interfaces, multimodal transportation, interoperability of the systems, excluding standards of ITS application, radio problems and EMC.
- IEEE 802.11/p (WAVE) and E 1609, which play a key role in terms of communication at smaller distances.

The most important products of normalization organizations are subject to public discussion and voting. Their neutrality with respect to concrete solutions available for equipment and software and neutrality with respect to technology of their manufacturing is also assumed, which causes that the standards should be free of local particularism and orientation towards narrow interests. Regardless of the degree of obligatory use, norms and actual standard which are not formal norms represent the basic tool for maintaining interoperability of telecommunication and information systems.

Furthermore, the scope of functioning of ITS is regulated by ISO 14813-1:2007. The structure of ITS services was based on different national and international standards of classification (which come from the USA, UE, Japan) as presented in Table. 1.

Table. 1. Domains and groups of services ITS according to ISO 14813-1:2007. Based on [2, 5, 8, 15]

No.	Domains of services	Groups of services
1.	**Traveller information**	Pre-trip information On trip information Route guidance and navigation – pre-trip Route guidance and navigation – on-trip Trip planning support Travel services information
2.	**Traffic management and operations**	Traffic management and control Transport-related incident management Demand management Transport infrastructure maintenance management Policing/enforcing traffic regulations
3.	**Vehicle**	Transport-related vision enhancement Automated vehicle operation Collision avoidance Safety readiness Pre-crash restraint deployment
4.	**Freight transport**	Commercial vehicle pre-clearance Commercial vehicle administrative processes Automated roadside safety inspection Commercial vehicle on-board safety monitoring Freight transport fleet management Intermodal information management Management and control of intermodal centres Management of dangerous freight
5.	**Public transport**	Public transport management Demand response transport Shared transport
6.	**Emergency**	Transport related emergency notification and personal security After-theft vehicle recovery Emergency vehicle management Hazardous materials and incident notification
7.	**Transport related electronic payment**	Transport related electronic financial transactions Integration of transport related electronic payment services
8.	**Road transport-related personal safety**	Public travel security Safe enhancements for vulnerable road users Safe enhancements for disable road users Safety provisions for pedestrians using intelligent junctions and links
9.	**Weather and environmental conditions monitoring**	Weather monitoring Environmental conditions monitoring
10.	**Disaster response management and coordination**	Disaster data management Disaster response management Coordination with emergency agencies
11.	**National security**	Monitoring and control of suspicious vehicles Utility or pipeline monitoring
12.	**ITS data management**	Data registers Data dictionaries Emergency messages Control centre data Enforcement Traffic management data

Development of ITS causes that more and more countries have formed their own national and international ITS architectures. These include:

- the first national ITS architecture was designed in the USA. It was co-financed by the U.S. Department of Transportation and implemented in June 1996. All the present implementations are obliged to cooperate with the national architecture,
- common framework for the ITS architecture in Europe was developed within KAREN project (Keystone Architecture Required for European Networks). The first version was published in 2000 and since that time, it has been developed and updated within FRAME (Framework Architecture Made for Europe) projects. These include projects financed by the European Commission: KAREN (1998-2000), FRAME-NET (Framework Architecture Made For Europe - Network) and FRAME-S (Framework Architecture Made for Europe - Support) (2001-2004), E-FRAME (Extend FRAMEwork architecture for cooperative systems) (2005-2011).

The objective of FRAME is to update and improve European ITS architecture which might be used as a basis for ITS implemented in individual European countries. Among the projects that operate within national ITS architectures based on the European ITS Architecture, the most important are: ACTIF (France), ARTIST (Italy), TTS-A (Austria), TEAM (Czech Republic), AVB&STIS (the Netherlands), TelemArk (Finland), VIKING (Scandinavia), NARITS (Romania). These projects have common approach and methodology but each of them is supposed to focus on the aspects essential for the particular country and solve local problems with substantial precision. Apart from Europe, other countries such as Japan, China, Chile and Australia have implemented similar projects.

3. Intelligent transportation systems architecture

Intelligent Transportation Systems architecture definitions according FRAME [24] is shown on Fig. 1.

ITS architecture represents a common plane for planning, definition and integration of individual subsystems. It is defined based on the needs of the users and composed of the following structures:

- general: which is a model approach, presents the concept of the whole system and principles of operation,
- functional (logical), which determines the functions which should be realized by a particular system in order to meet the expectations of users. It takes into consideration the relationships with the environment and users of the system and the sets of the data used,
- physical, which is a specification of different technical equipment with software, based on the elements of transportation infrastructure which is aimed at performing specific functions,
- communication, which defines resources that help exchange information between the elements of the system i.e. means of transfer of data streams. Flow of information and data combine the functions of the system and physical subsystems in an integrated wholeness.

Intelligent Transportation Systems Architecture

Informal definition	Formal definition	Technical definition
A set of general statements which allow for planning and implementation of integrated applications and services. This usually involves technical aspects and the related organizational, legal and economic problems, and is aimed at ensuring that implementation of ITS: • can be logically planned, • is effectively integrated with other systems, • operates at expected efficiency, • behaves according to expectations, • is easy to be managed, maintain and extend, • meets expectations of the users.	Conceptual project, which defines the structure and/or behaviour of the integrated intelligent transportation system. Description of the architecture represents a formal description of the system which defines the components of the system or blocks of which the system is composed of. The architecture also includes the plan of creation of products that form the system that takes into consideration the functional and economic aspects.	• Scope of works of the highest level, • strategic, non-deterministic plan of designing, which defines "what is necessary" and "how it will be implemented", is independent on the technology (life of ITS architecture is usually longer than the time of utilization of any particular technology), • set of assumptions of the highest level (minimum of what is necessary rather than maximum of what is possible).

Fig. 1. ITS architecture definitions according FRAME [24]

Numerous studies all over the world have dealt with the problems of ITS architecture, e.g. [1, 7, 14, 25, 26]. The prototype architecture which is popular worldwide is ITS architecture present in the USA (Fig. 2)

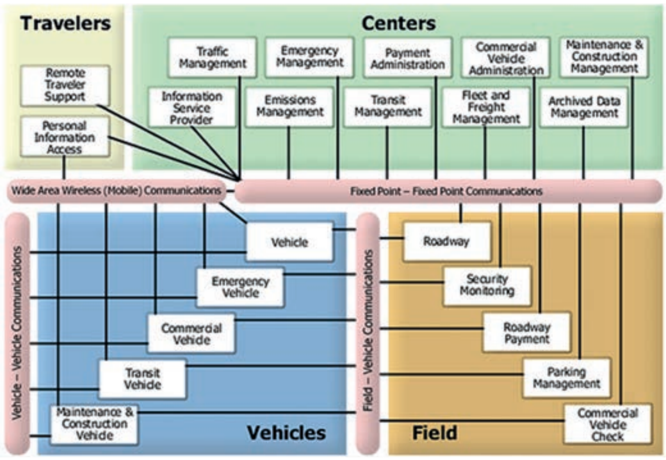

Fig. 2. High level architecture diagram description [25]

The literature in Poland is not as numerous, although several studies on ITS architectures ([3, 9, 13, 21, 23]) or interrelated components of the transportation system ([16-20]) have already been published.

4. National ITS architecture in Poland: current status

Based on the European architecture for building FRAME systems and in consistency with the European Directive on the frameworks for implementation of ITS and the guidelines developed on its basis, the General Directorate for National Roads and Motorways in Poland developed the National System for Traffic Management (Krajowy System Zarządzania Ruchem, KSZR). It is being planned that the KSZR system will start operating in 2020. At present, the KSZR architecture is undergoing public and trade consultations. In the future, KSZR is expected to extend over the whole network of motorways, expressways and national roads. The system will give drivers easy access to information about current difficulties in road traffic, available detours or alternative routes. KSZR is also designed to collect information from rest areas (Miejsce Obsługi Podróżnych, MOP) and inform the interested people about e.g. how many free spaces are available in nearest MOP and where are the next ones. At present, some systems which represent a substitute of ITS are already present, such as weather stations, vision monitoring cameras, systems of vehicle weighing and more complex systems of traffic management in the expressways and motorways.

For a variety of technical, organizational and financial reasons, the implementation of KSZR is planned in stages, divided into several separate projects [6]:

- KSZR in TEN-T network: this is a basic project, which has to be implemented in the first place. Its scope is supposed to include the roads in the area of Poland that are located in trans-European TEN-T networks.
- KSZR POIiŚ II – this is the project aimed at implementation of KSZR in the network of national roads that are not located on the TEN-T network. Within this project, functions of KSZR will be implemented mainly in the national roads connected with the area of Warsaw's urban agglomeration and Silesian urban area.
- As an element of road building, KSZR represents a project that consists in installation of the components of KSZR in newly build sections of the roads within road construction contracts. These activities are aimed at quick activation of the functions performed by KSZR in the new sections of national roads.
- In other projects, KSZR is a project with the range that will include the tasks focused on implementation of KSZR in the roads which are not qualified for any of the above projects. These are most often the local tasks which are aimed at improvement in conditions of road safety.

The basis for each KSZR project is the same system architecture, which guarantees that the systems designed in individual projects will form a coherent wholeness in terms of function, communication and organization.

In recent years, apart from the KSZR architecture, traffic control centres (Centrum Sterowania Ruchem, CRS) have been implemented in many cities of Poland. The CSRs in individual cities have been built without national standards and ITS architecture, thus, in many cases, the architecture of these systems is incompatible with other CSRs. The first integrated CSR in Poland was established in 2008 in Warsaw. The system incorporates such subsystems as a system for control of traffic lights, system of monitoring and measurement of road traffic, system for information for road users about the conditions on the roads and traffic difficulties (through installation of road signs with changing contents), system of quick reaction to road incidents, including dangerous incidents, system for assigning the priority to vehicles of public transportation (buses or trams) in the area integrated into KSZR, system for information for road users about the environment conditions using weather stations and boards with changing contents, system for monitoring and controlling the traffic in the tunnels, subsystem of giving priority for special vehicles (e.g. ambulances, police, fire brigade etc.). Further stages of extension of the system will involve implementation of the subsystems for management of car parks, information about dangers and management of road works. Another example is CSR in Tricity in Poland designed within the Tristar projects named Tricity Agglomeration Intelligent Transportation System (Trójmiejski Inteligentny System Transportu Aglomeracyjnego) (more information about the system see: [11, 12, 22]). The system was started in 2013 and includes e.g. the following subsystems: control of traffic lights, detection of moving vehicles, information for travellers (in the form of bus stop boards that inform passengers about public transportation of vehicles and delays of buses and trams), monitoring and measurement of road traffic parameters, management of car parks (through displaying information on light boards with free parking places and recommended routes to this car park), weather stations (which provide information about current weather). The CSR in Gliwice has been operating since 2013. This system includes such systems as: traffic light control along the street traffic routes (through the choice of plans for traffic light signalling coordinated linearly or automated), monitoring and measurement of parameters of road traffic, on-line information for road users about intensity of traffic in the area of intersections. Wrocław is another city that implemented CSR, which has been operating since 2013. This system includes e.g. the following subsystems: traffic light signalling (opportunities for switching on a "green wave" for rescue teams), information for travellers (in the form of bus stop boards). In the future, all the buses and trams are supposed to send information about their location. It is also planned to activate the system of informing the drivers who move on the main arteries of the city using the road signs with changing contents. These signs are supposed to display how much time it takes to cover five routes in the city and, if necessary, they should warn against the queuing of vehicles, accidents or sleet. It is expected that this system will also provide information about free car park places near the specific location and the messages played on the phones about the route a driver plans to take during the trip. Furthermore, CSRs have also been established in other Polish cities, e.g.: Kraków, Szczecin (since 2012), Stryków (this CSR has supervised traffic over 100-kilometre section of A2 motorway between Konin and Stryków), Poznań, Łódż, Olsztyn (since 2013) and Kalisz (since 2013).

5. Conclusion

Thick road network and dynamic development of telematics and intelligent transportation systems have caused that, at the moment, numerous systems of control and management of road traffic are being designed and implemented. In many cases, these systems are restricted to the administrative limits of a particular city or urban agglomeration. Consequently, this leads to difficulties in compatibility of these systems or the lack of any coordination of tasks with systems in other cities or agglomerations. There are also the cities and areas in Poland where several incompatible systems for road traffic management are operated at the same time. Therefore it is legitimate to unify and implement standardized principles and obligatory rules in the form of a homogeneous ITS architecture, which will substantially facilitate mutual exchange of information between individual CSRs and, in the future, will represent the basis for central and integrated units of road traffic control.

If the basic ITS architecture continues to be missing, the problems connected with ensuring the expected level of services provided by the traffic control centres, difficulties with extension of this type of systems, lack of opportunities for adaptation of new technologies and lack of opportunities for integration of already existing systems can be expected. Consequently, this might generate higher costs of maintenance ITS technology and traffic control centres, limitations in the access to road services and failure to reach full ITS efficiency.

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