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The concept of automatic road safety evaluation

Abstract: Supervisors of all existing and planned roads of trans-european transport network TEN-T, in accordance with Directive 2008/96/WE, are obliged to perform regular road safety audits (RSA). In Poland alone, this duty belongs to GDDKiA and 27 mayors of cities with county rights, and includes 4800 km of road network. EYEVID project is meeting this need - applying tools and methodology to perform RSA over the most important aspect of road safety – visibility. Use of eye-tracking devices and high class driving simulators in RSA introduce to EU new quality of audit services. Proposed solution would be first of the kind and one of the first in EU, with scientifically based methodology, which will support so far used expert assessment. Description of the content of the paper, obtained results and conclusions;

Keywords: *road traffic safety, driving simulators, eye-tracking*

Koncepcja systemu do zautomatyzowanej oceny infrastruktury drogowej

Streszczenie: Unia Europejska podejmuje działania zmierzające do zmniejszenia ryzyka związanego z użytkowaniem infrastruktury drogowej. Jednym z istotnych elementów wpływających na poziom zagrożenia uczestników ruchu drogowego jest architektura i stan techniczny infrastruktury. W celu ujednolicenia procedur ocen nowo-budowanych dróg i ich otoczenia, w obszarze Unii Europejskiej wprowadzono Dyrektywę 2008/96/WE, która nakłada obowiązek stosowania audytów na wszystkich eksploatowanych i projektowanych drogach transeuropejskiej sieci transportowej TEN-T. Tego obowiązku musi w Polsce dopełnić Generalna Dyrekcja Dróg Krajowych i Autostrad oraz 27 prezydentów miast na prawach powiatów, którzy nadzorują łącznie około 4800 km dróg tzw. sieci TEN-T w Polsce. Naprzeciw nowej potrzebie rynkowej wychodzi projekt EYEVID, którego celem jest wytworzenie zaawansowanych narzędzi i metodologii oceny najważniejszego aspektu bezpieczeństwa na drodze – widoczności. W tym celu przewiduje się wykorzystanie urządzeń okulograficznych i wysokiej klasy symulatorów jazdy. W efekcie, zostanie opracowane interaktywne narzędzie wspomagające ocenę infrastruktury drogowej w aspekcie widoczności. Badania będą zatem prowadzone w warunkach zbliżonych do rzeczywistych. W artykule opisano założenia przyjęte w projekcie, planowane efekty i sposób ich realizacji.

Słowa kluczowe: *bezpieczeństwo ruchu drogowego, symulatory jazdy, urządzenia okulograficzne*

1. Introduction and background

For over a decade Directorate-General for Mobility and Transport of European Commission has been supporting research and actions which main purpose was to reduce traffic related death rate [2].

Road traffic safety significantly influence social and economical costs related with traffic accidents consequences. The idea of improving the state of road traffic safety in European Union has been formulated in White Paper – European Transport policy for 2010: time to decide; in September 2001, and was continued in European Parliament resolution of 27 September 2011 on European road safety 2011-2020 [3]. The main aim of the strategy is to reduce road traffic deaths by 50% by the 2020 year. This purpose will be achieved with the use of Road Safety Audits (RSA) and other ways of evaluating road traffic safety, like regular infrastructure inspections and controls of road signs state. According to Directive 2008/96/WE all European Union countries are obliged to conduct Road Safety Audits on the roads which are in the Trans-European Transport Network (TEN-T).

Polish government has adopted Directive 2008/96/WE by changing law acts (Dz.U.2012 nr 472) on 13 April 2012. Adjusting existing tools to support RSA is one of the main EYEVID Project's objectives. Therefore, our project meets an existing and urge need. Mention that there are about 4 800 km of TEN-T roads which has to be examined (Fig. 1).

Road safety audits should be conducted on every build or modernized road of Trans-European Road Network. Moreover, these expert analyses should be made at every stage of planning and designing a road. According to GDDKiA (Polish Highway and Main Road Administration)RSA are introduced at the stage of:

- technical, economical, environmental study and program concept (an early stage plan in which the course of road is designed),
- construction project, supplementary and end drafts (a stage in which an exact project of the road is made, including all parameters),
- stage before opening the road,
- early stage of road exploitation.

The obligatory phased way of conducting audits has been developed to limit errors in the final stage of constructing a road.

Fig. 1. Trans-European Road Network in Poland

Road traffic safety is an imprecise issue. That situation is caused by the very wide range of interpretation. The concept of road traffic safety concerns methods and measures which were meant to predict probability of occurring a situation in which a person will be killed or seriously injured in a road accident. The road users are not only the drivers but also pedestrians, cyclists and passengers (including public transport passengers).

There are many ways of considering road traffic safety, measurements seems to be most precise and useful in research. Considering the range which is covered, three kinds can be distinguished:

- global measurements,
- detailed measurements,
- individual measurements.

In EYEVID project critical sections of road will be selected for further examination. Therefore, we have chosen detailed measurements to be the most appropriate for that purpose.

Detailed measurements enable to evaluate safety in a particular localization (e.g. intersection) or in a region (with a needed range of detail). These measurements can be formulated in many different ways, considering localization to which they are related or aspects of road traffic safety which whey will describe.

EuroRAP has developed a set of examples of detailed measurements. They are related to number of collisions/casualties for length of road, in particular to specified sections. These measurements are particularly useful in pointing out dangerous road sections. Additionally, they can be related to other than number of collisions/casualties values, but still they enable to define relations between threat to safety and different road user's categories (e.g. truck drivers).

The measurements mentioned above should be used together with data about road network and transport work for every road section, enabling to type out the most dangerous sections, which is the main aim of determination these measurements.

Another example of detailed measurements, commonly used to qualify sections of road with a concentration of collisions is a method of qualifying at the basis of road network safety. The basis for qualifications in this type of method are information about road exploitation for 3-years period of time. The aim of qualifications made with the use of that method is to identify the most dangerous sections and prioritize ones with the highest potential in improving the state of traffic safety. It can be assumpted that these methods not only describe traffic safety of network but also they are measurements of safety on the road.

According to method described above, road is devided into sections of 20±1 km length (for non-urban roads) and 10±0,5 km length for other road types). To each section a class is assigned:

- A class – where over 12 people died in road accident,
- B class – where 7-11 people died in road accident,
- C class – where 4-6 people died in road accident.

Other cases are not included in this method.

In the method of classifying road network safety another criteria can be used. Division is similar 20±1 km length for non-urban roads and 10±0,5 km length for other roads. There are following classes and criteria:

- class I – at least 51 accidents, or at least 151 collisions or at least 30 accidents and 70 collisions,
- class II – 31-50 accidents or 101-150 collisions or 16-20 accidents and 50-70 collisions,
- class III – 16-30 accidents or 50-100 collisions or 10-15 accidents and 20-50 collisions.

Other cases are not included in this analysis.

EYEVID Project covers applied studies conducted to compile tools for supporting research on road infrastructure safety and road safety audit.

Being the first tool of that kind on the European market where no such tools exist and road safety audits base on expert evaluation. Research conducted with EYEVID tools will cover studies on complex road safety evaluation in the context of visibility of crucial road safety elements e.g. road signs. This aspect plays a significant role since it affects drivers' attention and behaviour on the road. Our modular set of tools, contains a module for automatic classification of critical section of the road in the real and in the virtual environment. The program for operationalization of obtained test results is dedicated to a defined group of recipients – road investors, road safety auditors, local governments – who will participate in the process of program formation. Therefore, our program will meet the real needs of road users.

The main aims of our Project concern:

- development of methodology for research on road infrastructure with the use of eye-tracking devices,
- defining representative features of road traffic participants,
- project and construction of stand for eye-tracking research in the real road environment,
- project and implementation of complex stand for specified research on road infrastructure in virtual environment,
- project and realization of additional tools for automation of the process of research on road infrastructure,
- verifying the made tools and methods on a representative group of drivers.

All of the above mentioned aims could be summed up as a project and tools for research on road traffic infrastructure. This set of tools, using up-to-date technology will enable to automatically analyze data obtained from research on road infrastructure and will limit human factor errors in this process. It will also provide an additional instrument for road safety auditors and will help to maintain an appropriate level of their objectivity.

The EYEVID consortium is formed by 3 research centers: Motor Transport Institute in Warsaw, Military Aviation Medicine Institute in Warsaw, Rzeszow University of Technology; and 2 enterprises: Neuro Device Group Sp. z o.o. and ODIUT Automex Sp. z o.o..

2. Main project assumptions

In all research which concentrate on road traffic safety, a human-vehicle-road (surrounding) system is examined. The EYEVID project concentrates, in particular, on the interactions between elements of that system. Therefore, subject area covers wide spectrum of cases, demanding thorough knowledge in many fields, which makes the project interdisciplinary and the results are expected to bring some innovative solutions.

Concerning the complexity of so framed problem, we have decided to concentrate In particular on two elements. The first, and most important is the role of visual stimulus which affect a person when driving. Assumpting that visual perception is the most important initiator of driver's reactions, we have concentrated on researches on how the road surrounding influence driver's behavior. Driver's perception is related to attention processes (bottom-up processes) and to processes of undertaking a purposeful activity (top-down processes). Reckoning these processes is not the assumption of EYEVID project. However, describing processes of visual perception and related reactions are one of the most important elements of the project, as they are considered to have crucial affect on driver's behavior and, therefore, on road safety.

The second assumption is concentrating on elements crucial to road traffic safety. They are not only physical ones (e.g. road signs and elements of road infrastructure) but also some concepts (e.g. proper visibility). So defined elements are the base of road traffic safe as they make the use of road easier, more instinctive and understandable.

Considering the two preceding assumptions, EYEVID project concentrates on perception of road traffic safety elements. So defined research area includes several issues, description of which should be made, in order to elaborate tools for supporting evaluations of road infrastructure. These issues are:

- from the perspective of road user:
  - visual perception,
  - driver's attention models,
  - psychological abilities,
- from the perspective of road:
  - requirements for road projects,
  - requirements for road signs placement and development of road surrounding.

Elements of Road infrastructure important in the aspect of road traffic safety are main objects of EYEVID project's interest. To these elements should be ascribed not only road signs and road markings but also visibility zones at crossings.

Considering the influence of elements shown at Figure 2, four cases can be distinguished. The first situation – the driver sees an element, understand it an interpret it correctly but do not comply to it. That aspect of driver's reactions is not directly related to the project's issue. However, right interpretation could be additional objective of EYEVID project. It concerns incoherency between elements as well as illegibility of information – for instance inadequacy of appliance in the situation it has been used. Adjustment of driver's behaviour is off the project's issue. Complex psychological and incen-

tive conditions are not the object of our interest. One of the project assumption is that drivers will behave correctly, regarding road signs and markings.

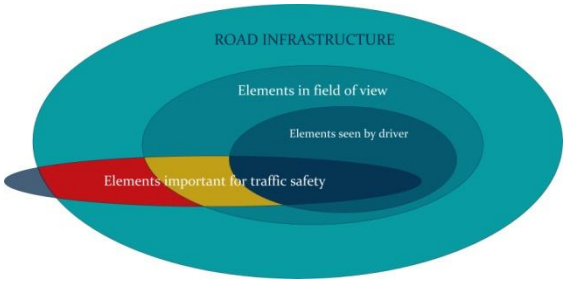

Fig. 2. Graphical representation of project issues

The second case describes a situation in which elements important for traffic safety are in potential field of view but they are not observer by driver. Such situation is related to driver's perception, in particular:

- location of the element,
- attention of driver,
- other elements in the field of view.

Considering these conditions, 3 cases can be distinguished:

- locating too many objects in the field of view,
- complex maneuvers and other demanding activities of driver acting in particular moment,
- distraction of driver's attention by other, more attractive objects in the field of view.

That problem concerns including average driver in Road Safety Audits and other safety evaluations. Research on real, natural behavior on the road could help in adjusting the road infrastructure and surrounding to the average user.

The third case is a situation in which an element is located in a proper way, but it cannot be observed by drivers due to some conditions. These are, first of all, cases when an object is obscured in some way and, therefore, is not in the effective field of view. It concerns inappropriate location of road safety element or of other elements in the road surrounding. Moreover, possibility of covering or obscuring an object because of other road users should be analysed – for instance by lorries.

The fourth case considers a situation when there is an evident lack of an important element in road surrounding. That problem can be solved as an additional aim of EYEVID project.

3. Project tools

EYEVID project was provided to meet the need for improving elements of road safety and it focuses on creating new and innovative tools and verifying them in the context of usability for road safety audits. Our set of tools will enable to analyze not only yet-existing but also planned roads of TEN-T (Trans-European Transport Network) as well as roads of "lower category" down to the local level. The project concerns the use of present-day computer science, eye-tracking technology and high-class simulators.

The eye-tracking technology is basing on tracking the movement of eye pupil with the use of special cameras. The main information which will be obtained is the fixation time – a period in which sight is focused on one point or object. In EYEVID project it will be selected elements of road environment, in particular road signs. Eye-tracking devices, which will be used, enable to define dynamic AOIs (Areas of Interest) of observer, concerning specific gaze pattern of drivers.

The importance of proper visibility while driving has been proved inter alia by A. Yarbus in his research on correlation between visual stimulus and brain functions [6]. Furthermore, research of C. Ho and C. Spence proved that drivers reactions are fastest for visual and multisensory (with dominance of visual) stimulus [4]. Therefore we can deduce on how important an appropriate vision is for safe driving and how significantly it influence road safety as a system [5].

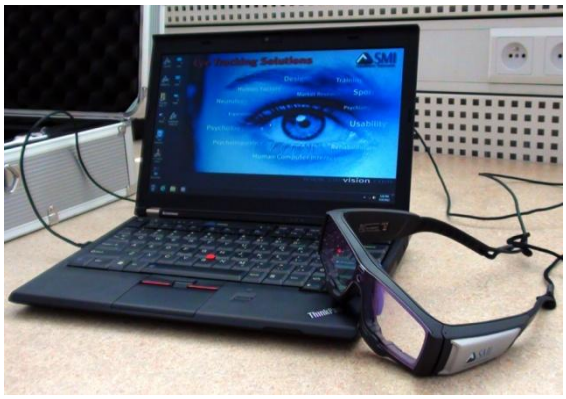

Fig. 3. Eye-tracking device

The most important and most frequently measured eye movements are fixations and saccades. In general, fixations are states when eyes are fixed on an object for 200-300 miliseconds, while saccades are defined as movements between two fixations which last 30-80 milliseconds [1]. Therefore, to obtain good quality results, frequency of camera should be about 100 Hz minimum.

Fig. 4. SMI Glasses - final film view

In eye-tracking technology, eye movements are recorded by single images. Regarding efficiency of measurement and possibly low onerousness to research participants, no-contact video technology is considered to be the best choice. It is based on reflection of infrared light on the pupil and cornea. Eye-tracking devices (named eye-trackers) constantly monitor movements of the eyes and enable to appoint AOIs.

According preceding information, the SMI Glasses were chosen to be the most appropriate tool in research for EYEVID (Fig. 3 and 4). They are on-head device, equipped with 3 cameras, two of them track pupil movements while the third one records the context (video of what the driver has in front of him). The final effect, a film with pointed spot where the research participant fixed his eyes, can be analyzed in the context of road traffic safety, in particular the visibility of road signs and other safety facilities.

Fig. 5. High-class driving simulator

Driving Simulators represent recently most often used tools in research on drivers. The major advantage of using that type of simulator is recurrence of experiment, in contrast with real road environment. The level of virtual environment reality in high-class simulators is sufficient to conduct reliable research (equipped with moving platform and system for visualization). The high reality of simulation can substitute driving in real environment.

Additionally, high-class simulators enable to examine situations in environment and circumstances, which could not be assured in natural road environment. The most important advantage is the possibility to repeat exactly the same situation and expose many drivers to it. Properly planned and created scenario allows a simulation adjusted to individual driving skills and abilities, but similar to all drivers in the context of light and road conditions That way of conducting research which results are easy to compare.

The driving simulator AS-1200-6, owned by Motor Transport Institute in Warsaw, consists of:

- full-scale and functional cabin of Opel Astra IV,
- visualization system,
- moving platform of six degrees of freedom.

Additionally, in the interior of cabin mechanical stimulus and appropriate sounds are dynamically generated in order to make the simulation as realistic as possible. The simulation process and each part of the system is constantly being supervised. Selected parameters of driving and car movement are recorded and driver's behavior is monitored by system's operator.

4. Expected results – project's potential

Automation of preparing and processing of data and developing a methodology for conducting research on visibility will allow to use eye-tracking devices in the process of evaluating road infrastructure and safety, especially in road safety audits. Therefore, RSA can be supported on every state – tests in virtual environment for planned and designed roads, or experimental rides on yet existing roads. Research will be useful in the process of determining threats to road safety, pointing out particular places and elements which should be change in order to improve road safety.

Fig. 6. Research with the use of high-class driving simulator and on-head eye-tracking device

In EYEVID project two complex research tools will be created – tool for conducting research in the real and virtual road environment and traffic condi-

tions. Additional software will be developed to enable automatic analysis of road infrastructure and road surrounding in the aspect of road safety.

To fulfil the assumptions an interdisciplinary consortium was gathered. Consisting of different knowledge fields representatives it has an undisputable potential. Specialists of: traffic engineering, traffic psychology, traffic simulation and eye-tracking are main participants of EYEVID project. Their knowledge and competences were selected to complement each other. These facts provide evidence to future success of EYEVID project.

Nomenclature/*Skróty i oznaczenia*

AOI Areas of Interest (in eye-tracking technology)/*obszary zainteresowania (w technice eye-tracking'owej)*

RSA Road Safety Audit/*audyt bezpieczeństwa ruchu drogowego*

TEN-T Trans-European Transport Network/*transeuropejska sieć transportowa*

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