State of Development of Intelligent Transport Systems Services on National Roads in Poland

Oskarbski Jacek, Mowiński Krystian, Żarski Karol

Gdańsk University of Technology, Gabriela Narutowicza 11/12, 80-233 Gdańsk, Poland

Abstract. In recent years we can see intensifying implementation of Intelligent Transport System (ITS) measures in Polish cities and on national roads. The architecture of the National Traffic Management System (KSZR) will enable the implementation of a uniform, integrated and intelligent ICT system to launch ITS systems that are the most important for drivers and the General Directorate for National Roads and Motorways (GDDKiA). This paper presents the current state of the implementation of the ITS services on national roads in functional, physical and logical terms and the premises for the KSZR's development. The description of the state of the development of ITS services on national roads was compiled within the framework of the RID 4D "The impact of the usage of Intelligent Transport Systems services on the level of road safety" research project, funded by the National Centre for Research and Development and the General Directorate for National Roads and Motorways

Keywords: Intelligent Transportation Systems, ITS services, National Traffic Management System, KSZR

1 Introduction

The National Traffic Management System (KSZR) is an undertaking that covers Poland's national roads. The key goals and benefits planned to be achieved under the KSZR concern the improvement of: safety by minimising the number of traffic incidents and their results (including by: warning, redirecting traffic, more efficient rescue operations), traffic flow, road maintenance efficiency, quality of cargo freight handling (providing information about free parking space), providing current and forecasted information concerning the traffic conditions on the national road network. The project's implementation will stimulate the country's economic development (by increasing the competitiveness of Poland's transport infrastructure), reducing traffic's negative environmental impact and improving the quality of travel on Poland's national roads versus European and world standards. In order to implement the KSZR project in 2014-2020 and in further years, the GDDKiA adopted a comprehensive management programme based on, among other things, 25 years of European experience, and the conclusions and observations of the GDDKiA staff during a pilot ITS project implementation. The KSZR management is based on the FRAME European ITS Framework Architecture [1].

Under the KSZR project, a number of documents were delivered that describe the ways the system will be implemented on Polish roads. The concept defines the requirements for contractors in order to make the system's structures and content uniform. Moreover, the physical architecture of the National Traffic Management System was based on the principles of the FRAME Architecture. The materials consist of descriptions of implementation modules, data flows and identified stakeholders [2]. The physical architecture shows the KSZR's division into implementation modules, presents the links between individual modules, operators and external stakeholders. It highlights the dispersed implementation modules installed in the roadway, centralised modules installed, for example, in traffic management centres and GDDKiA offices, transportable modules installed on transportable platforms such as GDDKiA vehicles and a mobile module covering video recorders on GDDKiA vehicles. Besides the physical architecture, information was also provided on the functional architecture: descriptions of the functions and flows between them compiled in table and graphic form. Under the RID 4D "The impact of the usage of Intelligent Transport Systems services on the level of road safety" research project, a model systematics of ITS services was developed with references to individual functions of the implementation modules used in the KSZR [3]. Furthermore, the GDDKiA developed a document entitled "Manual of the placement of implementation module classes in the roadway" that is a set of principles according to which it is possible to determine in which locations in the road network and under which circumstances a given class of implementation modules are used, e.g. related to the sending of messages with Variable Message Signs (VMS). It was assumed that the execution of particular functions of the KSZR should be in line with actual needs, i.e. that it should be implemented where it will yield significant benefits. Therefore, the criteria for the realisation of the individual implementation module classes are related to such factors as the road's technical class, traffic parameters and the concentration of traffic incidents. The structure proposed in the document relevant to each class is as follows: description of usefulness of application, principles of their location on the road network, guidelines on the justifiability of use [4].

Because of the functional complexity, hi-tech, extensive area of implementation and for financial and organisational reasons it was decided to implement the KSZR in stages. Therefore, in order to diagnose the current advancement of the project, in 2015 GDDKiA took an inventory of the devices used in the implementation modules that were part of the KSZR architecture.

2 Review of the implementation of selected ITS services used under the KSZR project

2.1. Implementation modules in KSZR

An update of the inventory of ITS devices on national roads was taken at the end of 2014 and the beginning of 2015. The inventory was taken according to the classification of the implementation modules within the framework of the KSZR's physical architecture. It included the following items:

- collecting traffic data (traffic parameter measurement devices),
- road lighting management
- traffic signals,
- speed and lane control (LCS),
- providing information and instructions for drivers (VMS),
- providing information and instructions for drivers in tunnels (VMS),
- detecting incidents with the available data resources (incidents detection),
- motorway emergency telecommunications,
- collecting weather and road surface data (meteorological stations),
- air pollution measurement,
- collecting vehicle data (devices that identify the features of individual vehicles, including weight preselection systems - WIM),
- collecting video data (video monitoring) [5].

The components that a given module consists of were systematised in detail according to year and place of installation (regional GDDKiA branch, number. and direction of road, mileage and geographical co-ordinates). Information concerning the class of the device was entered according to the guidelines for individual implementation modules. The current functional range of each device was determined with information about the functional standards it met. Upgrading requirements were noted for every device in order to adapt it to functioning in the KSZR system. Moreover, the types of the devices used were carefully labelled and in the case of some modules (signalling) the controllers and their manufacturers were determined. Message display standards (number of lines/characters displayed, type of displayed signs) were determined for devices providing information. Furthermore, information about the method of communicating with the device and the capacity of the connection were provided. Using this data, together with open-access information about the functional and logistics assumptions for each KSZR system module, a brief structure of the implementation modules in terms of functionality, information flows (logical structure) and physical components is provided below [6].

The "collecting traffic data" module is responsible for collecting data about each passing vehicle. The module has the following functions:

- collects data on each passing vehicle including: vehicle category, real time (time stamp), vehicle speed, direction and lane,
- analyses and aggregates the collected data,
- monitors the condition of the devices,
- provides data to other functionalities.

The „Road lighting management" module is responsible for control of road lighting switching on and off and its brightness adjustment depending on traffic, time of a day or night, weather conditions. It also contains features of recording lighting system errors, as well as historical data on lighting.

The „Traffic signals" module is responsible for traffic control at intersections and supervision of the proper operations of its equipment. The module enables communication between the operator and light-signaling devices on roads covered by the system. It has the ability to present the settings and parameters of these devices and issuing commands that change them. It allows operator to change the program depending on the scenario and to make change to the settings and parameters of the device.

The task of the "Speed and lane control" module is to provide information to drivers in cases of traffic rearrangement consisting of a change in the speed limit and/or the direction of driving on individual lanes. The module provides the capability of:

- controlling traffic lanes and speed,
- using output data in other areas of the system,

- monitoring the output data and entering possible corrections into them in order to prevent sending contradictory and inconsistent information to the drivers.

The "Providing information for drivers module" makes it possible to inform/warn/instruct drivers using devices installed in the roadway (especially variable message signs) and in vehicles, and also to use the output in other areas of the system and to monitor the output data and entering possible corrections into them in order to prevent sending contradictory and inconsistent information to the drivers. The module provides information about: travel time, incidents, road works, traffic disruptions and their impact on traffic, detours, recommended speed, and warnings and instructions for drivers.

The task of the module "Providing information for drivers in tunnel" is to provide information about the situation in the tunnel (tunnels) and the adjacent road network using equipment and infrastructure located both inside and outside the vehicle.

The "Detecting incidents with the available data resources" module is responsible for analysing data on traffic conditions, as well as the data from other functions (including video image analysis, speed gun data, etc.) in order to detect traffic incidents, e.g. traffic accidents.

The "Motorway emergency telecommunications" module is responsible for receiving and transmitting reports of columns of alarm and locating performing connection (driver). It enables voice communication between travelers and the operator.

The "Collecting weather and road surface data" module obtains point weather data in the roadway (e.g. air temperature, relative air humidity, wind direction and speed, precipitation intensity and type, visibility) and data on the condition of the road surface (road foundation temperature; warnings about slippery surface, winter road treatment, snow cover and thickness, column of water height (emergency water level). The module can send data for use by other functions of the system, including to detect traffic safety threats, maintenance work, providing users with information about traffic conditions.

The „Air pollution measurement" module is responsible for providing data on air pollution by using sensors that detect the concentration of harmful substances, which are related to traffic (including carbon dioxide, methane, nitrous oxide, carbon monoxide, non-methane volatile organic compounds, nitrogen oxides , particulates, sulfur dioxide, lead). The module provides the ability to transmit data on pollution for use by other system functions for such purposes like: mitigating nuisance from road traffic by the introduction of appropriate traffic management scenarios.

The "Collecting vehicle data" module enables obtaining information such as vehicle class, weight, number of axles, license number. The module can:

- obtain vehicle data,
- verify the correctness of the obtained data,
- send vehicle data to other KSZR functions and to the law enforcement services,
- self-diagnosis of whether the devices that perform this function work correctly (e.g. the roadside measurement stations),
- video analysis in order to obtain alphanumerical data e.g. license number, ADR plate,

The "Collecting video data" module is responsible for acquiring the image, upload the image to the other functionality and to the law enforcement services.

Under the RID 4D "The impact of the usage of Intelligent Transport Systems services on the level of road safety" research project, a detailed description of each module using the data obtained from the GDDKiA was developed. This paper outlines information about the two selected modules: "providing information and instructions for drivers" and "collecting weather and road surface data".

2.2. Providing information and instructions for drivers

On the basis of data from the inventory carried out in 2015 on Polish roads, 669 devices working within the providing information and instructions for drivers module including Variable Message Signs displaying useful information to drivers in the form of pictograms, warning signs, injunction, prohibition or text messages. In cooperation with the collecting weather and road surface data module, weather information with short text messages about current road conditions e.g.: "FOG. SLOW DOWN" is being displayed. Communication methods used within the module are: fiber optic transmission, GPRS, GSM and Wi-Fi. The logical structure of the module is based on cooperation with centralized modules:

- traffic management software in terms of the information provided,
- road maintenance support software in terms of the condition of the devices responsible for information transmission.

Terminators of the module are:

- driver - as the recipient of the content of traffic information provided by the device,

- law enforcement services - as a recipient of the content of the displayed information given to drivers - allowing to monitor the violations.

In the future it is also planned the flow of instructions for drivers using wireless communication I2V, where the role of the terminator will be fulfilled by the vehicle with I2V interface.

Devices within this module are divided into 7 classes: A and B (incidents, road works, road difficulties) - 373 devices and 229 devices, C (detours management) – 16 devices, D (time of travel) – no devices, E (waiting time on border crossings) - 2 devices, F (automatic radio announcements CB) - 33 devices, G (carriage variable message signs) - 16 devices. 60% of all equipment needs to be modernized to standard functionality, which is determined for each module in the operational concept of the KSZR system [2, 4, 6].

Locations with the largest concentration of this module devices are: A4 motorway (Zgorzelec – Brzesko section), A1 and A2 motorways in Łódź branch, S8 express road (Piotrków Trybunalski – Rawa Mazowiecka section), S7 express road in Kraków branch [Fig. 1].

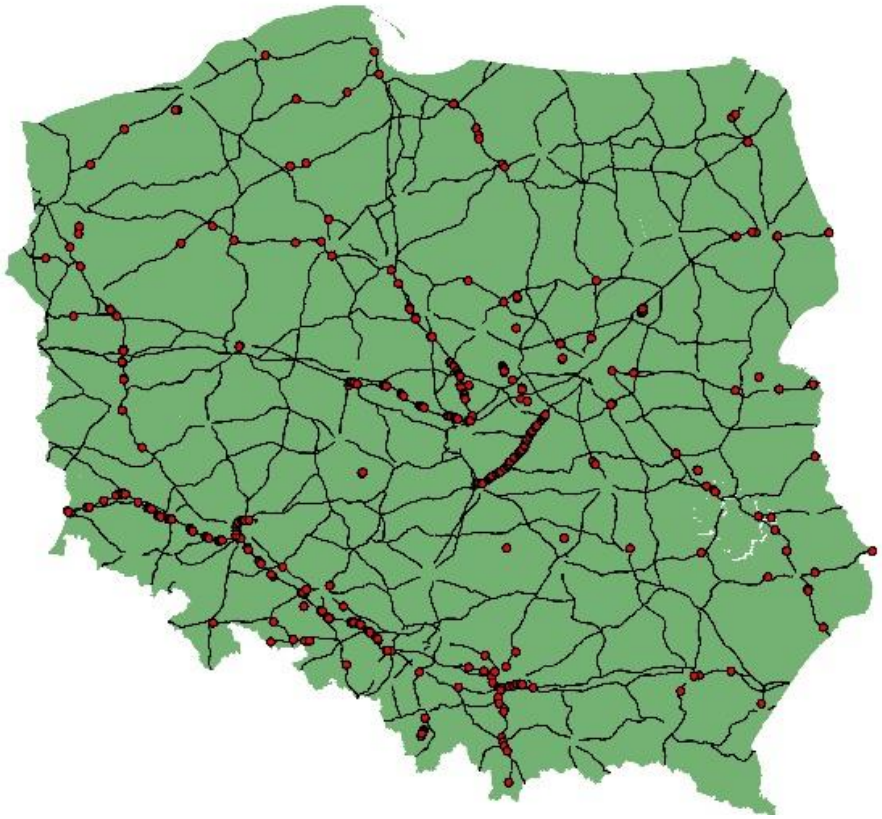

Fig. 1. VMS coverage on national roads in Poland [own study based on GDDKiA data]

2.3. Collecting weather and road surface data

The collecting weather and road surface data module includes 486 devices on the Polish national roads (weather stations, temperature sensors, humidity sensors, ground temperature sensors, visibility sensors, wind speed and direction sensors, laser modules for monitoring surface). Communication methods used within the module are: fiber optic transmission, GPRS and GSM. Information is also available on the Internet. The logical structure of the module is based on cooperation with centralized modules:

- traffic management software in terms of the content of environmental data,
- road maintenance support software in terms of the condition of the sensors responsible for data acquisition,
- collecting and archiving alphanumeric data software in terms of weather data acquisition.

The main terminator is “road environment” - the conditions such as weather, road lighting, noise, which have impact on traffic. It provides indications for sensors, which then collect and forward information about weather conditions and road surface further to the system. In the future it is also planned the flow of weather information and road surface condition directly to the driver using wireless communication I2V, where the role of the terminator will be fulfilled by the vehicle with I2V interface.

Devices within this module are divided into 8 categories: A (collecting data about the road surface and weather conditions for traffic management, road maintenance, supervision of road maintenance) - 462 devices, B (for early warning of glazed frost in characteristic points) – 42 devices, C (for automatic prevention of glazed frost) – no devices, D (dedicated to bridges for traffic management, maintenance) - 5 devices, E (warnings about sudden visibility decrease) - no devices, F (traffic management - information about the obstruction of traffic due to the flooding of the road) - no devices, G (taking action in the field of road maintenance due to high water levels in reservoirs and water courses) - no devices, H (mobile meteo stations). 74% of all equipment needs to be modernized to standard functionality [2, 4, 6].

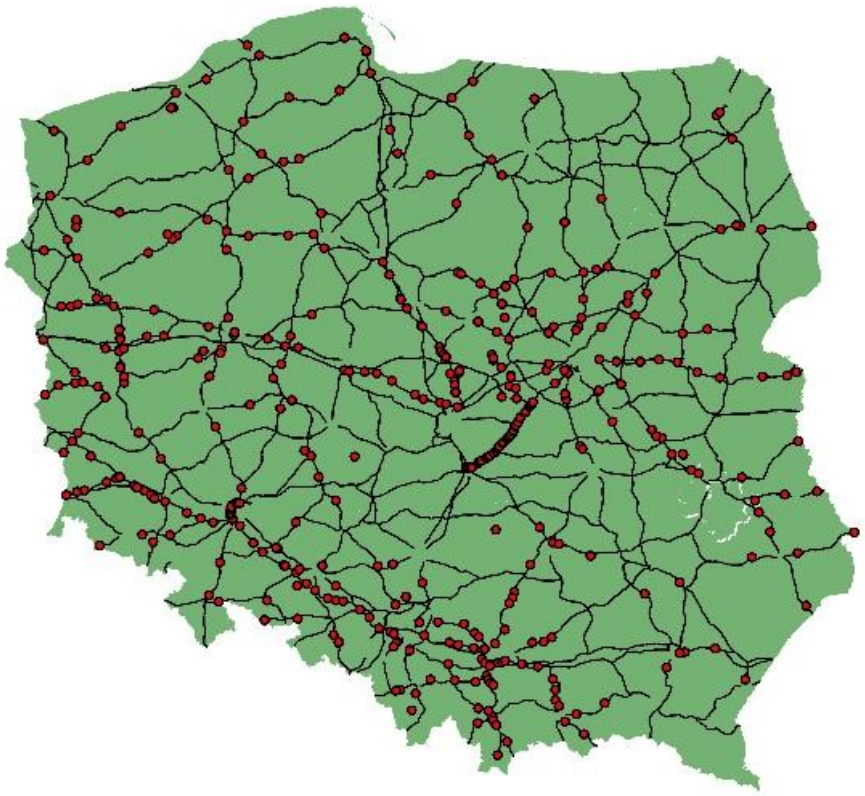

Fig. 2. Weather stations coverage on national roads in Poland [own study based on GDDKiA data]

Locations with the largest concentration of this module devices are: north sections of the road No. 91 and S6 express road, road No. 92 from Poznań to Warsaw, A1 motorway (Łódź branch), A4 motorway (Wrocław and Katowice branches), A6 motorway, A8 motorway, S7 express road (Warsaw branch), S8 express road (Warsaw and Łódź branches) and S12 express road (Lublin branch) [Fig. 2].

2.4. viaToll system

Other devices related to ITS services are the viaTOLL gates. They are part of an electronic toll collection system that is in force on selected Polish roads [7].

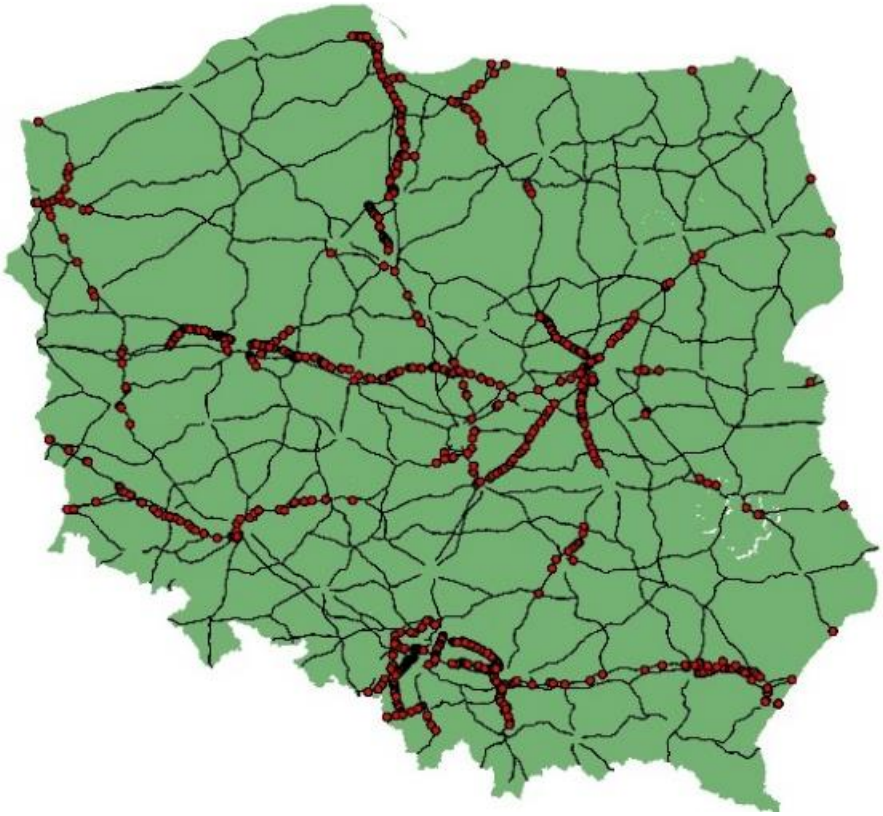

Fig. 3. Coverage of viaToll system on national roads in Poland [own study based on GDDKiA data]

The viaTOLL system has Permanent Enforcement Facilities (PEF) equipped with laser meters, located in the viaTOLL gates. There are 30 of them. They collect data about any vehicle that crosses the section of the road covered by the meter. They classify vehicles into eight categories. They do not measure speed. The data from the PEFs is aggregated into hourly intervals, for each lane and direction. The system was part of the GPR2015 General Traffic Measurement, meaning that each PEF was a separate measuring point in GPR2015. The viaTOLL system's primary element are Tolling Facilities with DSRC readers. The data that can be collected is commensurate with the PEF gates, but is obtained only with regard to vehicles with on-board Viabox devices. The classification corresponds to the types of vehicles covered by the toll [6].

Based on location data (voivodeship, GPS co-ordinates, road number, mileage), year of installation (stage of network development) and information about the type and number of the gate, numerical breakdowns of the current state of the implementation of the IST service responsible for electronic toll collection using viaToll devices and the dynamics of the entire system's development were compiled. Currently there are 782 gates with DSRC readers. The greatest number of gates are on the northern section of road No. 91 and S6, road No. 92 between Poznań and Warsaw, on the A4 motorway (Wrocław and Katowice branches), A8, A6 and on roads S7, S8 (especially the Warsaw branches) and S22 (Elbląg) [Fig. 3].

3 Analysis of the current state of ITS implementation on national roads in Poland and development plans

The first ITS devices began to be implemented as early as in the 1990s. They began to be implemented en masse only in 2006, with over 200 devices regularly installed over the following 5 years. The most devices were installed in 2011-2012, which is clearly visible on the time distribution function. (Fig. 4) There are currently over 3200 ITS devices installed on Polish roads.

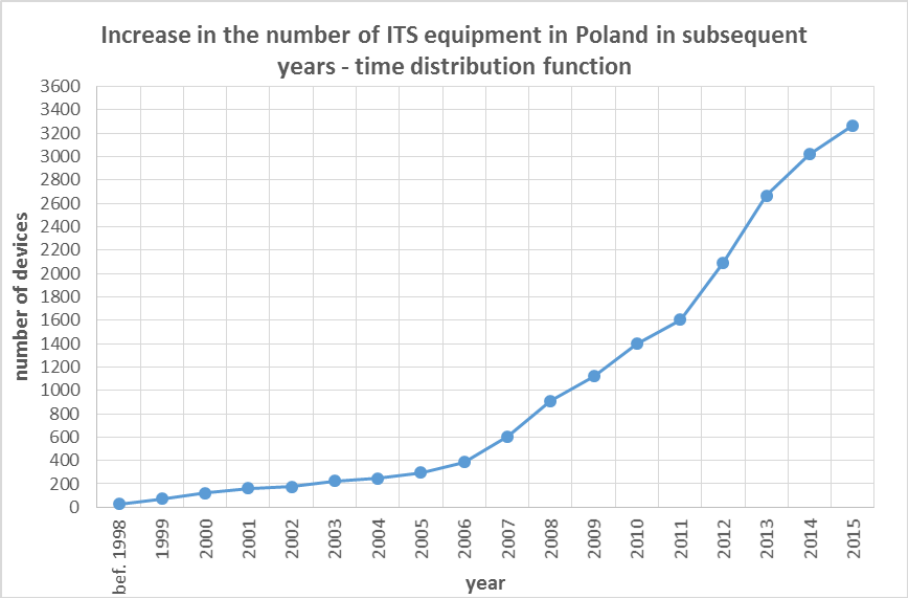

Fig. 4. Increase in the number of ITS equipment in subsequent years – time distribution function [own study based on GDDKiA data]

3.1 Current state of ITS implementation

Statistical results for the selected motorways and express roads in Poland are presented in the table 1. The percentage coverage of ITS devices with regard to these sections of roads where there is a regular implementation of the devices, not just a single scattered cases was diagnosed. The length of these sections are related to the entire length of the road. Density ratio of ITS devices per 100 km road was also calculated. The calculations were made for the entire length of the road at the end of 2016. Road data collection refers to the information about the parameters of traffic (traffic parameter measurement devices). Vehicles data collection includes devices that identify the features of individual vehicles.

Table 1. Statistical view on ITS implementation on selected motorways and express roads in Poland (2015 inventory) [own study based on GDDKiA data]

road number/length	A1/446km		A2/487km		A4/673km		A8/22,4km		S3/267km		S6/64km		S7/291km		S8/435km		S12/86km	
	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]	coverage [%]	density [dev/100km]
road data collection	10%	4,3	20%	11,1	30%	12,9	100%	62,5	20%	4,9	30%	10,9	20%	4,8	15%	5,1	50%	51,2
lighting control	15%	7,2	20%	3,5	5%	2,7	0%	0,0	25%	3,7	60%	23,4	10%	4,8	15%	7,4	0%	0,0
traffic signals	0%	0,2	0%	0,0	5%	0,7	15%	4,5	0%	0,0	15%	6,3	0%	0,0	0%	0,2	0%	0,0
speed and lane control	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	50%	41,9
VMS	25%	7,6	40%	22,8	60%	22,0	100%	67,0	30%	7,1	5%	10,9	25%	15,8	25%	17,0	50%	32,6
incident detection	0%	0,0	10%	5,7	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0	0%	0,0
weather stations	25%	5,2	30%	3,1	50%	5,2	100%	49,1	30%	7,1	10%	9,4	15%	8,2	20%	10,3	50%	26,7
vehicles data collection	10%	2,2	10%	2,1	0%	0,1	0%	0,0	25%	1,9	10%	4,7	0%	1,7	30%	7,1	0%	0,0
visual data collection	10%	1,1	20%	4,3	60%	18,4	100%	133,9	30%	7,9	10%	7,8	15%	6,9	30%	11,5	50%	18,6
ViaToll	60%	7,2	50%	2,5	90%	8,9	100%	22,3	80%	8,6	60%	21,9	25%	15,8	80%	20,0	50%	15,1
Overall	-	**35,0**	-	**55,0**	-	**71,0**	-	**339,3**	-	**41,2**	-	**95,3**	-	**58,1**	-	**78,6**	-	**186,0**

The comparison (table 1) allows to mention about several sections in which the implementation state of ITS services is at a high level. We can notice complex implementation of VMS, weather stations, video and vehicles data collection at motorways and express roads:

- A1 – section near Łódź (approx. 80 km) and Bydgoszcz (approx. 70 km),
- A2 – section near Łódź (approx. 100 km),
- A4 – section near Katowice (approx. 30 km), Kraków (ok.50km), Opole (approx. 100 km) and Wrocław (approx. 200 km),
- A8 entire route,
- S7 – section near Kielce (approx. 20 km)
- S8 – section near Łódź (approx. 80 km)
- S12 – section near Lublin (approx. 50 km)

The density of ITS devices in these sections is highest. Other parts of these roads (e.g. Expressways S3 and S6) are characterized by either lack of any implementation or their distribution is very scattered. There are several modules for which implementation needs to be developed (e.g. road lighting management). Incident detection module was installed only at about 100 km section of A2 near Łódź. Speed and lane control module was implemented only at S12 section near Lublin with highly ITS infrastructure density. We can notice a high density factor of the coverage by viaToll system at selected sections of the road network.. The most complex and advanced solutions have been developed at A4, A8, S8 and S12 motorways and express roads.

3.2 KSZR development plans

Besides the existing infrastructure, the initial principles of the KSZR assumed implementation modules for which the devices have not yet been implemented. These are the following modules:

- Ramp metering,
- Monitoring traffic in rest areas/car parks and calculating the condition and occupation of the rest areas/car parks,
- Transmitting information about the occupation of the rest areas/car parks,
- Noise measurement,
- Obtaining travel data.

Moreover, based on surveys carried out under the RID-4D "The impact of the usage of Intelligent Transport Systems services on the level of road safety" project, individual GDDKiA branches locally determined their development and upgrading plans for the next three years. These include plans for the implementation within the KSZR system, the possibility to open a lane for passing a column of trucks and prohibiting the overtaking of trucks in heavy traffic, e.g. with Variable Message Signs. Some branches note that the mileage reference system should be improved.

In it also planned to upgrade the meteorological shield and traffic management system on the A4 motorway and the motorway information system on the A8. Moreover, there is a plan to build a Traffic Management System on the S5 between Korzeńsko and Wrocław and to expand monitoring on the A4 in order to detect incidents.

In order to implement a uniform integrated ICT system, it is also necessary to upgrade existing module components. The GDDKiA chiefly refers to modules that inform about the condition of the road network, speed and lane control, dynamic detour setting, area and corridor traffic management and child alert. Based on data it is noticed that as many as 2/3 of all devices require upgrading to the standard functionality.

4 Conclusions

In recent years, we can observe the continuing implementation of ITS services on Polish roads. The work carried out within the planning of the National Traffic Management System (KSZR), mainly within the framework of the system architecture including the technical and functional requirements, form the basis for systematic and consistent development of a coherent traffic management system, taking into account both - system users (drivers, traffic management road services, emergency services) and suppliers of ITS components. Among the implemented modules of KSZR, the largest group are devices associated with traffic parameters and vehicle data collection, monitoring weather and road surface conditions, video monitoring and providing information to drivers. We can find ITS services relating to the detection of incidents and the management of speed, however, such services require the extension of implementation and functional development, inter alia, providing information via VMS in case of incident occurrence. Services described above are developed mainly on motorways and expressways (the

most comprehensive implementations can be seen on the roads A4, A8, S8 and S12). ITS services on other national roads are mainly used to control traffic with use of traffic signals. So far some of intended ITS services have not been implemented (e.g. ramp metering, noise measurement or obtaining travel data - analysis of the implementation of these services are in various stages of development). Assessment of the progress of implementation is extremely difficult due to significant dispersion of ITS services, functions and devices. Taking into account the intensive deployment of ITS services in the Polish cities [8], [9], [10] and the expected further deployment of ITS services on national and regional roads, should be more emphasis on the integration of urban and rural systems. Work on the integration is coordinated by GDDKiA within the framework of the implementation of the National Access Point. Nevertheless, the word "integration" is crucial not only in relation to the need to improve the exchange of data, but also to improve and develop the operational cooperation between the road managements of different roads (urban, national, regional) and with the operators of public transport, emergency services and prevention services.

This paper describes realization effects of RID 4D (41) called “The impact of the usage of Intelligent Transport Systems services on the level of road safety” funded by National Research and Development Center and General Directorate for National Roads and Motorways (agreement no. DZP/RID-I-41/7/NCBR/2016 from 26.02.2016).

References

[1] "KSZR - Overview" Internet: www.kszr.gddkia.gov.pl/index.php/pl/o-kszr, [January 12, 2017]

[2] A. Kobuszewski et al., "Architektura teletechnicznego powiązania urządzeń w systemach KSZR" Inteligentne Systemy Transportowe – Specyfikacja Techniczna vol. 4, GDDKiA and ITS Polska, Poland, July 2012

[3] J. Oskarbski et al., "Systematics of ITS services – periodic report" RID-4D The impact of the usage of Intelligent Transport Systems services on the level of road safety, Gdańsk University of Technology, Poland, 2016

[4] "KSZR - Manual of the placement of implementation module classes in the roadway" Internet: www.kszr.gddkia.gov.pl/ images/Instrukcja rozmieszczenia klas moduw wdroeniowych.pdf, [January 12, 2017]

[5] T. Kamiński et al., "Cele, koncepcja i założenia Krajowego Systemu Zarządzania Ruchem" "Logistyka" vol. 4/2015

[6] J. Oskarbski et al., "The overview of the National Traffic Management System in Poland – periodic report" RID-4D The impact of the usage of Intelligent Transport Systems services on the level of road safety, Gdańsk University of Technology, Poland, 2016

[7] "viaToll System" Internet: www.viatoll.pl, [January 12, 2017]

[8] J. Oskarbski, M. Zawisza, M. Miszewski, „Information System for Drivers Within the Integrated Traffic Management System – TRISTAR", Tools of Transport Telematics, Book Series: Communications in Computer and Information Science, vol. 531, pp. 131-140, 2015

[9] J. Oskarbski, M. Zawisza, K. Żarski, "Automatic incident detection at intersections with use of telematics", Transport Research Arena TRA2016, Book Series: Transportation Research Procedia, vol. 14, pp. 3466-3475, 2016.

[10] J. Oskarbski, D.Kaszubowski, "Implementation of Weigh-in-Motion system in freight traffic management in urban areas", Transportation Research Procedia, vol. 16, pp. 449-463, 2016.