Intelligent Safety Vehicle Systems

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The aim of this paper is to introduce vehicle safety. Introduced will present intelligent vehicle safety systems, which are used in today's advanced intelligent vehicles. Progress in technology and information systems open up new possibilities in vehicle safety, which can reduce traffic accidents.

Słowa kluczowe: vehicle safety, active and passive safety, intelligent vehicle safety systems, intelligent vehicle, intelligent transport systems

Introduction

The most common cause of road accidents is the reduction in driver's attention due to fatigue or simply because the driver is devoted to other tasks such as tuning the radio, phone use and communication with traveling companions. Using qualified estimate it can be assumed that with the application of "intelligent" systems in vehicles, over 50% of human lives could be saved. In recent years the most attention was given to improving the passive safety of vehicles, making vehicles of today four times safer than they were in the 1970s [29,32,33].

Vehicle safety is also an element of competitiveness; therefore vehicle manufacturers are paying increased attention to this issue when developing new cars. The modern car is designed with particular emphasis to ensure a high level of safety of passengers and other road users. To ensure a high level of security, vehicles are fitted with systems that support certain conducting activities, and in some cases they can replace the driver, for example in a traffic accident the system could report the location of the vehicle and call for help (eCall). Progress in measurement techniques and information systems opened up new possibilities for automation of the vehicle control process. It is now technically possible to build fully automated vehicles, but the user problems arise from the technical difficulties that have arisen in the course of testing in urban conditions and also the applicable laws that fail to address the legal responsibility for driving intelligent vehicle without a driver and causing an accident [30,38].

1. Vehicle safety

When developing new vehicles i tis emphasized that the vehicle meets the safety requirements. These requirements are set by valid regulatory acts, but also by customers needs. In addition, vehicle manufacturers themselves are developing a variety of safety features that are intended to increase the safety of the vehicle [34,40,43]. The main purpose of vehicle safety is life and health of the vehicle crew, but also other road users (pedestrians, cyclists, other vehicles, etc.). In general, the goal is to minimize the likelihood of an accident and if this occurs, to ensure protection of health and life. To achieve this goal it is possible to apply different features that can be called safety of the vehicle.

The term safety of the vehicle means two basic categories of safety: active and passive safety.

2. Integrated intelligent safety systems

Development in vehicle safety focuses on linking of pre-existing systems, streamline their operations and lower their prices, which allows the application of these systems within the lower price categories of vehicles. Intelligent vehicle will also need support intelligent road network. The road network must be integrated with telematics applications; transport management systems and equipped with communication systems [36,35,44].

Categories of integrated safety systems:

1. Autonomous active safety systems;
   - o systems continuously supporting the activity of the driver;
   - o the systems active at the time of the expected impact;
2. Systems of active safety cooperating;
   - o with the other vehicles;
   - o with the infrastructure;
3. Systems active at the moment of impact;
4. Systems active after the crash - autonomous;
5. Systems active after the crash - cooperating.

Integrated intelligent safety systems are results of the evolution of the automotive industry and various technologies of competing vehicle manufacturers. Their deployment in vehicles is partly voluntary (competitive advantage in terms of security) and partly compulsory due to the legislation for vehicle type approval for operation in road traffic.

2.1 Autonomous active safety systems

The best way to reduce road accidents is to prevent them. Active safety systems can be classified in terms of function over time into continuously operating systems, and systems that act at the moment of potential danger (the chance of a traffic accident).

Active safety systems ensuring its continuous support for the driver are also called "driver assistance systems" also known as ADAS (Advanced Driver Assistance Systems) or DSS (Driver Support System) [39,42,41].

2.2 Systems continuously supporting the activity of the driver

The systems continuously supporting the activity of the driver should be able to adapt to the current situation anticipate needs and, if necessary, take the initiative. The systems continuously supporting the activity of the driver include the following technologies:

1. **Anti-lock braking system (ABS)** - Anti-lock brakes, preventing the wheels from locking during braking, allowing the driver to maintain control of the vehicle. Locked wheels cannot transmit lateral guidance forces. The control unit controls the ABS wheel-speed sensors through a number of revolutions of all-wheel vehicles. If there is a blockage of a single wheel, the solenoid valve will reduce the anti-skid control unit for brake pressure to that wheel until the same does not rotate freely. The pressure is then increased again to limit blocking. The vehicle retains stability and maneuverability. The driver feels the intervention of the anti-lock system, a light pulse in the brake pedal. On dry surfaces may slightly lengthen braking distances. Its main task is, especially on slippery road surfaces while at the same time enable the driver to brake and change direction of the vehicle.

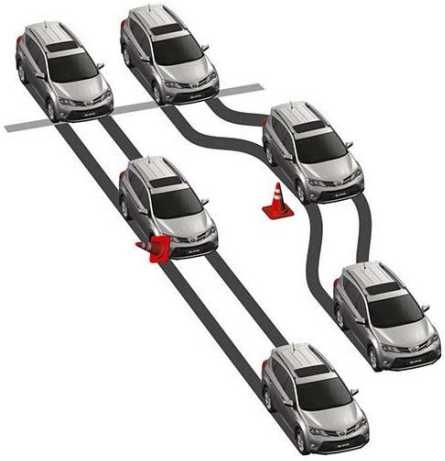

Fig. 1. *Anti-lock braking system (ABS)[24]*

2. **Anti-Slip Regulation system (ASR)** or **Traction Control System (TCR)** - prevents wheel spinning on slippery surface, changing direction on acceleration; Smarter systems are capable on one axle torque split, if one wheel is on a slippery surface and one on the hard disk.

Fig. 2. *Anti-Slip Regulation system (ASR) [20]*

3. **Electronic Stability Program (ESP)** or **Electronic Stability Control (ESC)** - Improves management control and automatically stabilizes the vehicle in all situations. Electronic Stability Program identifies critical situations and prevents the fact that the vehicle is deviating from the track. It should actively prevent uncontrolled skidding of the vehicle and assist the driver to stabilize the vehicle if it gets to skidding. It directly cooperates with ABS and ASR. It compares the behavior of the vehicle with calculated values. It checks the desired direction of travel based on the steering angle, the actual speed based on the wheel speed. Compares lateral acceleration and vehicle rotation around the vertical axis with calculated values. The vehicle may become unstable when cornering with excessive speed, or when the road surface unexpectedly changes (water, ice, pollution), or during an unexpected evasive maneuver. The controlling unit in Electronic Stability Program recognizes the kind of volatility based on data from sensors and intervenes in the engine management and brake control. When the vehicle understeer it's entering the bends by front wheels, while it's not turned enough. ESP targeted brakes at the rear wheel, on the inside of the bend and if necessary simultaneously reduces engine power. If the driver begins to brake, ESP also hits and reduces the braking force on the outside of the bend. We must emphasize that electronic stability program cannot overcome the boundaries of physical laws. If the driver overestimate the possibilities of chassis the Electronic Stability Program fails to prevent an accident.

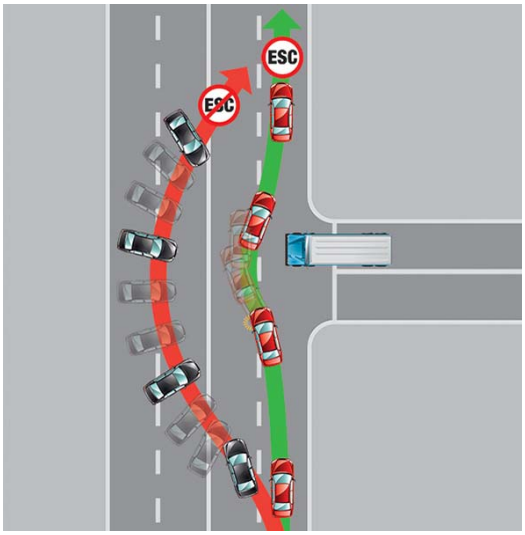

Fig. 3. *Electronic Stability Program (ESP) or Electronic Stability Control (ESC) [22]*

4. **Brake Assistant System (BAS)** - assistant braking action; in crisis situations and in cases where ABS regulates brake pressure, brake pedal may begin to vibrate, which can lead the driver to release the pedal to avert these vibrations, which however will reduce braking effectiveness. Brake Assist is activated in case of the critical braking. When the driver breaks suddenly, in most cases, will strongly hamper with some delays. BAS evaluate rapid responses by the driver and automatically define the will of the braking system and increases braking pressure in the system, thereby shortens the braking distance by up to 2 m. If the driver does not increase the pressure on the brake control system pressure in the system is released again.

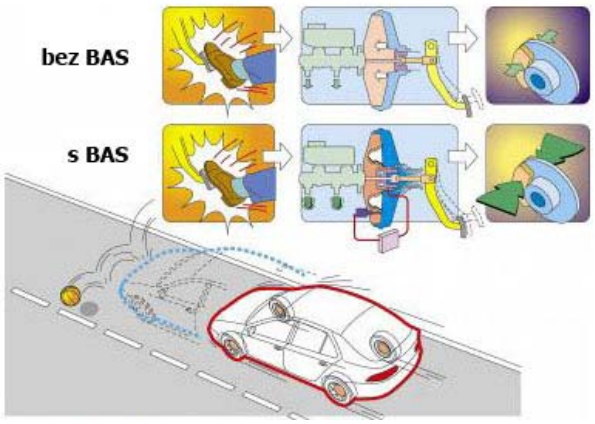

Fig. 4. *Brake Assistant System (BAS) [3]*

5. **Blind Spot Monitoring (BLIS)** or **Blind Spot Detection** – the blinds spot monitoring system is checking the blind spot on both sides of the vehicle, where the vehicle in the rear-view mirrors are difficult to see; so called blind spot, using audio and visual alerts for the driver when moving into an occupied lane; more modern systems are able to alert even of an rapidly approaching vehicle (from rear).

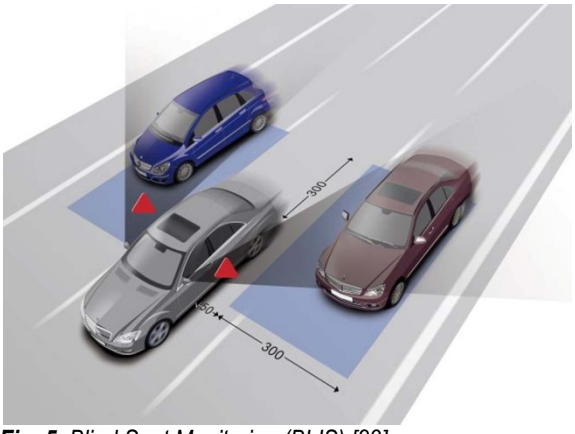

Fig. 5. *Blind Spot Monitoring (BLIS) [23]*

6. **Tyre pressure monitoring** - manufacturers offer different systems to monitor tire pressure, giving drivers early warning of loss of air pressure in the tyres; Most commonly these systems are ITS (Intelligent Tyre System), TPMS (Tyre Pressure Monitoring System) and DDS (Deflation Detection System)

ITS system directly measures the tyre pressure. It comprises a central receiver and four modules in the tires, which are not powered by the battery. The modules measure the actual pressure taking into account the tyre temperature. These data is wirelessly transmitted to the receiver. For the optimal protection against damage let's say during the installation, they are firmly attached to the tyre. The ITS allows the tyre to interact with electronic devices of the vehicle. Drivers have constant flow of information about all the tyres directly behind the steering wheel. In addition to information about pressure and temperature in the tyres, these modules can also transmit additional data on vehicle electronic devices. In this way, they are able to positively affect the maneuverability and ride comfort features. The temperature and pressure of the tyres is shown on the display dashboard.

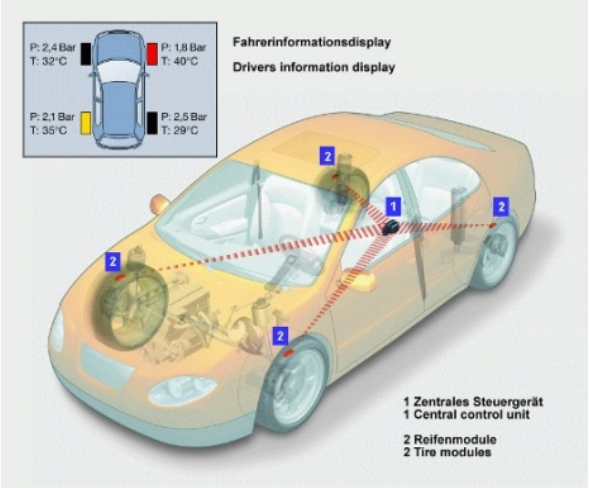

Fig. 6. *Intelligent Tyre System (ITS) [38]*

The TPMS directly measures tyre pressure. It consists of a main receiver (eg. Keyless entry controls) and four modules in the tyres, that are not powered by the battery. The modules measure the actual tyre pressure, taking into account the tyre temperature. Tyre position is determined automatically by the electronic braking system (EBS). The display on the dashboard warns the driver of an excessive drop in the tyre pressure. Integration into the EBS system allows for other useful functions - without the need for any additional sensors.

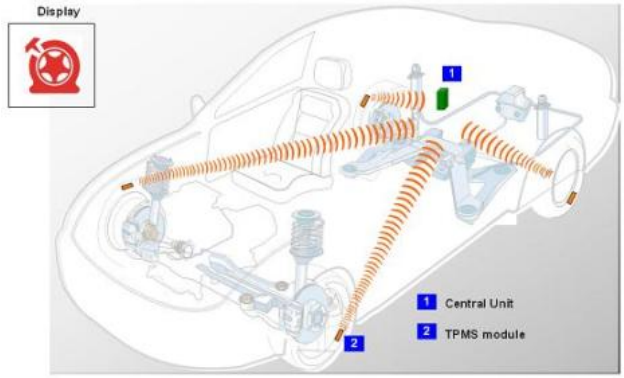

Fig. 7. *Tyre Pressure Monitoring System (TPMS) [38]*

DDS system indirectly measures the tyre pressure and immediately warns the driver if the tyre pressure falls below a specified threshold. Deflation Detection System is a 100% software solution that evaluates the data from the ABS wheel-speed sensor. It can operate without any sensors of its own. Any loss of pressure changes the radius of the tyre and leads to certain electronically detectable change in signal of the speed. The system warns the driver if the tyre pressure falls below a specified threshold.

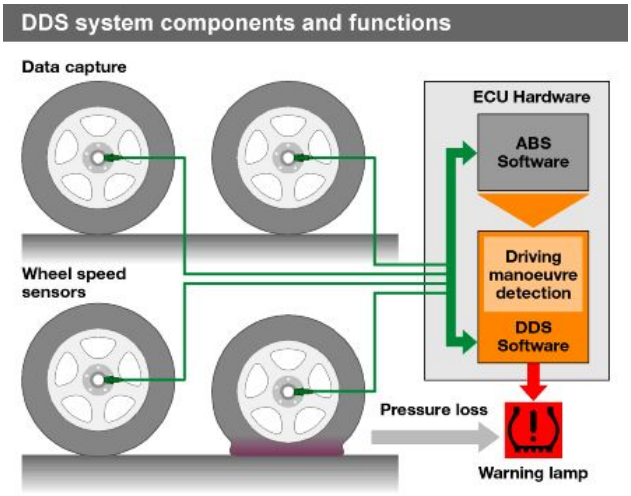

Fig. 8. *Deflation Detection System (DDS) [38]*

7. **Seat Belt Reminder (SBR)** - a system to warn the driver and passengers that seatbelts are not being used.

Fig. 9. *Seat Belt Reminder (SBR) [38]*

8. **Warning that the doors are not closed properly** - devices to warn the driver when the doors is not closed properly.

Fig. 10. *Warning that the doors are not closed properly [9]*

9. **Lane Departure Warning System (LDWS)** or **Lane Assistance (LA)** - system that control undesired Lane Departure Warning operates as a (light, sound, vibration, etc.) when moving from lane to lane without indicating (in the case of lack of attention.).

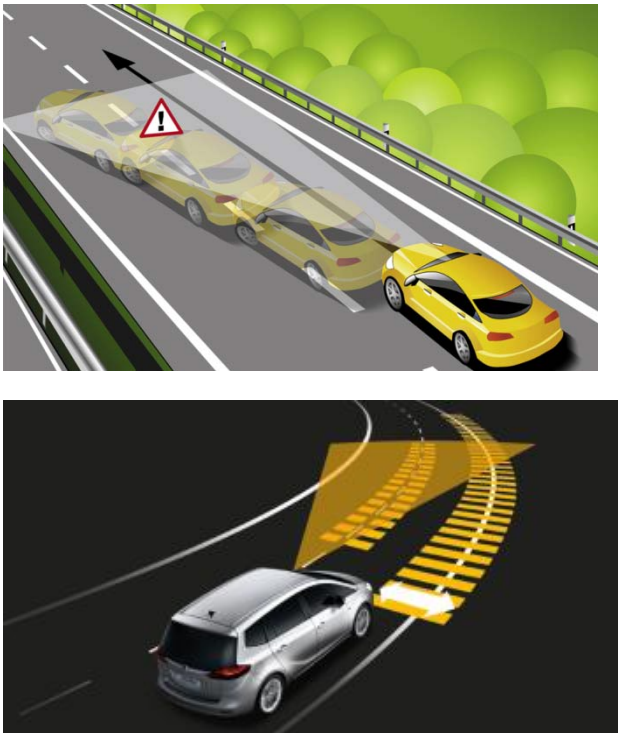

Fig. 11. *Lane Departure Warning System (LDWS) [16]*

10. **"Speed Alert"** or **"Speed Eye"** - a system containing a special camera that recognizes traffic signs with speed limits and traffic signs prohibiting overtaking and displays them on the dashboard.

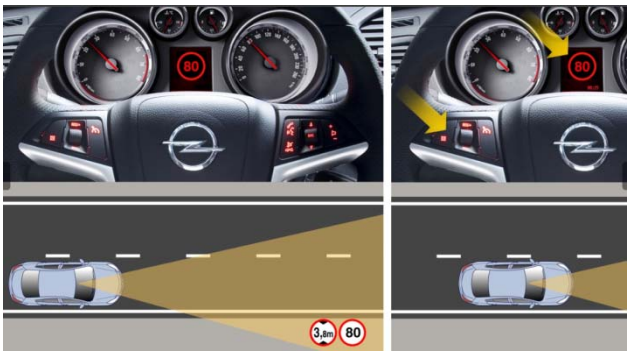

Fig. 12. *Speed Alert [13]*

11. **Intelligent Speed Adaptation (ISA)** - the system can operate in three different ways that differ in the intensity how they affect the speed; first and least invasive way is a sound or video alert that warns the driver that he had exceeded the speed limit; the second level is to create resistance against the accelerator (if the system detects that the car goes faster than if should, it will create a pedal pressure). The system relies on the fact that people will not want to push and simply change the speed regulation; the last most aggressive way is the automatic speed reduction by the system.

Fig. 13. *Intelligent Speed Adaptation (ISA) [21]*

12. **Adaptive Cruise Control (ACC)** - in addition to the main task (to maintain a chosen speed) it monitors the space in front of the car and adjusts the speed to traffic ahead; advanced systems in combination with the automatic transmission are capable when entering into city traffic smoothly stop and restart while maintaining the selected distance from the vehicle in the front. The system uses the radar, infrared spectrum, visible spectrum, and ultrasound. ACC also contains the emergency braking system, which prepares the brake system for more efficient braking if necessary. The safe distance detector monitors the distance from the vehicle ahead, and if one gets too close, it warns with an acoustic a light signal.

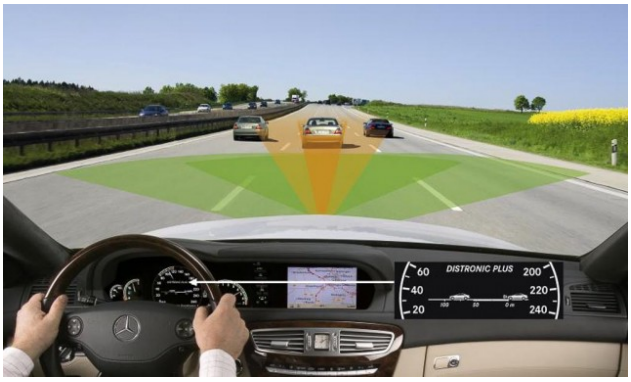

Fig. 14. *Adaptive Cruise Control (ACC) [19]*

13. **City Safety** - in city traffic at speed up to 30 km/h system will automatically stop the vehicle when the vehicle driver fails to react to slowing or stopping of the vehicle ahead, or when the vehicle approaches a fixed obstacle.

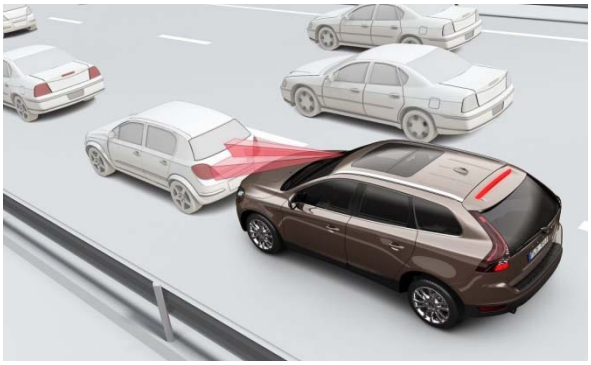

Fig. 15. *City Safety [14]*

14. **Advanced Emergency Braking Systems (AEBS)** - the system warns the driver using visual and audible signals when it is approaching an obstacle. If the driver does not respond (or does not respond adequately) the system is able to automatically activate the brakes and safely stop the car before colliding with the obstacle.

Fig. 16. *Advanced Emergency Braking Systems (AEBS) [18]*

15. **Collision Avoidance System (CAS)** - a system using radar to detect imminent collisions; once the collision is detected, the system gives the driver warning and in case of a collision without immediate action by the driver performs braking or steering; the system uses the same sensors as Adaptive Cruise Control (ACC).

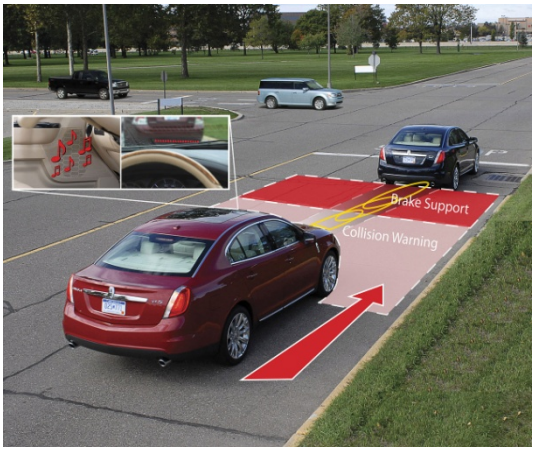

Fig. 17. *Collision Avoidance System (CAS) [6]*

Some automakers warn of the event of a rear impact. Imminent collision activates the rear warning light signal with increased frequency and this increased frequency attracts the attention vehicles behind. In case of persistent risk of collision the passengers protection measures are activated in the vehicle - among others, the automatic tightening of the seat belts. If the vehicle during a dangerous situation stands, immediately before the impact, the system brakes, which reduces the ejection of the vehicle forward and significantly reduces the risk of whiplash of the passengers. The immobilization of the vehicle can furthermore prevent the occurrence of secondary accidents such as hitting the car in front of you, in the case of a vehicle in the intersection; colliding with the car coming from the opposite direction but also with pedestrians who are just crossing the road.

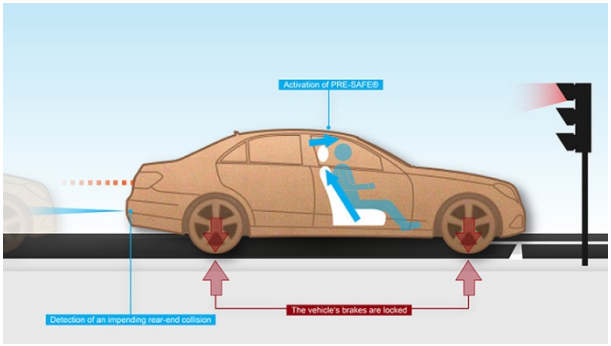

Fig. 18. *Collision Avoidance System from rear [10]*

16. **Heads-Up Display (HUD)** – displaying the data relevant to the driver in the driver's field of vision.

Fig. 19. *Heads-Up Display (HUD) [1]*

17. **Adaptive Headlights (AHL)** - automatically set up headlights to provide good illumination of the road in all conditions for when entering curves and cornering at a tight angle.

Fig. 20. *Adaptive Headlights (AHL) [15]*

18. **Driver Monitoring System** (**DMS)** or Driver Alert Control (DAC) - system analyzes the driver's attention based on his behavior. A tired driver often corrects the direction of travel, has a sudden reaction and his eyes will stop moving when searching for information on the traffic situation. Based on the direction correction, the suddenness of motion and the eye movement, the system can recognize driver's fatigue and warn him of the need for break.

Fig. 21. *Driver Monitoring System (DMS) [12]*

19. **Route Guidance or Navigation Systems** - systems using maps, arrows and voice interfaces to help the driver to get to his destination.

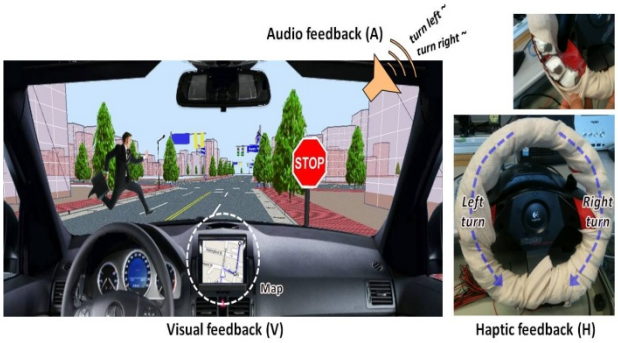

Fig. 22. *Route Guidance and Navigation [11]*

20. **Vision Enhancement** - uses infrared light that the human eye does not perceive, and so it does not blind oncoming traffic; the system allows to identify pedestrians, cyclists, parked cars and other obstacles along the way much faster. There is an integrated infrared camera in the windscreen that records the image of the road ahead and transmits it to the display. Some vehicle manufacturers offer systems, which thanks to infrared light on dashboard display the night road scene as illuminated and marks identified person; optional spot light flashes to pedestrians at the roadside.

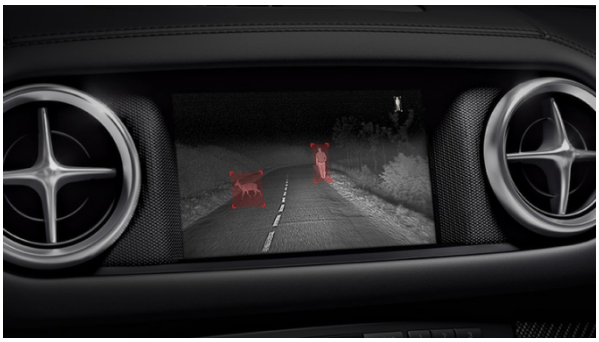

Fig. 23. *Vision Enhancement [9]*

21. **Alcohol interlocks** - a device for blocking the vehicle's engine in case of a positive breath test for alcohol via a device installed in the vehicle.

Fig. 24. *Alcohol interlocks [25]*

2.3 Systems active at the time of the expected impact

In case of imminent threat of a traffic accident smart vehicle will

- alert the driver mechanically (light vibration of the steering wheel or seat) or visually;
- activate the braking system (adjusts the brake elements into working position);
- tighten the seat belts, to shorten the time for the 'stretcher' during the possible impact;
- anchoring electrically operated seats in the optimum position in terms of security;
- in the event of a unavoidable collision activate automatic vehicle braking system.

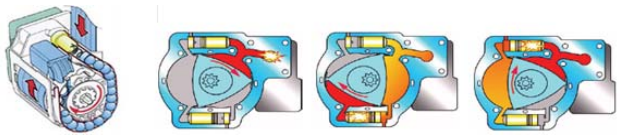

Fig. 25. *Tighten the seat belts [5]*

2.4 Active cooperating safety systems

Systems that cooperate between vehicles are referred to as Car2Car. The vehicles that are within range of each other form an ad hoc network in which they let each other know their position, speed and direction. The Car2Car allows other vehicles to provide warnings and information.

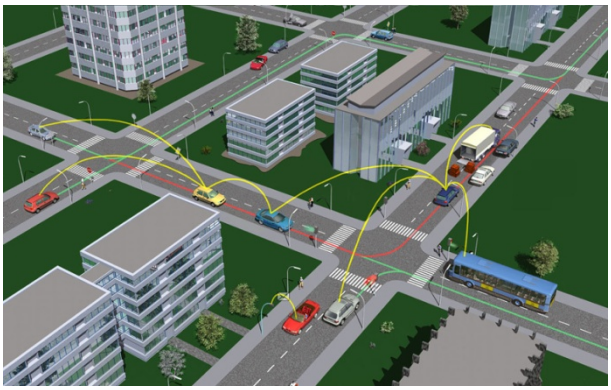

Fig. 26. *Car2Car [27]*

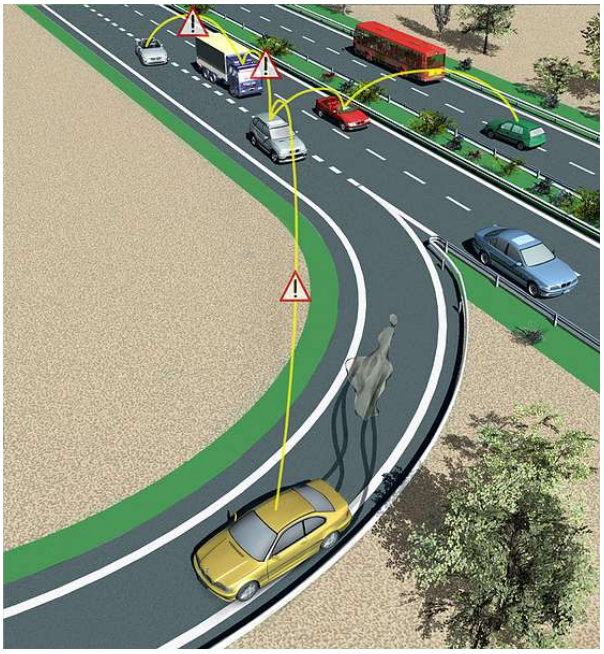

Fig. 27. *Providing warnings for other vehicles of the risks through the system Car2Car [28]*

2.5 Systems cooperating with infrastructure

Systems cooperating with infrastructure are referred to as Car2Infrastructur. This technology encompasses any technology between the vehicles and any stationary communication equipment (stationary in terms of time of static), which means that to this group also belongs and the vehicle communication with portable traffic signs or warning device.

Fig. 28. *Warnings for drivers of vehicles about changes in traffic through the system Car2Infrastructur [26]*

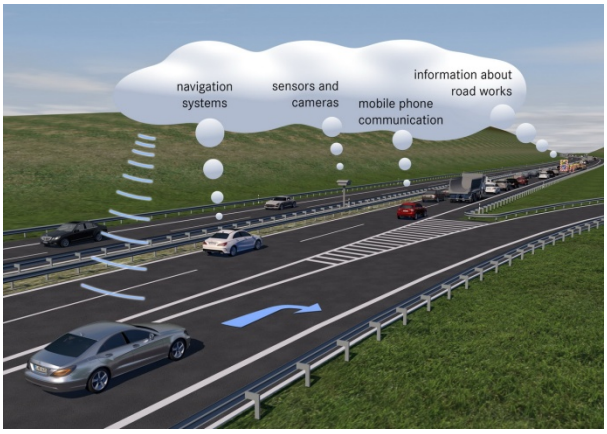

Fig.29. *System cooperation between vehicles and infrastructure [7]*

2.6 Systems active at the moment of impact

Amongst the active systems at the moment of impact are mainly passive safety systems of the vehicle, namely: belt tensioners; driver's airbag; passenger's airbag; side airbags for the front seats; front and side airbags for the rear seats; roof airbags; active head supports; active bonnet that protects vulnerable road users.

Fig. 30. *Airbags system [17]*

Fig. 31. *Active bonnet that protects vulnerable road users [8]*

2.7 Systems active after the crash - autonomous

Autonomous impingement systems are tasked to protect the crew against any future threats. The most commonly applied autonomous vehicle operations are: disconnection of the fuel

supply; unlocking of the vehicle; disconnection of the battery; launch of the warning lights.

2.8 Systems active after the crash - autonomous

Amongst the after crash actively cooperating systems belongs the automatic reporting system for emergencies. At present, some vehicle manufacturers offer such a system, that in case of emergency could contact the call center of the vehicle manufacturer with information about the place of the accident, the number of people carried, the intensity of the impact, what direction was the shock held, the amount of used airbags, the way the seat belts were being used, information on rollover and other details.

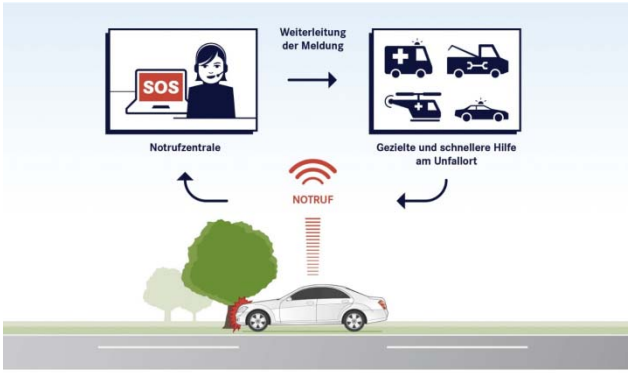

Fig. 32. *System of automatic notification of emergencies to Mercedes-Benz's call center [2]*

Given that vehicles should not contact the call centers of the vehicle manufacturers, but directly emergency services, ensuring faster help, the installation of on-board feature known as eCall will be compulsory. It is expected to shorten the response times of emergency services, which should lead to reduction of the number of car accidents related deaths in the European Union, as well as the severity of injuries caused by car accidents. An interoperable eCall service across the European Union should also bring savings to society by improving the incident management and reducing congestion and the number of secondary accidents.

Fig. 34. *eCall system [4]*

4. Conclusion

Currently, vehicles are packed with smart technology solutions for active safety, which should avoid the risks associated with driving. Improving the control of the vehicle in different driving situations, increasing the safety and passenger comfort, facilitating of communication and controlling the situation on the road. The active lighting systems provide better visibility for the driver and a faster reaction to emerging obstacles along the way. These vehicles are equipped with a large number of sensors, receivers, actuators and control units whose task is to coordinate cooperation of all electronic and mechanical components of the vehicle and to communicate between other road users.

Safe and intelligent vehicles characteristic not only by innovative energy sources for propulsion, but also the ability to interact with intelligent infrastructures.

The main advantages of moving vehicles in automatic mode are:

- road safety;
- lower fuel consumption;
- improves traffic flow due to the communication between vehicles;
- reduction of congestion in urban areas.

The big challenge for intelligent transport systems is to reduce the dangerous human behavior on the road. This relates to the decision of the driver (respecting traffic laws and safe driving) and the behavior of other road users.

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