cars, directives, intelligent systems, road safety

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ROAD TRAFFIC SAFETY IN CONJUNCTION WITH IN-VEHICLE ITS

Summary. Interest in Intelligent Transportation Systems comes from the problems caused by traffic congestion, road accidents and air pollution. Traffic congestion continues to grow worldwide as a result of increased motorization, population growth, changes in population density and urbanization. Interest in ITS can also be attributed to reducing road accidents and increasing traffic safety. The most common causes for road accidents are excessive speed, inattentive driving and ignorance of the right-of-way rules. To eliminate these causes, experience, knowledge of traffic regulations and a new car are not enough – vehicle safety systems have to take part as well. Therefore, the European Union issued a directive on the installation of intelligent systems, whose functions are active support during driving, warning the driver in dangerous situations and alerting passengers of the car in case of irregularities in motor function or actions carried out by the driver that may cause danger, such as swerving while falling asleep. These systems help drivers to avoid accidents, and in the event of a collision, an emergency call is automatically made. Furthermore, they can be used to regulate traffic patterns or to reduce engine performance, which would reduce pollution. With these benefits in mind, the EU has indicated to the automotive industry that installation of these new Intelligent Transportation Systems should be mandatory in their new vehicles.

BEZPIECZEŃSTWO RUCHU DROGOWEGO W POŁĄCZENIU Z POKŁADOWYM ITS

Streszczenie. Zainteresowanie Inteligentnymi Systemami Transportowymi (ITS) wynika z problemów spowodowanych przeciążeniem ruchu drogowego, wypadkami drogowymi oraz zanieczyszczeniem powietrza. Przeciążenie ruchu stale wzrasta na całym świecie, jako rezultat wzrostu motoryzacyjnego, zwiększenia liczby ludności, zmiany w gęstości zaludnienia oraz urbanizacji. Zainteresowanie ITS może również być przypisane redukcji wypadków oraz zwiększenie bezpieczeństwa na drogach. Najczęstszymi powodami wypadków drogowych są nadmierna prędkość, nieuważne prowadzenie samochodu oraz ignorowanie zasad ruchu drogowego. By wyeliminować te powody, doświadczenie, wiedza o zasadach ruchu drogowego oraz nowy samochód nie są wystarczające – powinny tu również brać udział systemy bezpieczeństwa pojazdu. Dlatego też Unia Europejska ustanowiła dyrektywę o instalowaniu inteligentnych systemów, których funkcje to aktywne wspieranie podczas jazdy, ostrzeganie kierowcy o sytuacjach niebezpiecznych oraz powiadamianie pasażerów samochodu w razie nieprawidłowości w działaniu silnika lub o działaniach powodowanych przez kierowcę, które mogą powodować niebezpieczeństwo, takie jak zbaczanie z drogi w wyniku zasypiania. Systemy te pomagają kierowcom zapobiec wypadkom oraz w razie kolizji wykonują automatycznie telefon alarmowy. Co więcej, mogą być stosowane do regulowania wzorców ruchu lub redukcji osiągów silnika, co zmniejsza ilość zanieczyszczeń. Mając na uwadze te korzyści, Unia Europejska zaleciła przemysłowi motoryzacyjnemu, instalowanie Inteligentnych Systemów Transportowych w nowych pojazdach.

1. INTRODUCTION

In today's society, we can't imagine life without means of transportation, as we need it for many of our everyday tasks. Mobility is essential for the functioning of modern society. With mobility increasing at such a fast pace, our traffic safety is becoming more and more important. The European Union (EU) is leading the way with new initiatives which they hope will help to decrease the number of mobility-related deaths by half annually. For example, in paper [17] describes how to use ITS for road safety in the conditions of Lithuania. Involved in this initiative are all EU members, including Slovenia, as well as its National Programme for Road Traffic Safety. The National Programme for Road Traffic Safety deals with the demanding problems of road traffic safety. It includes measures in the following fields: human behaviour, traffic environment, vehicles and institutional areas, and for each measure provides activities to achieve the common European objective of Vision Zero [15]. Road accidents account for a severe threat to human well-being, from physical injuries to financial obligations. However, accidents occur due to human error, circumstantial error and negligence. Today, special attention is focused on the technologies that can help to reduce traffic accidents [13].

Road traffic safety is one element of common safety where law and order are maintained and ensured and where – through different inspections of municipal constables, police and judiciary – an adequate protection of transport infrastructure is provided. Traffic is to be understood as an open system where it is necessary to assess the threat of accidents that lead to traffic disasters for a reduction of the problem to be successful [15]. The field of road traffic safety in Slovenia is defined by the Road Traffic Safety Act [18], shorter RTSA, which was adopted by the National Assembly of the Republic of Slovenia. It is divided into four fields: Act of rules in road transport, Drivers act, the Road Traffic Safety Act (RTSA-1) and the Road Transport Act. Enforcement of this act began on the 1st of April 2011, although it began to be used on 1 July 2011. The main objectives of the Act are to reduce the number of road accidents with the worst consequences, including changes, which have immediate effects on traffic security.

Based on data collected from the Ministry of the Interior [4], we have established that in a period of ten years in Slovenia, there were 2715 people killed due to road accidents. In 2000, 315 people died, according to National Road Safety Programme, while there were only 138 deaths in 2010; the number of deaths decreased by 56.19% compared to 2000. Compared to 2004 when Slovenia joined the EU, the number of deaths has decreased by 49.64%. In 2009, 171 people lost their lives, which is 20.1% less than in 2008. Based on this evidence, it can be stated that the preventive measures undertaken by various organizations have had a positive impact in reducing the number of mobility-related deaths, as well as reducing the number of road accidents. In 2009, the number of road accidents has reduced by 10.6% in comparison to the year 2008. In 2010, the number of road accidents increased by 3.20% compared to the year 2009, but in 2010 there were 19.30% less deaths. When we compare the number of road accidents in Slovenia with other EU members, we can find that the number of road accidents in Slovenia with fatal outcome is 24.64% higher than the average for all EU members. Slovenia is ranked number 11 among 27 EU members in regards to number of road accidents.

We established that most road accidents happen due to inappropriate speed, inadequate safety distances, overtaking, driver fatigue and pedestrian carelessness. To this end, we analysed safety systems that can operate alongside the vehicle, whether on the front or the rear side of the vehicle. These systems assist the driver during driving and have an alert function. They are tasked with informing the driver about the systems that actually take partial or full control of the drive.

The problem of our research is the large number of road accident and potentials for their reduction. To overcome the problem of a large number of road accidents, it is necessary to combine modern technology with the users of means of transport. This can be achieved with an incorporation of intelligent transport systems into vehicles. These systems cooperate with drivers, as well as with the environment in which the vehicle moves.

2. SAFETY AND INFORMATION SYSTEMS IN VEHICLES

Traffic accidents are an integral part of traffic activities and they appear in all forms of transportation. Most often they happen in road traffic. Road safety is influenced by various factors: man, environment and vehicle. Man is a factor in traffic safety and he can appear in traffic directly as a participant and indirectly as a teacher in the field of traffic education, an instructor in a driving school, a car manufacturer, and as a manufacturer of systems for improved road safety [3]. The environment plays an essential role, for instance the terrain in which cars and other motor vehicles drive upon is vital and relevant in accordance with road safety and migration. To ensure safe driving there must be visible road signs at intersections and crossroads. The driver must have a good vision field -- horizontally and vertically as well as outstanding peripheral vision in order to achieve safe driving. The drivers' manoeuvres and safety depend on their vehicle and natural skills. Road safety requires a good driver and a well manufactured vehicle. Therefore, on 6th August 2010, the EU [16] published Directive 2010/40/EU of the European Parliament and Council on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. This directive is extremely important for the coordinated implementation of intelligent services in whole Europe, while allowing the EU members to freely decide on the use of intelligent safety systems within their own country. These changes are long-term and are in connection with the development of active and passive protection in vehicles.

We are referring to systems that allow managing of traffic safety hazards and inconveniences on the basis of modern technological solutions, based on vehicle-vehicle and vehicle-infrastructure communication with real-time data transfer. These are intelligent vehicles or intelligent transport systems. The Directive of the European Parliament and the council on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport [12] in its fourth Article defines "intelligent transport systems" or "ITS" as the systems in which information and communication technologies in the field of road transport are used, including infrastructure, vehicles and users, and network management and mobility management, as well as interfaces with other transport modes. These systems must be reliable, accurate and user-friendly. They must be manufactured in the way that they can be handled by each driver and that when many systems are turned on at the same time, they do not confuse the driver. It is important that the driver is advised on all the systems contained in his or her vehicle.

EUCAR (European Council for Automotive R & D) is the European Group for Research and Development in the automotive industry, which together with its members - major European car manufacturers - through the framework programmes conducts research funded by the European Commission. All projects are presented on the CORDIS (Community Research and Development Information Service for Science, Research and Development) information portal of the European Union service for information on research and development. These projects and sub-projects were the basis for the development of cooperative systems, active and passive systems, and systems for the development of human-machine interfaces. Cooperative systems transfer information between the vehicles and take care of the two-way communication between the vehicle and infrastructure and vice versa. The leading role in the development of cooperative systems projects is taken by COOPERS (Co-operative Systems for Intelligent Road Safety), CVIS (Co-operative Vehicle-Infrastructure Systems) and SAFESPOT. For the development of preventive and active safety systems, the European Commission supported the project called PReVENT (Preventive and Active Safety Applications Integrated Project). The project was an activity of the European automotive industry and was co-financed from the European Commission. It consisted of a significant number of sub-projects that were active in various fields. The motivation for the creation of the project APROSYS (Advanced Protection Systems) came from the encouragement of the White Paper, EUCAR plan and from the plan for the development of passive vehicle safety systems. In the context of the development of passive safety systems, the eCall project stands out. This system represents one of the most exposed projects of European initiative for improved eSafety with an intention to establish a single European emergency call number for passive vehicle calls. On 21 of August 2009, the European Commission issued a report to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, entitled "eCall: Time for introduction". Because there has not been any greater progress in a voluntary introduction of the system since 2009, the European Commission has decided to adopt legislative measures. Therefore, the EU called upon all members to ensure the update of mobile infrastructure and to facilitate a smooth and equally treated emergency call. The task of the mobile operators is the introduction of such systems, which recognize that an e-call is being made, and redirect it to the trained emergency operation centres. The project AIDE (Adaptive Integrated Driver-Vehicle Interface) has dealt mainly with the development of methods and technologies for the installation of the interface between the driver and the vehicle which is necessary for the efficient and secure connection between the driver, vehicle and information exchange with the environment.

In the context of active and passive safety we are mostly dealing with the following intelligent systems: Anti-lock Braking System (ABS), Adaptive Cruise Control (ACC), Brake Assist System (BAS), Obstacle and Collision Warning, Adaptive Brake Assistant, Speed Alert, Curve Speed Assistant, Night Vision, Adaptive Headlights, Driver Drowsiness monitoring System, Blind Spot Monitoring (BSM), Lane Change Assistant (LCA), Lane Departure Warning System (LDWS), Lane Change Warning (LCW), Lane Keeping Assistant (LKA), Anti-slip regulation (ASR), Electronic Stability Control (ESC), Tire Pressure Monitoring System (TPMS), eCall.

ABS is a system that is part of the standard equipment in all new cars from 2007 onwards, and does not need to be presented separately, as the task of this system is already well known. Broughton & Baugh [7] note that the ABS has a significant impact to reducing traffic accidents, but the drivers because of poor knowledge of the system do not take advantage of the most functional.

We will briefly outline the importance of all the other systems discussed. ESC regulates engine operation and distribution of braking power for each wheel independently. It helps to maintain safe braking and vehicle stability in quick changes of direction. Vaa et al. [11] analyzed the effects of ABS and ESC in a traffic accident. It was found that the ESC system is very effective in reducing road

accident. Green & Woodroofe [2] explored the effect of ESC on reducing road accidents due to loss of control. For passenger cars they found a 30% reduction in accidents of vehicles fitted with ESC. Farmer [9] notes that the vehicles that are equipped with the ECS system have 41% lower risk of traffic accidents than vehicles without the system. Similar findings also represent other researchers (Aga & Okada [12], Dang[1]). Bahouth [6] also found that vehicles with standard built-in serial VSC system are less involved in accidents as vehicles, which offered this system as an option.

An ASR system has its “roots” in the mid-1980s, when the method and strategies of anti-slip regulation had been studied in many countries [8]. ASR system can improve starting drive efficiency, automobile attractive ability, manoeuvre ability and stability [14] and TPMS provides continuous monitoring of tire pressure, allowing the tires to prevent damage and consequently the possibility of an accident. Those systems maintain vehicle stability. The systems presented below take care of the longitudinal control of the vehicle.

The ACC improves the function of standard cruise control in the way that automatically adjusts the speed and distance to the vehicle ahead. Rudin-Brown and Parker [10] found that the ACC system the driver can perform better a secondary task, but the response time to brake increased when a safety hazard was introduced .The BAS enables a reaction where even at a very small force with which the driver presses the brake pedal, the system enables maximum pressure on the brake. The BAS system is also very efficient in reducing the severity of pedestrian accidents [5]. The Obstacle and Collision Warning System with the help of combination of long and short range radar activity and with a video camera, enables the detection of vehicles and obstacles ahead and warns the driver of danger on the road with audio or visual signs. ABA operates based on a sensor, which is built into the front part of the vehicle. With the sensor it measures the distance to the vehicle ahead and its speed. In the event of the driver braking suddenly due to a vehicle ahead, the system calculates the necessary emergency braking and with how much force it is necessary to brake. If the driver exceeds the speed limit, the System Speed Alert warns him, or the driver himself can assess and reduce the speed of the vehicle.

BSM, LCA, LDWS, LKA and LCW are systems performing lateral control over the vehicle. The difference between them is that some systems only warn and others are actively involved in driving. The task of BSM is that it warns the driver that there is a vehicle or an obstacle in his blind spot on which the driver must pay attention while turning left or right, it does so with a light icon in the mirror, a sound signal, or with both options. The LCA is a combination of instructions for longitudinal vehicle safety and control over the steering, with which support of the adaptive cruise control and the directional stability system is given to the driver during changes of lanes. With the system LKA, a camera recognizes a lane, which helps the driver with staying on the lane without driving over the line. The LCW system is used when the driver turns on the indicator and the system detects that the driver will carry out an illegal lane change due to the approaching vehicle.

The next group is the so-called additional systems. These include the Adaptive Headlights System that is designed to illuminate the road during driving in turns and on hills, so that the front lights move to the left, right, up or down. Driver Drowsiness Monitoring System alerts the driver in case of sudden fatigue by recognizing facial expressions as well as body motions like the moving of arms and legs and by analysing the eyelids and position of the head. It also detects changes in heart beat rate. In the group we can also include the Night Vision System, which is based on heat detection in the surroundings and by using an infra-red camera which can see bright shapes and indicate that there is a human or an animal nearby.

3. METHODOLOGY

With the survey we wanted to analyse the use of ITS and its impact on the prevention of various situations that lead to road accidents, which can in the long-term help to improve road safety and reduce fatalities. At the same time, we wanted to determine the current situation or the presence of these systems on Slovenian roads. We also prepared a model of road accident probability dependent on intelligent systems, with which we presented the factors that influence road accidents as well as possible scenarios caused by these factors. For each scenario, we found a suitable ITS and explained how it prevents road accidents.

We tried to confirm or refute our thesis:

Installation of information systems into vehicles helps improve safety and reduces the number of road accidents.

To this end, we conducted a study in which we used already collected data on the number of newly registered vehicles in 2010, which in Slovenia is governed by the Motor Vehicle Section. Of the 19 vehicle size classes, we randomly selected six classes. These are Class A – mini vehicles, Class B - small vehicles, Class C - lower middle class vehicles, and Class D - upper middle class vehicles. We will also cover class E, together with class F, where there are executive and luxury vehicles. We then looked at the newly registered cars and chose the top 15 brands and vehicle types from each class. This was done separately for each month of the year. Finally, we got figures on each sales-type for the entire year of 2010.

With the help of technical information and data on the supply of equipment, we verified what each vehicle offers as standard or optional equipment. In every car class we analysed in detail the active and passive systems offered by each brand and type of a vehicle. For active safety systems, we studied the Vehicle Stability Systems (ABS, ESC, TCS, TPMS), side control (BSM, LCA, LDWS, LCW, LKA), longitudinal control (ACC, BAS, Obstacle and Collision Warning, Curve Speed Assistant Speed Alert, Adaptive Brake Assistant) and additional safety systems (Night Vision Driver Drowsiness Monitoring System, Adaptive headlights). In the context of passive systems, we checked the presence of eCall systems.

4. RESULTS OF RESEARCH

All together, we dealt with 40,330 new vehicles first registered in 2010. We found that the ABS system is present in all vehicles, which is consistent with the law, which states that all vehicles from 2007 onwards must have ABS fitted as standard equipment. Other systems in 2010 were not required as standard equipment and their presence is as follows: ESC is present in 45% of the vehicles, mostly in vehicles of Classes E and F. The ASR system is in 15,493 vehicles, which corresponds to 38.42% of all vehicles, the TPMS system is in 4.12% of the vehicles and the BAS system is in 56.31% of the vehicles. The Adaptive Brake Assistant System is in 1.35% of the vehicles and the Curve Speed Assistant system is in 0.79% of the vehicles. The adaptive headlights are in 0.27% of the vehicles and the system for detecting driver fatigue is in 0.23% of the vehicles.

Other discussed systems are not available as standard equipment; therefore they are not included in the table below. Among them, there are some systems offered by the automotive manufacturers as a part of additional equipment. Their purchase and installation in vehicle depend on the customer.

Table 1

The presence of Intelligent Transport Systems

Systems	Car Classes						
	Total Class A	**Total Class B**	**Total Class C**	**Total Class D**	**Total Class F and E**	**Total number of ITS:**	**Total presence of ITS in %:**
ABS	1.578	18.249	15.480	4.444	579	40.330	100,00
ESC	137	5.908	8.105	3.421	579	18.150	45,00
ASR	9	4.406	6.108	4.444	526	15.493	38,42
TPMS	/	/	1.056	458	149	1.663	4,12
BAS	822	6.415	11.588	3.421	462	22.708	56,31
Adaptive Brake Assistant	/	/	/	452	93	545	1,35
Curve Speed Assistant	/	/	/	229	91	320	0,79
Adaptive Headlights	/	/	/	96	11	107	0,27
Driver Drowsiness Monitoring System	/	/	/	/	93	93	0,23

Legend: Data in the table, labelled with / means that there is no system in the car class

5. DISCUSSION

The most developed and accessible are systems for the vehicle's stability. This accessibility is related to the fact that systems are relatively simple and that they do not need the development of additional systems in order to operate. This also relates to the price of a system and its installation.

Therefore, these systems are available in all car classes and are accessible to the general population.

We came to the conclusion that vehicles from class D were the best-selling vehicles. The highest presence of the ITS is in class E and F.

We prepared a model of road accident probability in dependence on the intelligent system (Fig. 1). We included road accident factors and possible scenarios.

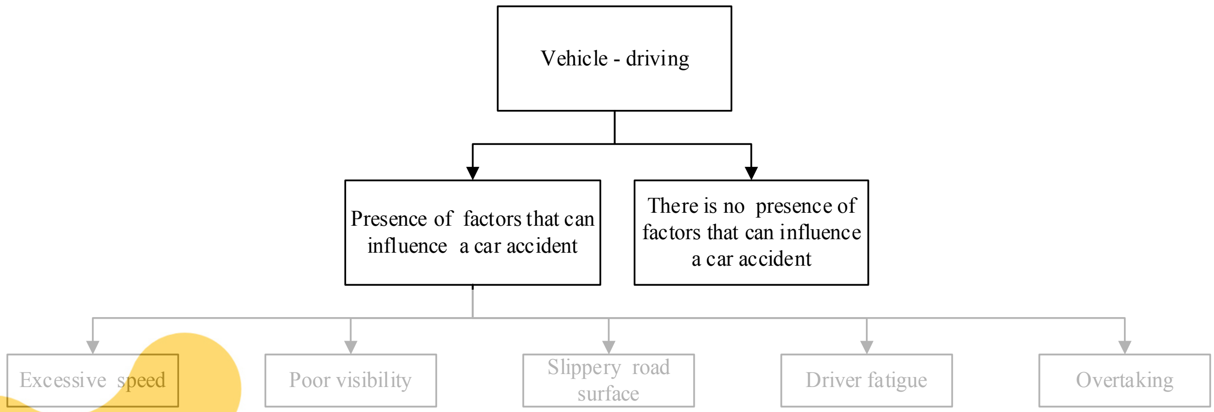

Fig. 1. A model of the road accident probability in dependence on the intelligent system

Rys. 1. Model prawdopodobieństwa wystąpienia wypadków drogowych w zależności od inteligentnego systemu

In cases where the system was not present, a road accident had occurred, and where ITS had been installed in the vehicle, there was a particular system identified for each possible scenario. Inclusion of a system is based on its function: preventing a road accident and helping the driver in a critical situation. Below, we present the factors, which can influence a car accident. First important factor is excessive speed. In Fig. 2 is shown the various intelligent systems related to excessive speed.

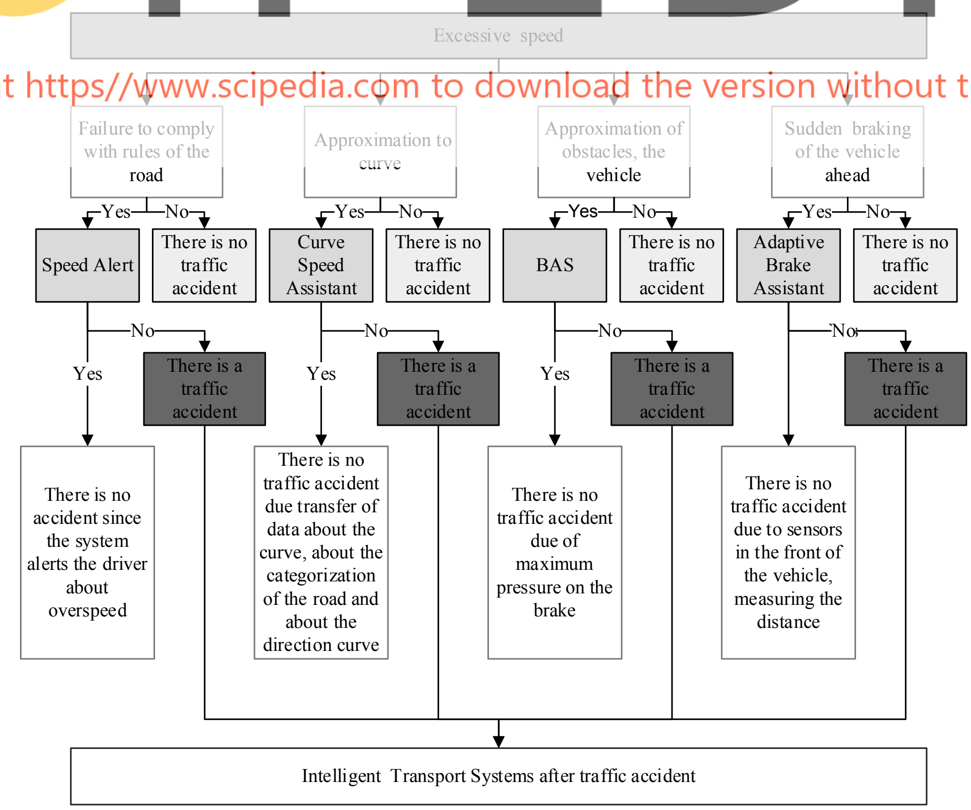

Fig. 2. Excessive speed

Rys. 2. Nadmierna prędkość

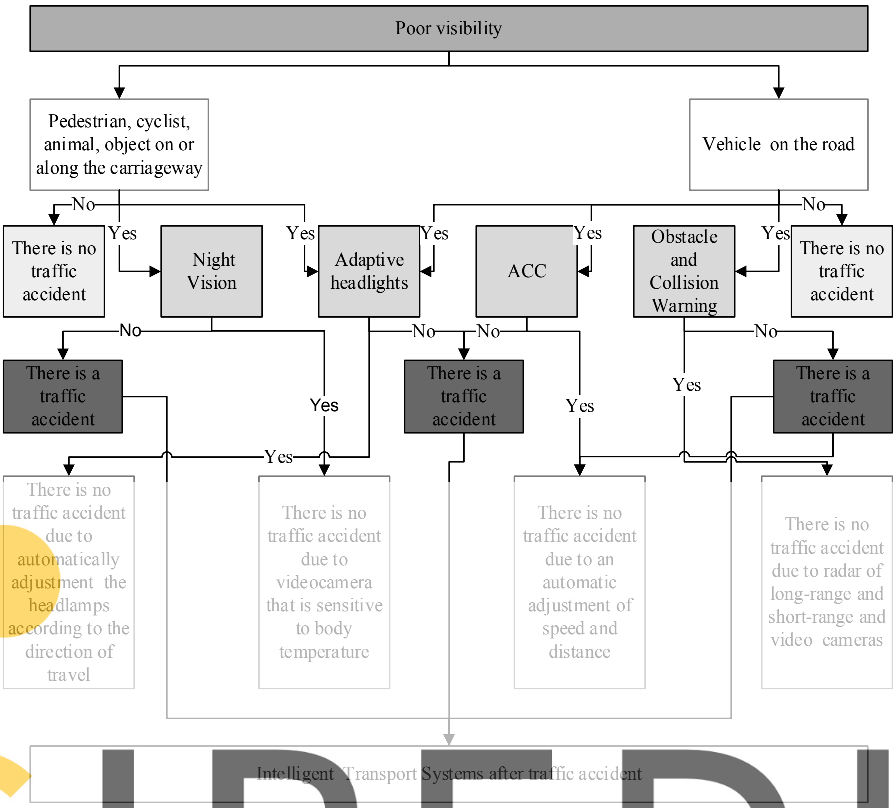

Fig. 3. Poor visibility
Rys. 3. Słaba widoczność

Slippery road also impact on pedestrians, cyclists and other vehicles in traffic. Intelligent technologies to prevent accidents are ASR, ESC, ABS and TPMS.

If the vehicle has built-in system to recognize driver fatigue, it is highly likely to avoid accident, because these systems constantly monitor the heartbeat and movements of the driver's eyes.

A greater presence of ITS in a vehicle could be burdensome for the ordinary driver. For example, at a stage when the driver is leaving a crossing, several systems could switch on and this would confuse the driver. The reason for the inclusion of a large number of systems are, of course, to respond to different situations (oncoming vehicle, inappropriate vehicle speed in a turn, control of the blind spot, information about possible delays, ...) based upon the actual surroundings. Each alarm (visual, acoustic) from the ITS may divert the driver's attention from the real situation in the area.

If the vehicle is in the blind spot, there is no traffic accident in case we use cameras on the mirror and radar on the rear bumper or we have a system to detect forthcoming vehicle. Other systems are shown on fig. 6.

We also need to think about the impact of the ITS on health. As mentioned earlier, these systems operate using radars and sensors, which are built into different sides of the vehicle. We all know that devices for mutual communication use a particular energy and emit electromagnetic radiation, which may, in the long-term, affect user health.

With the hypothesis confirmed, we tried to demonstrate the impact of each ITS on the cause of each accident, hence also the system link with the final result of the road accident, and to what extent the system can help reduce fatal accidents as well as accidents with severe or minor injuries. We tried to confirm the hypothesis through research on the presence of the ITS on Slovenian roads and a visual model of integration of the ITS with the formation of road accidents. We established that for every cause of a road accident, there is a system that actively helps the driver, by warning or advising him. As we found out that the presence of these systems on Slovenian roads is extremely low, resulting in several road accidents, we may confirm our hypothesis.

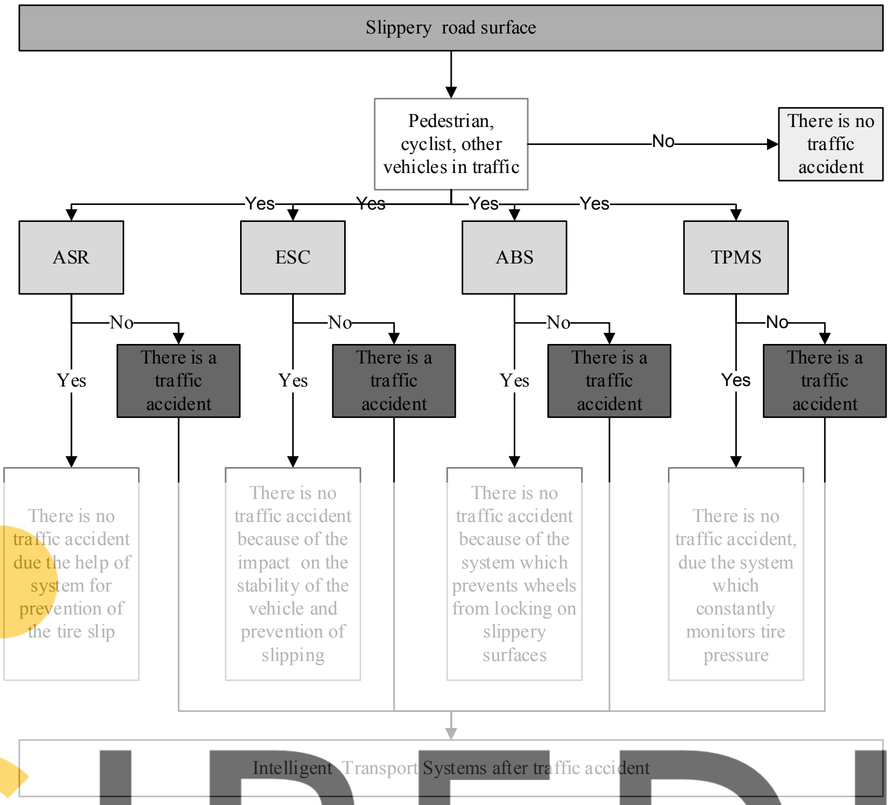

Fig. 4. Slippery road surface
Rys. 4. Śliska nawierzchnia drogi

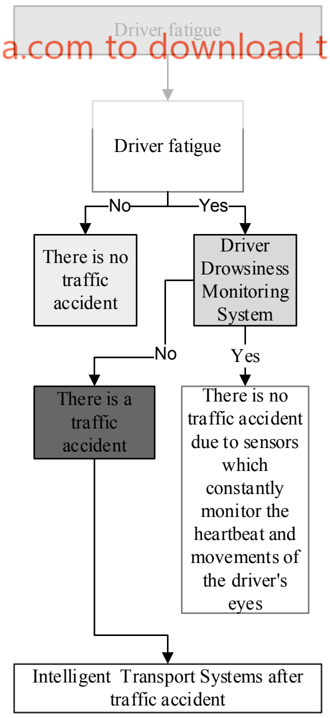

Fig. 5. Driver fatigue
Rys. 5. Zmęczenie kierowcy

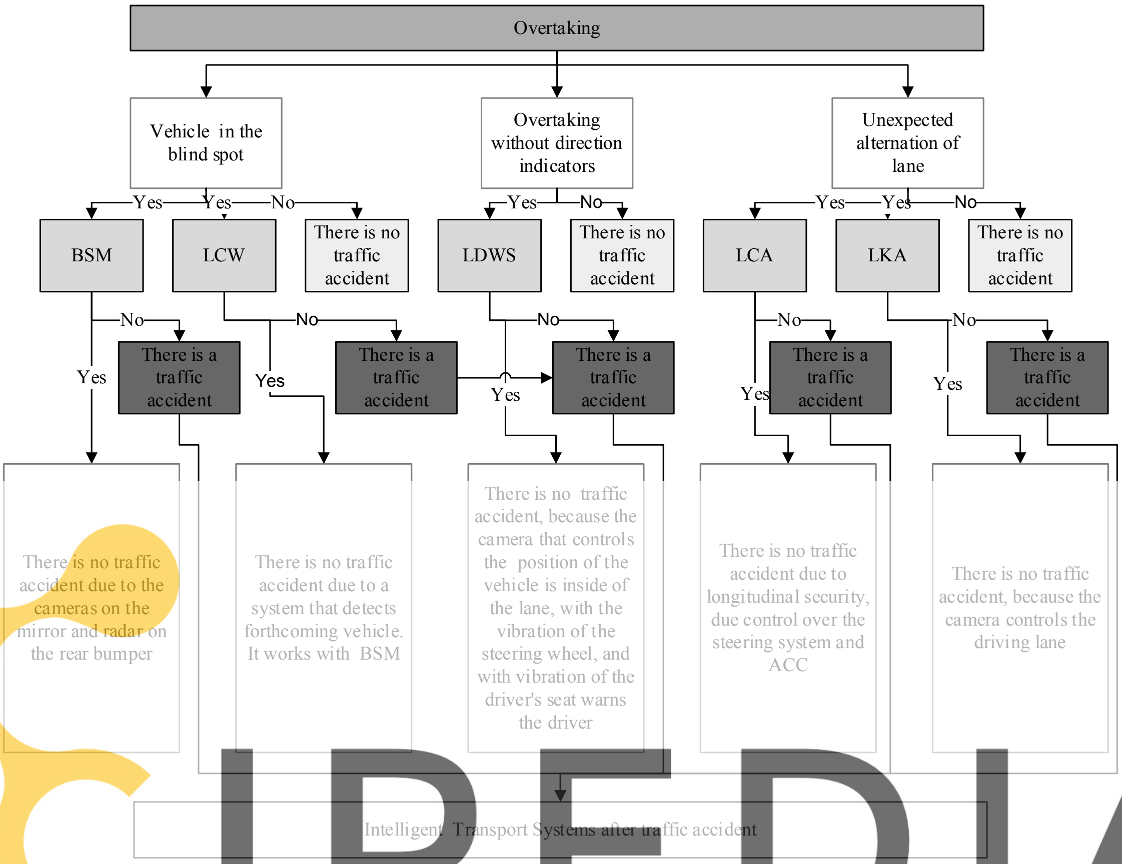

Fig. 6. Overtaking
Rys. 6. Wyprzedzanie

The presence of eCall System results in a faster response by emergency services and, consequently, a smaller risk of casualties.

This is only a small part of our paper research. The entire work is designed to learn more about EU measures, its projects, and the development of systems with which the EU hopes to meet its goal of Vision Zero. This research paper is for anyone who wants to get some basic information about intelligent systems and are interested in the actual availability of these systems in the Slovenian market.

List of Abbreviations

AIDE	Adaptive Integrated Driver-Vehicle Interface
ABS	Anti-lock Braking System
ACC	Adaptive Cruise Control
APROSYS	Advanced Protection Systems
ASR	Anti-slip regulation
BAS	Brake Assist System
BSM	Blind Spot Monitoring
COOPERS	Co-operative Systems for Intelligent Road Safety
CORDIS	Community Research and Development Information Service for Science, Research and Development
CVIS	Co-operative Vehicle-Infrastructure Systems
ESC	Electronic Stability Control
EU	European Union
EUCAR	European Council for Automotive R & D

ITS	Intelligent transportation system
LCA	Lane Change Assistant
LCW	Lane Change Warning
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assistant
PReVENT	Preventive and Active Safety Applications Integrated Project
RTSA	Road Traffic Safety Act
TPMS	Tire Presure Monitoring System

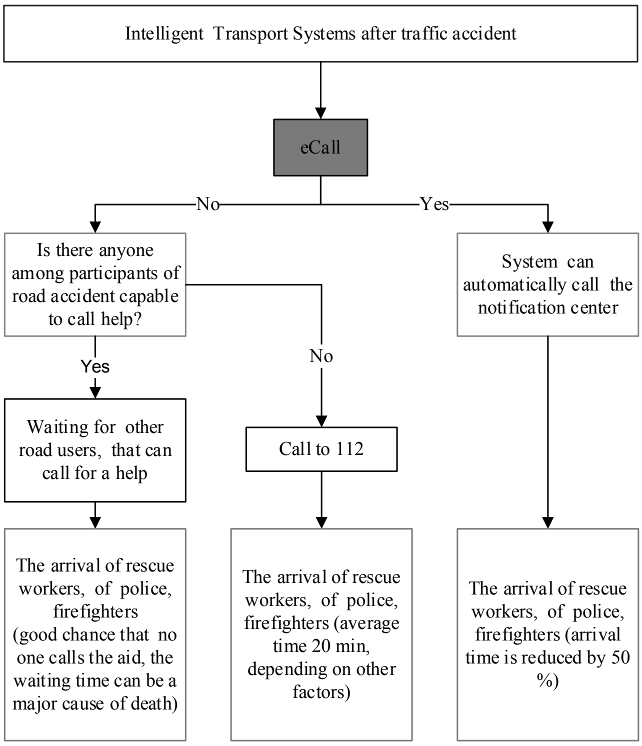

Fig. 7. A model of the road accident probability in dependence on the intelligent system
Rys. 7. Model prawdopodobieństwa wystąpienia wypadków drogowych w zależności od inteligentnego systemu

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