Impact of ITS services on the safety and efficiency of road traffic

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Abstract. This paper describes the project entitled: "Impact of the use of Intelligent Transport Systems on the level of road safety" (agreement no. DZP/RID-I-41/7/NCBR/2016), implemented as part of the Road Innovations Development (RID) programme, funded by the National Centre for Research and Development and the General Directorate for National Roads and Motorways (GDDKiA). The project is run by a consortium comprising the Motor Transport Institute, University of Gdańsk, Warsaw University of Technology, Military University of Technology and Research Institute of Roads and Bridges. The impact of ITS services and accompanying modules on road safety may be considered in functional, logical or physical terms. The aim of the project is to understand how ITS services change road safety.

1 Introduction

The project entitled: "Impact of the use of Intelligent Transport Systems on the level of road safety" (agreement no. DZP/RID-I-41/7/NCBR/2016) is implemented as part of the Road Innovations Development (RID) programme, funded by the National Centre for Research and Development and the General Directorate for National Roads and Motorways (GDDKiA). The project is run by a consortium which includes the Motor Transport Institute, University of Gdańsk, Warsaw University of Technology, Military University of Technology and Research Institute of Roads and Bridges. The impact of ITS services and accompanying modules on road safety may be considered in functional, logical or physical terms.

The functional aspect is investigated based on the influence of services and groups of services on road user behaviour and the homogenization of the traffic stream. Both contribute to a change in the level of road safety, characterized by a reduction in road traffic hazard. Many years of research conducted in the US, Japan and Europe have shown that ITS-based services and services designed to inform travellers using variable message signs, boards, or traffic lights (at intersections and entries to motorways or express roads - in the case of ramp metering) have helped to reduce accidents by approx. 80% using advanced traffic management systems, by 25-50% using ramp metering and 30-40% using traffic control via variable message signs [1–4]. Automated traffic surveillance (speed limit enforcement) contributes to a reduction in accidents by 20-80%.

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Improving traffic safety and efficiency is logically associated with improving cooperation between road managers and emergency services and with implementing solutions designed to reduce rescue operation time in order to reduce accident severity, minimize the period of exposure to the risk of secondary events and minimize the loss of time of the travellers. According to the principle of the "Golden hour" the life of 20-40% of seriously injured victims can be saved if they receive hospital treatment within 60 minutes of the event. The probability of survival is greater when first aid is provided quickly at the scene prior to being transported to hospital (during the "Golden ten minutes").

Based on the results of European research, it is estimated that transport telematics can reduce the response and intervention time of rescue services by up to 30% (US studies show a 20-40% shortening of the rescue operation time), and the use of emergency calls, automatically generated by in-vehicle systems increases the probability of survival of accident victims by 15% [5,6]. Linking traffic management with a rescue operation is very effective. The traffic events management systems (including automatic detection, verification of events, guiding the emergency services and restoring normal traffic conditions) contribute to shortening detection time by up to 65%, shortening the time needed for emergency services to arrive by about 45% and reducing secondary accidents by 7-50% [4].

The level of road safety is also affected by the use of ITS services in private vehicles (collision avoidance support systems, monitoring the condition of the driver, etc.) and emergency vehicles (e.g. automatic vehicle location, navigation to the scene of the incident, traffic lights priority). Indirectly, the modules associated with the physical layer (reliability of the equipment and IT systems) are important for the overall security of ITS systems. The above effects of implementing ITS services have been elaborated based on statistical surveys carried out in country-specific conditions. Due to the diversity of the evaluated solutions, an approximate assessment of their impact on road safety was developed.

The project "Impact of the use of Intelligent Transport Systems on the level of road safety" was initiated due to a lack of assessment methodology. The project plans to use advanced driving simulators and simulation software Vissim/Saturn/Visum to obtain vehicle motion parameters such as velocity, acceleration, braking power, velocity profile, etc. as the reaction of drivers on ITS services. These parameters will be used in safety models for evaluating the level of road safety.

Another project task is to use the multi-criteria Analytic Hierarchy Process (AHP) method to understand how ITS services change road safety and traffic efficiency defined as a stream of vehicles driving in a specific period of time.

Both project tasks are currently under way and will be described in papers to come. This will help to define further research directions.

2 Project assumptions

The objective of the project described in the article is to develop tools designed to evaluate the impact of the expected Intelligent Transport Systems solutions on road safety, particularly in the context of the implementation of the National Traffic Management System. For the purpose of the project it is assumed that the level of road safety (as related to ITS services) will be mainly affected by the following factors, depending on the scope and type of implemented ITS solutions:

- features (factors) related to the road and the traffic organization (among others road class, geometric solutions and traffic layout solutions),
- traffic features (among others speed, density, intensity, utilization of throughput),
- road illumination,
- weather conditions and the state of the road surface,
- reliability of the physical layer (in terms of hardware and ICT),

- features (factors) associated with the driver behaviour (i.e. driving speed and failure to adapt it to the road and traffic conditions.

It is understood that traffic efficiency can be characterized by traffic flow volumes. The impact of ITS services on the level of road safety will be determined using advanced driving simulators and Visum/Saturn/VisSim simulation software and traffic efficiency will be determined using simulation software which depends on the specifics of the adopted assessment method.

Driving simulators are used to evaluate the road cross-section and road sections. The simulation software helps to assess the road corridor (road network area).

The project will be implemented mainly in relation to the area covered by the National Traffic Management System (KSZR), which will be implemented in 17 modules:
- Module 1 – "Transmission of information and instructions for drivers",
- Module 2 – "Output to control the speed and traffic lanes",
- Module 3 – "Collecting data about the vehicles",
- Module 4 – "Event detection from the available resource data",
- Module 5 – "Collecting data on the journey",
- Module 6 – "Motorway Alarm Telephony + CB",
- Module 7 – "Video data",
- Module 8 – "Transmission of how busy MSA/Car Parks are",
- Module 9 – "Obtaining information on how busy MSA/Car Parks are",
- Module 10 – "Managing road lighting",
- Module 11 – "Dosing entry (Ramp Metering)",
- Module 12 – "Traffic lights on the roads",
- Module 13 – "Collecting weather data and the road surface condition data",
- Module 14 – "Noise measurement",
- Module 15 – "Air pollution measurement",
- Module 16 – "Transmission of information for motorists about the tunnel",
- Module 17 – "Collecting traffic data from the national road network".

These modules will have a direct impact (e.g. by displaying information on traffic conditions, or a dynamic introduction of speed limits - variable contents signs) or indirect impact (e.g. by obtaining information about the weather conditions and the state of the road surface) on road safety. The implementation of Intelligent Transport Systems within the roads managed by the GDDKiA is currently under way. The implementation work must be preceded by research and development that will help select optimal solutions (meeting the criteria developed) to be justified in terms of implementation costs. In this way it will be possible to achieve the maximum cost benefits.

According to the strategic objectives of the National Traffic Management System:
- ITS systems should address the needs of their users;
- requirements for the systems should take into account the real needs, rather than market trends, or the current capabilities of suppliers;
- data exchange between the public sector significantly increases the efficiency of ITS investments;
- experiences in other countries and the technology market are rapidly changing, hence the need for cooperation with the ITS sector, scientific community and other units of the road administration needs to be addressed.

There is no scientific proof of how individual ITS devices influence the recipients, i.e. road users or the proper way to deploy these devices within road infrastructure. This gives us some freedom to choose functional, organizational, hardware and telecommunications solutions of these systems, which are characterized by a certain dissimilarity in how the information is provided to the end users (road users). They also differ in terms of the message content.

There are no guidelines or recommendations in this respect at the European and national level. This justifies the need for the project to analyse the impact of ITS systems on road safety. It would be wrong to assume that road statistics alone with injury and serious injury numbers are sufficient for the purposes of such an evaluation. ITS systems can be highly complex and feature mutual interactions, interactions with the rest of the road infrastructure, emergency systems, in-vehicle on-board systems and ITS solutions implemented in cities.

To examine the impact of a single ITS system or service, based on the statistics of time period-based road accidents, would require long-term studies, assuming that other technical and traffic conditions on the road have not changed significantly. Even 2-3 years of road safety research on a section with an ITS system would not give a clear answer to the question about the impact on road safety or traffic efficiency. Let us take the example of a road section, on which two accidents occurred over two years, in which two people died. In year three a bus accident happens leaving 17 people dead. The analysis of statistical data might suggest that the danger on the road measured by the number of accidents increased 17 times in the last year, compared to the previous 2-year period. It is also possible to evaluate safety based on specific events, for example, traffic conflicts. In most cases, however, this method would not be reliable.

3 Evaluation of the impact of ITS services on road safety

As part of the above work, the analysis will take into account ITS solutions which affect traffic flow and safety significantly. The comparative studies of the impact made by ITS services will be made along the selected road stretches in the course of data analysis from a real ITS system.

The comparison will be based on vehicles speeds along the stretch of the road in a situation when the systems would not display any information for the drivers and a situation when such information would be displayed. The influence of the displayed content on the driver behaviour will be evaluated.

In a series of experiments with advanced driving simulators the listing of Variable Message Signs will be made along the section of the road on which the actual ITS system is functioning (the section dealt with in the first phase of work). This will be the basis for developing research scenarios. Next, a simulation will be made involving drivers, during which the data will be recorded to assess the impact of ITS systems on the drivers. The data will then be analysed for quantity (vehicle speed, vehicle speed change, etc.) and quality (lane change, compliance or failure to comply with the recommendations and commands of the road administrator, etc.) in order to assess the impact of ITS services on road safety.

Finally, an experiment will be conducted to assess the impact of ITS services on traffic flow and road safety, using simulation Visum/Saturn/VisSim software. Simulations will be performed both on the micro scale (road section, a single intersection) and area. The models which will be used for the simulation will be calibrated using data from the real-life advanced traffic management system. Various system configurations providing various ITS services will be studied. It is expected that the models will be verified using data from the real ITS system.

Despite the well-known limitations and disadvantages of the proposed simulation methods, it is estimated that the evaluation of the impact of ITS services on road safety and traffic efficiency will be a better option than a similar evaluation using incomplete and insufficient volume of data from the actual ITS systems.

It will not be possible in every case to evaluate the impact of ITS services on Poland's road safety using data from foreign ITS systems. This is because of a slightly different behaviour of drivers and some other legal regulations in the field of road traffic. Based on the previous experiments, indicators will be developed in order to assess the impact of ITS

services on the effectiveness of traffic and road safety as well as the guidelines and recommendations for their practical application and multi-criteria method to assess impact of ITS services on road safety and traffic effectiveness.

Currently, the impact of ITS services on road safety is assessed primarily based on the individual assessment of experts, statistical surveys or the few road safety models which still require more work. There is no structured or uniform assessment method that would provide an opportunity to compare the effect of ITS services and their different configurations on road safety and traffic efficiency.

The advantage of the proposed solution is the use of a holistic approach to the abovementioned problem which involves a combination of:

- research based on data and information from real advanced traffic management system incorporating a variety of ITS services (e.g. passing the information over to the drivers, traffic control, etc.);
- studies using advanced driving simulators, with experienced road transport psychologists to interpret test results;
- tests using Visum/Saturn/VisSim vehicle movement simulation software.

The unique combination of three different approaches will enable a comprehensive analysis of the impact of ITS services on road safety and traffic efficiency. It is envisaged as a two-stage evaluation. The first stage will be carried out by an assessor, not necessarily an expert in the field of road safety and ITS services. They will use the multi-criteria evaluation method, developed under this project, evaluation criteria and guidelines for the evaluation and selection of ITS services.

The second stage of evaluation will be carried out in exceptional cases where a clear-cut evaluation of the impact of ITS solutions is not possible. This may be due to the complexity of the system, numerous interactions between ITS services and the rest of the road infrastructure and the road surroundings (including local conditions). Then, an expert evaluation will be carried out using advanced driving simulators and the traffic simulation software.

4 AHP method

The multi-criteria AHP (Analytic Hierarchy Process) method was proposed by Thomas L. Saati [7] and applied in many areas. It allows a hierarchical analysis of the decision problem to choose one of the variants or objectively compare the proposed solutions. Variants may be technical objects with defined parameters as well as certain conditions associated with, for example, safety, risk or quality. The AHP method provides a multi-criteria approach that takes into account the evaluator's preferences. Unlike objective measurements of the magnitude of a solution it makes it possible to take into account the preferences of the evaluator, treating them as a natural phenomenon for the choices made by a human. This method allows for taking into account not only the quantitative parameters characterizing the given phenomenon, but also the qualitative characteristics associated with the desired properties of the object.

The hierarchical structure of the decision-making process consists of levels of purpose, criteria, sub-criteria (optional) and variants. The decision maker's judgment is determined by the relative importance ratings determined by comparing pairs of all objects from the hierarchy level. Ratings are expressed in numerical values, most often on a scale of 1 to 9.

The use of the AHP method includes:

- Building a model of a hierarchical object together with determining the importance of factors (criteria).
- Evaluating by pair comparison.
- Designation of general and personalized preferences.

- Classification of decision options in terms of the degree of achievement of the desired goal.

In the case of the RID 4D project, the AHP method will be used to combine an evaluation of the solutions, individual ITS services obtained, among others by simulations using advanced driving simulators, evaluations from the Vissim/Staturn/Visum simulation software and technical parameters (including telecommunications). Solutions will be applied taking into account the cost criterion of implementation. The purpose of the evaluation will be to provide the most favourable ITS services or a combination of services in a variety of road-motion conditions.

5 Implementation of the project results

The project results will be implemented as officially announced by the General Directorate for National Roads and Motorways (GDDKiA). As a final project result, there are plans to organize training courses for a group of 30 GDDKiA employees. The training will cover the practical application of the multi-criteria method developed in the project and assessment of ITS services impact on road safety and traffic efficiency. The trainees will be able to apply this method in conjunction with the indicators and guidelines for evaluation. The project results will also apply to the evaluation of ITS services on the roads not managed by the GDDKiA.

The project consortium also plans to organize a scientific conference to present the project results.

There will be a monograph on evaluating ITS systems' impact on road safety and traffic efficiency in a comprehensive and exhaustive manner. The monograph will be developed based on the results of the project after its completion.

After completion of the project, an offer will be prepared presenting the effects of the project to stakeholders. The stakeholders will primarily include managers of roads run by local governments and commercial companies offering ITS services provided occasionally under extensive nationwide systems.

An additional effect of the project will be the launch of comprehensive services in the field of assessing the impact of ITS services on road safety and traffic efficiency at the Motor Transport Institute and the Gdansk University of Technology. The service will incorporate the effects of the project, combined with advanced driving simulators and Visum/Saturn/VisSim software. The evaluation models will be developed based on the experience gained during the analysis as well as the data relating to the actual ITS services operating as part of the advanced traffic management system.

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