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Innovative Road Management: Analysis of Poland's National Traffic Management System and the Role of Intelligent Transport Systems

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ABSTRACT: This article aims to present the latest insights into the National Traffic Management System in Poland. The initiative is being implemented as part of the TEN-T program on the national road network, addressing the country's transportation challenges. The project comprises four regional projects and one central project based in the Mazowieckie Voivodeship. Through a review of available literature, the article evaluates Intelligent Transport Systems (ITS) devices intended for deployment within the project framework. Furthermore, it explores the scope of the project's realization, providing a detailed analysis of the functionalities introduced to enhance transport efficiency, safety, and sustainability.

1 INTRODUCTION

The development of urban intelligent transportation systems (ITS) in Poland has been known and practiced in various cities for many years. In some cases, ITS cover only a small urban area or only certain branches of transportation. An example can be seen in Warsaw Trams, where ITS mainly focuses on streamlining tram traffic in the city. Another example is the Tri-City area, where ITS implementation has been comprehensive, encompassing both public transportation aspects, such as signal priority for buses and trolleybuses, and individual transportation users through variable message signs, parking occupancy information, weather conditions, and many other components. Over the years, other cities have developed their intelligent transportation systems to achieve better traffic conditions, reduced pollution, and noise in the city.

2 NATIONAL TRAFFIC MANAGEMENT SYSTEM

In the course of events related to the development of ITS [1–5], the time has finally come for a National system in Poland, which will cover as many as seven voivodeships: Pomorskie, Warmińsko-mazurskie, Mazowieckie, Łódzkie, Śląskie, Opolskie, and Dolnoslaskie. The project is called the National Traffic Management System (NTMS) and is being implemented by the General Directorate for National Roads and Motorways[6], the manager of expressways in Poland. According to the project authors, "The National Traffic Management System (NTMS) [7]is a collection of interconnected projects and activities, the result of which will be the implementation of an integrated IT system enabling the provision of dynamic traffic management services, information on traffic conditions on the national road network, support for road infrastructure maintenance processes, and asset management. Individual ITS services will be implemented by ITS devices, called distributed modules, installed in the road lane and central modules, i.e., IT systems (software, data repositories) operated in Traffic Management Centers (CZR), circuits, regions, branches, and the Headquarters.

These solutions will streamline the implementation of statutory tasks of GDDKiA through increased automation of processes and procedures using tools provided by NTMS, which will consequently lead to improved road infrastructure management and more effective functioning of GDDKiA. In further consequence, these services will contribute to raising the level of road traffic safety[8], while increasing their efficiency and travel comfort. Their application will also have an impact on reducing the negative impact of transport on the natural environment.

3 THE TERRITORIAL SCOPE OF THE NATIONAL TRAFFIC MANAGEMENT SYSTEM

The total length of roads covered by NTMS from the TEN-T core network is approximately 1100 km, which constitutes about 28% of the length of the TEN-T core network in Poland[9]. The route begins in Gdynia at the Chylonia junction and continues along the S6 road to Gdańsk. From this point, it transitions to the S7 road, which leads to Warsaw. Next, the NTMS network includes the S8 road section from the Marki junction to the Konotopa junction, from where the A2 road leads to Łódź, specifically to Stryków. From Stryków, the A1 Road heads towards the Silesian Voivodeship, specifically to the Pyrzowice junction, where the subsequent roads in the project are sections of the A1, S1 roads up to the border with the Czech Republic and Slovakia. The continuation of the route is further along the A4 road from Gliwice to Wrocław at the Widawa junction. Figure X presents a map illustrating the route of stage 1 of NTMS

Figure 1. National Traffic Management System – Map ([7])

A total of five traffic control centers will be established. One national center, located in Warsaw on Płaskowicka Street, will be responsible for traffic management within the Masovian Voivodeship. Additionally, four regional traffic control centers will be created. The centre in Gdańsk-Dworek will cover the operational activities of the Pomeranian and Warmian-Masurian Voivodeships. Another regional traffic management centre will be established in Łódź-Stryków, responsible for the A1 and A2 roads within the Łódź Voivodeship. The third regional centre will be established in Zabrze-Kończyce and will manage traffic on the aforementioned roads of the Silesian Voivodeship. The fourth and final regional traffic management centre will be established in Wrocław-Widawa, where operators will be responsible for traffic on the A4 road in both the Lower Silesian and Opole Voivodeships.

4 DISTRIBUTED IMPLEMENTATION MODULE

The official definition used in the documentation for the KSZRD project states that "A distributed implementation module is defined as an element of physical architecture resulting from the grouping of functions contained in the functional architecture. It constitutes a functionally separated, interpretative element of the system, intended for implementation in the road lane." Thus, it can be simply assumed that a module is nothing more than a set of software along with a device fulfilling its functions. Another important definition for understanding the functioning of NTMS is the Module Class. The definition states that "The implementation module class defines the level of scope of functional requirements and technical parameters that limit a given implementation module. It is a specification of the implementation module with a description related to location and functionality. The implementation module class contains parameters for the functions performed, including parameters related to accuracy, resolution, scope, types of collected, processed, and transmitted data, and information about the types of detected events. The Distributed Implementation Module Class is intended for implementation in the road lane. Each class is then assigned guidelines related to the purpose of the given class, the use of the class in specific locations, guidelines for designers and other persons and entities performing management and maintenance functions on roads." Thus, it can be seen that the Distributed Implementation Module contains devices with a given function and can then be divided into classes to specify particular elements of the system. For example, in the case of Distributed Module 101, "Traveler Information," there is Class 101.A "Information about difficulties on the highway (A) or expressway (S)." The placement of each class of the distributed module is defined by the official "Instruction for the placement of implementation module classes in the road lane,"[9] which clearly states where each module can be located in the road lane. Within NTMS, 13 Implementation Modules have been designed, which are further divided into classes. In the following part of the article, all classes will be presented in detail.

4.1 *Module 101: Traveler Information*

It aims to provide drivers with information about traffic conditions, road incidents, road works, detours, weather conditions, waiting times at border crossings, and the status of road tunnels. Within this module, we distinguish the following classes: Class 101.A - Information about difficulties on A/S class roads, Class 101.B - Information about difficulties on S/GP/G class roads, Class 101.C - Detour management, Class 101.D - Travel time information, Class 101.E - Information about waiting times at border crossings, Class 101.F - Weather condition information, Class 101.G - Information via CB radio messages, Class 101.H - Information via portable variable message signs [10]. Therefore, it can be summarized that module 101 mainly consists of variable message signs to inform about various current situations. The only other form of information transmission is Class 101.G, where information is provided in the form of voice messages.

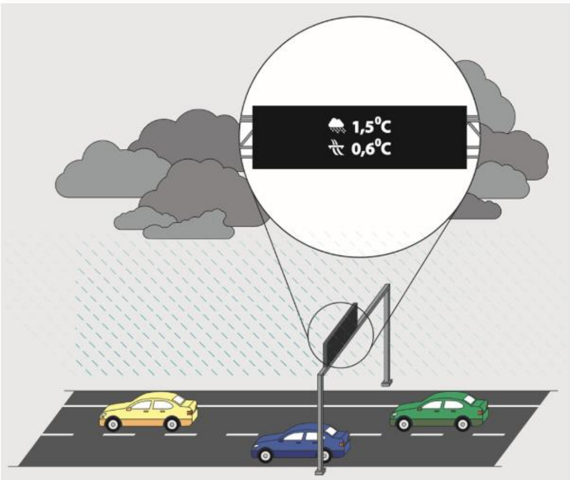

Figure 2. Class 101F [11]

4.2 *Module 102: Regulation of speed and lane usage*

Control of access to traffic lanes, lanes with variable traffic direction, traffic on the emergency lane, speed management on traffic lanes, and the introduction of overtaking restrictions. In module 102, we distinguish the following classes: Class 102.A - Traffic lane control, Class 102.D - Speed and other restrictions management, Class 102. E - Portable speed, traffic lane, and other traffic restrictions control. Classes A and D always appear in the same location as a combination of two functionalities. One set of signs is placed above the lane to manage its availability, and another set of signs is placed between the traffic lanes for information purposes. For example, drivers can be warned about road works and the closure of the outer lane

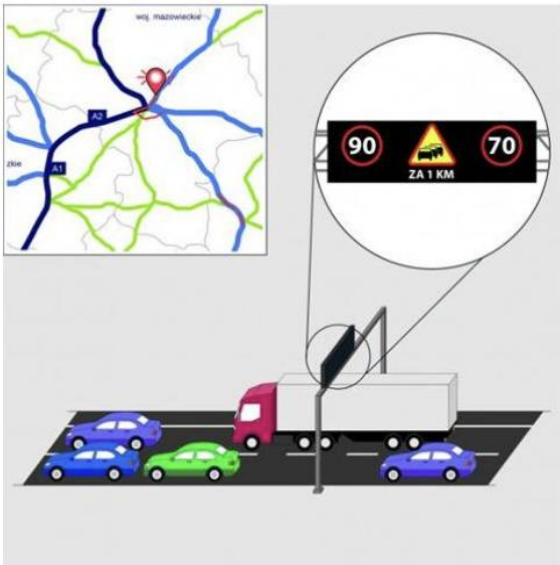

Figure 3. Class 102A and 102D [12]

4.3 *Module 103: Acquisition of vehicle data*

Acquisition of data on passing vehicles, such as vehicle category, speed, direction of travel, registration number, and transmission of this data to other functions of the Traffic Management System. Within this module, the following classes have been distinguished: Class 103.B - High-accuracy travel time measurement, Class 103.C - Low-accuracy travel time measurement, Class 103.E - Ad hoc traffic studies.

4.4 *Module 104: Local detection of events from collected data*

Analysis of locally acquired data on traffic conditions to detect road incidents, such as vehicle stoppage, wrong-way driving, and event detection based on images. Within Module 104, the following classes have been distinguished: Class 104.A - Detection of incidents at intersections and G/GP class roads, Class 104.B - Detection of incidents from available data resources, Class 104.C - Detection of incidents on A and S class roads with low detection level, Class 104.D - Detection of incidents on A and S class roads with high detection level.

4.5 *Module105: Detection of events through emergency communication*

Management of columns of highway emergency telephony and monitoring conversations conducted via CB communication to detect road incidents. The following classes have been distinguished: Class 105.B - CB communication. This communication is divided into two bands, one for broadcasting and the other for listening to messages.

4.6 *Module 106: Acquisition of visual data*

Acquisition of video streams from cameras located at road junctions, places with high concentrations of road incidents, and detour routes. Within this module, the following classes have been distinguished: Class 106.A - Image acquisition at junctions and other road locations, Class 106.B - High-resolution image acquisition on the main road or detour route, Class 106.C - Standard-resolution image acquisition on the main road or detour route, Class 106.D - Ad hoc video recording.

4.7 *Module 107: Acquisition of information on the occupancy of rest areas / parking lots*

Calculation of the status and occupancy of parking based on spatial data and data on entry/exit from rest areas/parking lots, and transmission of this data to other functionalities of the Traffic Management System. Within this class, there is only one Class 107.A - High-accuracy data acquisition.

4.8 *Module 108: Transmission of information on the occupancy of rest areas / parking lots*

Transmission of information about the number of available parking spaces for vehicles of a given category and the occupancy status of parking spaces. In this module, similarly to the previous one, there is only one Class 108.A - Transmission of information via variable message signs. Modules 107 and 108 are closely related because information cannot be displayed without data.

4.9 *Module 110: Metering of entry*

Control of ramp metering [13,14] onto the main road through traffic signals to ensure optimal traffic conditions. This functionality is commonly known as Ramp Metering. Ramp Metering is not yet implemented in Poland. It is only within the framework of NTMS that this functionality is planned to be implemented as part of Module 110, and its official name is Class 110.A - Metered entry on a single connector.

4.10 *Module 111: Traffic control through signal lights*

It enables the change of program, settings, and operating parameters of the signal controller depending on the selected scenario, time of day, day of the week, and the length of vehicle queues at the entrances. This module is divided into two classes depending on signal coordination: Class 111.A - Control of a single traffic signal, Class 111.B - Control of coordinated traffic signals.

4.11 *Module 112: Acquisition of weather data*

Acquisition of weather data, such as air temperature, humidity, wind direction and strength, precipitation intensity, air transparency, and road surface condition. The classes within this module are mainly dependent on the number of different measurements taken. The module includes Class 112.A - Acquisition of comprehensive weather data, Class 112.B - Acquisition of road surface condition data, Class 112.C - Acquisition of data for automatic counteraction to local slipperiness, Class 112.D - Acquisition of visibility data, Class 112.E - Acquisition of data on road flooding, Class 112.F - Acquisition of data on reservoirs and watercourses, Class 112.G - Mobile weather data collection.

4.12 *Module 114: Acquisition of traffic data*

Collection of data on each passing vehicle, such as vehicle category, speed, direction of travel, and real-time data. These modules are among the most important; without real-time data collection, the other system components would not be able to function correctly. The module distinguishes: Class 114.A - Acquisition of vehicle traffic data with E2 accuracy, Class 114.B - Acquisition of vehicle traffic data with A2 accuracy, Class 114.C - Measurement of axle loads and vehicle weights for statistical purposes.

4.13 *Module 115: Acquisition and transmission of information via I2V/V2I (Infrastructure-to-Vehicle/Vehicle-to-Infrastructure)*

Communication of I2V devices with passing vehicles and V2I devices inside vehicles with V2I devices located in the traffic lane, transmission of travel data, incidents, weather data, and information on parking occupancy. Like Module 110, this is a new application in Poland and will only be implemented within the framework of NTMS. We distinguish two classes: Class 115.A - Transmission of I2V data and Class 115.B - Acquisition of V2I data.

5 NTMS

Based on the tender documentation provided by GDDKiA in the form of the Description of the Subject of the Order, an analysis was made of the System that is to be built in the coming years in Poland on the expressway network. It should be noted that the order includes two modules that have not been previously applied in Poland, therefore, neither the provisions nor the regulations are yet known. As for Ramp Metering, there are no Polish regulations or Polish permission to place a signal on only one entry (connection at the junction), which means that a change in the law is necessary for the module to be fully implemented. As for module 115 communication with vehicles, it should be noted that this is a functionality only for new vehicles already equipped with this type of technology in vehicles. According to the tender documentation, and more precisely the indicative plan for the arrangement of Modules and the price form, only in the Mazovian Voivodeship will the above-described classes occur. Below (Table 1) is a summary of the number of individual MRs planned in the price forms of the tender documentation.

Table 1 The Sumary of the type of Distributed Module dependent on the province where it will be implemented

MR	dolnośląskie	łódzkie	mazowieckie	opolskie	pomorskie	śląskie	warmińsko-mazurskie
101	59	75	90	68	70	316	128
102	104	208	180	0	140	156	0
103	3	4	7	2	7	84	7
104	113	91	211	67	177	664	215
105	3	7	10	5	4	16	8
106	31	42	49	38	34	139	47
107	4	0	0	8	0	6	0
108	4	0	0	9	0	5	0
110	0	0	7	0	2	6	0
111	8	18	24	0	0	9	0
112	10	6	4	6	4	37	11
114	61	51	147	34	114	405	123
115	0	0	22	0	0	0	0
SUM	400	502	751	237	552	1843	539

As can be seen, the largest number of MRs will be implemented in the Silesian Voivodeship, i.e., in the Katowice Regional Implementation Project. This is also where the densest road network is located. It can also be seen that not all Modules are present in all voivodeships, e.g., Modules responsible for parking management are not present in the Łódź, Pomorskie, Mazowieckie, or Warminsko-mazurskie voivodeships. There are Modules responsible for, e.g., Ramp Metering or I2V communications only in the Masovian voivodeship. Below, in Figure 5, a map is presented in the form of a cartogram with the total number of modules marked, taking into account Polish voivodeships.

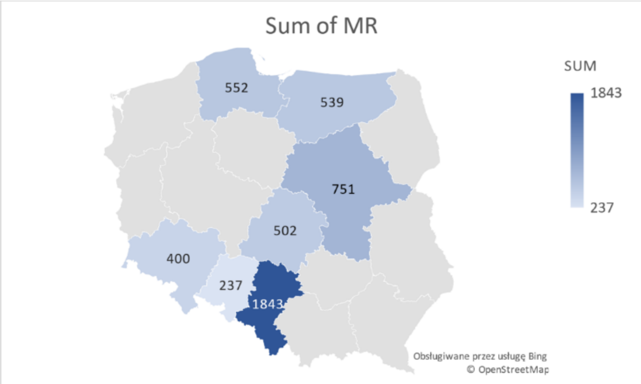

Figure 4 Map with sum of the number of Modules

The distribution of Modules on the road network was also analyzed, taking into account the road class. According to the MR distribution instructions, not all modules can be used on motorways, e.g., the module responsible for traffic lights, or they can be direct modules intended for bypass roads, which are of a lower class than motorways. Analyzing the map below, you can see two road sections, the first in the Mazovian Voivodeship from the Napierki junction to the Płońsk junction, and the second from the Piotrków Trybunalski junction to the border with the Łódź Voivodeship, where only Modules 105 and 101G are responsible for CB communication are present.

6 CONCLUSION

Summing up the analysis of the currently implemented National Road Traffic Management System based on publicly available tender documentation, it can be seen that the first stage will provide ITS devices from the north to the south of Poland. This is the first such large ITS equipment on national roads in the history of Poland. Due to the division of the project into a central project and four regional ones, it has a greater chance of success due to its smaller scope. The analysis of the distribution of Modules indicates that the most densely implemented modules will be within the Katowice regional project, which is directly related to the density of high-class roads, such as motorways, in this province. One can also notice the continuity in the use of modules responsible for CB communication as this module is planned at more or less equal distance on the entire network in the first stage of NTMS.

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