Road Traffic Efficiency and Safety Improvements Trends

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Keywords: Unmanned Vehicle, Traffic Management, Human Factor, Traffic Regulations, Reducing Accidents, Driver Aids, Crash Avoidance, Driver Assistance, Vehicle Safety Systems.

Abstract: Given article covers the next few problems: safety in highway traffic management; electronic assistance in conventional transportation; cooperative movement of conventional vehicles and driverless cars; some of the unmanned vehicle technologies.

1 INTRODUCTION

Road traffic efficiency and safety remains an actual task of the automotive industry and road services. The challenge of reducing the costs of transportation, decreasing negative environmental impact of the roads, minimizing road accidents, developing network of customer care and support services are closely related. These issues get comprehensive solutions provided by vehicle manufacturing companies, by state and regional road traffic organizations and regulation bodies. Traditionally, vehicle manufacturing companies test their models using criteria such as: adult passengers' safety protection, children passengers' safety protection, safety protection of pedestrians and availability of the safety systems in the car. Rating of each car model shows how successfully certain technical solutions incorporated into a design of a car have manifested themselves.

Modern automobile technologies offer two pathways to achieve the main goal – efficient and safe driving conditions. The first way offers driver assistance facilities, while the other proposes elimination of the "human factor" in context of driving functions by replacing him with robot.

1.1 Crash Avoidance and Driver Assistance Systems

The primary target for creating this class of electronics and automatics is to help driver to make right decision in difficult road situations, warn him about possible appearance of such incidents and also eliminate some of the weak points like human reaction time, concentration and attention. Described below are some of the driver's aids with few valuable additions.

1.2 Blind Spots Monitoring System

If there is a faster car approaching from behind and at some point it gets into blind spot to the left or right behind the vehicle, a warning light starts twinkle in the external mirror. The first to introduce a similar electronics in their cars was Volvo company and now it is put on cars of different brands. But Mazda has been able to develop the idea. First, the system is not only able to engage the warning lights in the side mirrors when there is a car in the blind spot, but also to predict the behavior of vehicles approaching from behind. Computer monitors the area of 50 m behind the car and if the faster car approaches, the indicator lights up 5 seconds before the latter will appear in dangerous proximity. Secondly, electronic assistant starts beeping when the driver engaged the turn signal when there's another car close enough on the adjacent lane (Mazda.com, 2013).

Today, only onboard computing resources and sensors are used within technology, but its abilities can be significantly extended after integration with positioning system and communication modules. In a automotive mesh network vehicles could exchange data about obstacles in blind spots of each other, thus improving safety of road maneuvers in very difficult traffic conditions.

Glazunov V., Kurochkin L., Kurochkin M., Popov S. and Timofeev D..
Road Traffic Efficiency and Safety Improvements Trends.
DOI: 10.5220/0004589504390446
In *Proceedings of the 10th International Conference on Informatics in Control, Automation and Robotics* (ICINCO-2013), pages 439-446
ISBN: 978-989-8565-71-6

1.3 Night Vision Camera

Such equipment is often found on the German car models, although the first to implement this kind of technology was Cadillac. 2000 DeVille was first production car equipped with the infrared night-vision camera. Picture is transmitted to the display in the dashboard and additional information and icons are projected on the windshield. The fact is that the original image coming from an infrared camera is quite specific and difficult to perceive by human eyes. Therefore, Audi engineers decided to use a special unit that processes image in their vehicles. It paints an image so that the driver could clearly distinguish important information such as pedestrians which are sometimes visible only at the last moment before accident. Most interesting is that night vision systems are able to distinguish between people on the sidelines (not dangerous) and emphasizes those who come to the roadway. People on the road are shown in red as opposed to "safe" green pedestrians at the roadside. The system is able to recognize people from a distance of up to 100 m. Moreover, the camera adjusts to the lighting conditions and the processor ensures that other warm objects (street lights, car headlights) do not "pollute" the picture with excessive light (Audi.com, 2013).

Adding communicative abilities to such system will drastically improve pedestrian safety at night by sending coordinates and speed of the obstacles from one car to others in range so that their drivers know about possible danger in advance.

1.4 Traffic Sign Detection

Traffic sign recognition is a driver support function which can be used to notify and warn the driver which restrictions may be effective on the current stretch of road. Examples for such regulations are speed limit zones or "no-overtaking" indications. The system can help the driver to maintain a legal speed, obey local traffic instructions, or urban restrictions. It is also able to recognize country specific signs.

One of the developers of such technology is Mobileye, whose system is available from 2008 on the BMW 7-series. The system uses camera-based object recognition and can be developed to compare the data with those coming from digital maps of a navigation system and traffic services. This will offer additional system robustness, especially in cases where the vision system cannot provide the needed information, such entering urban areas which are not marked by traffic signs. With a VGA resolution imager the system can provide reliable detection for targets with a lateral distance of 10 m, a vertical distance of 7 m and at vehicle speeds of up to 250kph. This provides the current system with a very high performance even in challenging high speed situations on multi lane highways. As high resolution sensors become available for automotive use, there will be abilities to increase the effective detection range, as well as detecting more “context” and iconic information (Mobileye.com, 2013).

1.5 Lane-Keeping System

Even some reasonably priced cars like Opel Astra and Ford Focus have already received equipment which monitors the road marking and control the car so that it is always kept in its lane. Usually, system scans the road with a video camera at the top of the windshield but then different brands of this feature work a bit different. Infiniti’s electronics begins to slow down left or right wheel slightly to steer the car to the center of the lane. Ford uses electric power-steering mechanism; furthermore if the car is going out of lane without enabling turn signals, the steering wheel vibrate. All manufacturers of the system at the same time give the warning sounds and light the corresponding icon on the dashboard (Media.ford.com, 2013).

System can be enhanced with usage of communication capabilities and navigation functions. When installed on a large amount of cars, lane-keeping system can collect data about road marking and send it bundled with geographic coordinates and timestamps to a dedicated cloud service. This allows creating very detailed lane-based road maps in a brief time. Maps will be updated automatically using data collected from vehicle on a daily or weekly basis.

1.6 Automatic Emergency Braking

Automatic braking is a car technology that “senses” an imminent collision with another vehicle, person or obstacle and responds by applying the brakes to slow down the vehicle without any driver participation. One of the currently available in production cars is Mercedes-Benz' Pre-Safe Brake system. It constantly monitors the area in front of the car and activates warning sound and light signals for the driver if the distance to the obstacle ahead shrinks so fast, that according to the computer’s calculations a collision will occur in 2.6 sec. If at this point the driver starts braking, but according to the calculations slowing down isn't enough, then it will automatically increase the braking force. If the driver doesn't use brakes at all, then brakes will be applied automatically at the time of 1.6 seconds before the collision. Initially, electronics doesn't use brakes at 100% of braking force, giving the driver an opportunity to decide to drive around obstacles. But in 0.6 seconds before impact the brakes will automatically go to the maximum (Euroncap.com, 2010).

Using such systems to prevent crashes is problematic, so practical systems are often snap into action only to reduce crash speed in some situations.

Sensors used to detect other vehicles or obstacles can include radar, video, infrared, ultrasonic or other technologies. GPS sensors can detect fixed dangers such as approaching stop signs through a location database. Such GPS-assisted system was announced by Toyota (Mydigitallife.info, 2008).

1.7 Adaptive Cruise Control

This system is also known as Active cruise control. It automatically adjusts the speed of the car to keep safe distance behind the lead vehicle. The system uses laser or radar to measure the distance to the next car, it then relies on basic cruise control features to accelerate or slow down the vehicle according to changing gap between the cars. Adaptive cruise control often includes a pre-crash system, which warns the driver and provides brake support if there is a high risk of collision (Media.ford.com, 2012).

System can also be improved with communication abilities and navigation services integration for retrieving actual traffic information, such as average speed on specific roads. Automotive mesh network can be used to "tell" the following car about maneuvers and speed changes on leading car. Such systems are used in cars equipped with autonomous driving systems.

1.8 Early Collision Preparation

Unfortunately, if the "electronic intelligence" has realized that a collision is unavoidable it can't do very much. In the last moments before crash seat belts are tightened, seat bolsters are tightly wrapped around the body (unless of course they are adjustable), windows and sunroof are closed and if there is a sliding monitor then it will be folded. To some extent, these functions are now available in the different car maker's vehicles.

Again, one of the most advanced technology of the time is Mercedes-Benz' Pre-Safe system. Equipment of the latest generation, which was for example the current E-Class, can even adjust the front head restraints and cause rear seats to move to the upright position because it reduces the risk of sliding under the seat belt. Moreover, electronics differently prepares for different types of accidents. That is, for example, if there is a risk of a flip-over, the windows and sunroof will be closed and in other cases they will remain open. In that case it will be easier to evacuate the victims. All of the actions taken by Pre-Safe are reversible: if the collision is avoided, tension is removed from the seat belts and the occupants can readjust their seats (Autoevolution.com, 2011).

1.9 Emergency Call

In case of a serious accident people's life may depend on delay between the crash and emergency call. Medical assistance or fire brigade should arrive to the required site as soon as possible. Electronic assistant can instantly send SMS with the geographic coordinates of the accident, the data on the impact force (the nature of an accident and risk to humans can be roughly determined by the activated airbags), and the number of passengers. It also turns on the speaker phone when connected with emergency service operator. Call comes not to an ambulance or the police, but on the vehicle brand's own call center. Experts will decide how to act according to information they received from on-board systems (Ford.co.uk, 2012).

Some of the above-considered systems and technologies are already available on production cars; others are on their way to commercial realization. Most of the reviewed systems were developed independently and by many different equipment manufacturers. Therefore, there is no standardization in protocols and interfaces used and allowed by these products. One of the very important tasks is integration of all of the onboard computing resources and technologies into a dedicated redundant computer with standard interfaces, protocols and communication capabilities. All of its functions could be programmed in software using high-level programming languages and almost unlimited set of peripheral devices (sensors, cameras, communication modules, etc.), which could be plugged-in or upgraded to add new features and improve system performance and reliability. This should be done on a basis of open standards, which allows any manufacturer to create its own solutions and ensures equal access for all participants, such as car makers, device manufacturers, software developers, regulatory authority, etc.

2 AUTONOMOUS CARS OR PERSONAL AUTOMATED VEHICLES

The design of unmanned vehicles equipped with sensors and the necessary software should be considered as a new way to increase safety. The work in this direction is conducted by the major companies such as Audi, Nissan, Toyota, Lexus, Mercedes, Google, VOLVO and some others. The most obvious advantages of unmanned vehicles is increasing safety of vehicles and pedestrians. The vast majority of the road accidents are caused by human factors: fatigue, inattention, distracting affairs, ignorance of the road traffic rules, slow reaction, lack of the car driving experience in emergency situations, lack of information of the road conditions, and more (Census.gov, 2012).

The modern concept of an unmanned vehicle envisages equipment of a vehicle by a sensor system, technical facilities management units and AI software.

The hardware and software system allows to get the real time detailed model of a vehicle in motion surrounding area, location of neighboring vehicles and obstacles, presence of pedestrians, details of the road markings, traffic lights and overall road traffic characteristics. This data is further used to estimate the traffic situation and to develop the controlling signals on the vehicle aggregates (Robots.ox.ac.uk, 2012).

2.1 Advantages

Safety. Google developers claim that an autonomous car driving system is able to process a lot more information and to make decisions much faster than a human driver can, by thus effectively protecting passengers from road accidents. Besides that, thanks to a high-sensitivity sensors, a car will be able to "see" the objects in the dark (walking on the sides of the road pedestrians or running across the road animals) that are inaccessible to the human eye, and to timely react on the road situation, slowing the car speed down to the full stop (En.wikipedia.org, 2013).

Precise Compliance to the Traffic Rules. Unlike the usual driver, unmanned vehicle will never make a deliberate violation of the traffic rules. If a computer system will treat the traffic situation as potentially dangerous, it will take preventives measures to avoid possible accidents, starting from choosing the most optimal driving route up to a full stop. In addition, broad usage of unmanned vehicles will decrease traffic jams caused by drivers.

Comfort. The owner of an unmanned vehicle may forget about such problems as searching for a parking space - standalone car driving system will find a free parking space in the final destination and will park a car independently. Equipped by an accurate information about the traffic in a given point of the route, a "drone" will see in advance a traffic jam, will evaluate its scope and will choose an alternative route if needed.

2.2 Limitations

Reducing the posItioning Precision with Worsening Weather Conditions. Changing weather conditions affect the state/environment characteristics, laser and radio signals, and have a detrimental effect on the accuracy of radar systems and sensors used to provide active safety systems for manned vehicles, as well as unmanned ones, in particular the ones designed by Google. The reflecting ability of other objects is also affected by the changing weather conditions reducing working accuracy of active safety systems. Inaccurate estimation of the road surface - icy or wet impedes a proper automatic selection of the most suitable mode of transmission and suspension systems settings.

Road Traffic Outside the Highways. The lion's share of testing of unmanned vehicles is conducted in megacities and on highways having high quality road surface, road markings lines and lighting devices. Research in automation of a car moving over a rough terrain are getting active today, for example, Google has recently announced of inclusion of SUV Lexus in their unmanned vehicles test park.

Legal Questions. To date, the existing legislation systems of several developed countries do not contain provisions for determining the persons responsible for the accidents with unmanned vehicles. This situation is seriously slowing down the process of deploying and testing unmanned vehicles in the real world traffic conditions (Greencarcongress.com, 2011).

Accuracy of Electronic Maps. At the heart of an unmanned car controlling system, for example the one from Google are laying electronic maps with panoramic objects views. The absence of such maps, or having them out of date including the maps being not in accordance with the season of year is a serious barrier to the usage of unmanned vehicles.

Cost of the Test Sample. To date, the cost of the test sample of Google unmanned vehicle is more than 150 thousand dollars. The main cost (about 70,000 dollars) constitutes the usage of an optical sensor LIDAR.

Dependence on a Navigation Signal Quality. Usage of GPS or GLONASS systems to position unmanned vehicles causes difficulties while operating in tunnels, canyons and in other places having unstable level of GPS or GLONASS signals coverage.

In the dispute between the supporters and the opponents of unmanned vehicles the formers' position is more preferred because standalone machine scans the surrounding area over a very large radius (60-80 meters) and therefore the amount of data, which is taken into account to make solutions is much larger. This is a human-driver who might miss a child suddenly popping-up on the road. This is a human-driver who might linger and get scared. This is a human-driver who would have at least 0.5 seconds reaction to a sudden obstacle on the road. This is a human-driver who regularly exceeds the traffic speed.

A computer system does not have all the mentioned above disadvantages, in a fraction of a second and for many tens of meters, it will notice the people running to or crossing the road, or standing on the sidelines, and it will instantly make an optimal decision. An autopilot will timely detect a pedestrian moving quickly enough to get under the car wheels, and then that autopilot will slow down its car to predict the movement of this pedestrian and to eventually eliminate accident.

If there are any objects on the road sidelines hindering the view, an autopilot will slow down up to a full stop to ensure there are no pedestrians where they can appear provoking accidents.

An autopilot will react faster than a human in the case of emergency and will handle the situation using an optimal program. If an accident does occur its consequences will be less severe. The car's computer will immediately notify emergency services. Images from the cameras will instantly get transferred on board and into the ambulance. All these actions will reduce the time and will increase the chances of the injured people. The computer will record all the telemetry, and that records will simplify the legal disputes.

Even if an accident would be caused by a fault of a computer system the odds according to the overall statistics are that such an accident would happen 10 times less frequently than when a car would be driven by a human.

In the same time, the running nowadays polemics of supporters and opponents of unmanned cars is based on an objective contradiction, originating from the fact that we are currently trying to combine an informal system of movement of vehicles with a formal one. The dominant of the former system is a person (a car driver) while the dominant of the latter is an unmanned vehicle system (actually a robot). The person is weakly formalizable object, and the robot is a machine, though endowed with some traits of "intelligence". Simultaneous participation of such diverse entities in highways traffic does designate the difficulties that the road traffic regulation organizations are trying to resolve.

From the objective contradiction, we have outlined above, follows the technical problem associated with the collection of the road traffic data. Currently, the entire set of technical systems displaying information about a road situation focuses on humans' perception, their senses and their ways of information gathering and processing. The cars sensors capabilities could in some respects be better, and in other respects - worse than the ones of humans. In addition, humans always use their experience and intuition, their ability to foresee the situation, to analyze the behavior of the other participants of the road traffic.

It is easy to assume that a cooperative satisfaction of the requirements of the two systems will lead to an increase of complexity of the traffic control systems and to the growth of negative ratings of the practical usage of unmanned vehicles (first of all by the undisciplined drivers).

The objective contradiction is possible to be resolved in two ways:

1. Developing regulations on driving unmanned vehicles on dedicated lines or highways only: in this case a new model of the road traffic control is created, new requirements for the operational information gathering systems is developed, new protocols of communication between vehicles and maintenance services and a set of documents determining legal responsibilities of the road traffic participants and regulators are elaborated. Detailed development and implementation of this option will solve the main problems of the road transportation organization - reducing accidents, reducing costs, improving the environment.
2. The organization of the group traffic of unmanned vehicles with one or more driver-instructors: in this case the road traffic rules have to be revised considering particular properties of

the group traffic of vehicles (crossing intersections, parking, stopping, maneuvering and other actions). This is a variant when the road traffic is carried out on the existing roads network, but the responsibility for the group movement of vehicles is assigned to the driver-instructors.

Nowadays, an example of the implementation of the second model is a project Sartr led by Ricardo UK Ltd. This project involves collaboration of the participating companies: IDIADA and Robotiker-Tecnalia of Spain, Institut for Kraftfahrwesen Aachen (IKA) of Germany, SP Technical Research Institute of Sweden, Volvo Car Corporation and Volvo Technology Sweden (green.autoblog.com, 2012).

The project aims to create a new model of personal transportation by organizing environmental auto-trains.

The new system will facilitate the safe movement of auto-trains on the UN-modified public roads in the close interaction with other participants of the road traffic.

The proposed scheme provides controlling functions and responsibility for an auto-train movement for a professional driver who is driving the leading car. The rest of the vehicles of an auto-train are moving in a semi-autonomous control mode, allowing the drivers of these vehicles to keep less driving control than usual, and to use their mobiles, to read the books, to watch the videos, to eat - to perform the actions that would normally be disabled in an usual driving mode for personal safety reasons (Sartre-project.eu, 2012).

However, the problem of the slave cars drivers' involvement in the decision-making process in the emergency cases is remaining unsolved. Usually, a driver reaction time is 0.3-0.7 seconds. If you are driving a car in a semi-automatic mode, the reaction time will lay in a substantially larger range. A driver, being in the middle of a road auto-train, would be unable to act autonomously, so the classic method of continuous inclusion of an operator in the management of an object with operator's dosed workload does not solve the problem.

It must be also noted that the proposed option should be considered as an intermediate and compromise, because of the fact that it leaves unresolved the issue of interaction on the road of a human and a robot. Besides of that, the cost of an unmanned vehicle is significantly higher than the cost of a traditional one, primarily due to the more complex devices that detect presence and behavior of humans on the road. (There is no way to use formal models and communication protocols of machines on the road).

2.3 Underlying Communication and Network Technologies

To ensure interoperability between different wireless technologies the use of concordant protocols for wireless data transmission networks is required. The most important requirement is scalability of frequency bands, the same for the different technologies, and standardization of the frequency spectrum. Besides that the flexible means of adaptation and adjustment of the system, including the antenna systems are demanded. The full set of requirements for the standard international mobile wireless broadband 4G network is specified in IMT-Advanced standard. And the list of requirements for adaptive antenna systems using Dynamic Digital Beamforming is included in promising LTE-Advanced and WiMAX standards. Thus, 4G systems will be coordinated with IMT-Advanced set of standards. At the user level, they will be distinguished by high data transfer speed – over 100 Mbit/sec for mobile subscribers (Msadaa, 2010).

At the technological level 4G systems will be characterized by:

– complete transition to the OFDM modulation (working in multipath conditions);
– consistent coordinated work on the physical protocol layer;
– high flexibility in selecting of the frequency bands and frequency ranges, adaptive tuning of modulation methods;
– application of the most accomplished methods of the channel correcting coding.

The full transition to IPv6 protocol will allow building IP networks over the roads networks. To increase bi-directional flow of messages at the mesh networks the following problems have to be solved:

– providing functional interoperability of mesh devices;
– increasing efficiency of the network protocols;
– improving the quality of the data transport services;
– reducing delays of the information transmission in the data networks.

For a wide range deployment of the mesh networks compatibility with existing network standards and protocols is needed, when available such compatibility would allow a large set of mesh networks from different manufacturers to interoperate at physical, channel and network levels of OSI, including IPv4 and IPv6 protocols. The network would be able to combine the devices having different wireless interfaces. Currently, Intel Corporation is working on solving this compatibility problem at the level of a radio transmission system changeover, adaptable to any wireless communication environment. This approach is significantly less expensive than implementing multiple wireless interfaces in each device (Suh, 2009).

3 CONCLUSIONS

Analysis of ways to improve the safety of road traffic management revealed the existence of the objective contradictions while trying at the same time to allow operation of unmanned vehicles and conventional vehicles driven by drivers. The most promising option to reduce accidents on the roads and transportation costs will be the use of independent lanes or even highways for unmanned vehicles movement with traffic regulations allow the movement in the column, and one by one.

The increase in bi-directional flow of messages, providing computerized support of road traffic, generates the new requirements for the informational maintenance of the data networks. Due to the constantly increasing amount of data transmitted it makes sense to separate the task of building a mobile mesh network as an independent component. Solving this problem at another level independently from other applications will reduce the load on the mobile networks data link channels by the margin of 15-20%.

A key issue is the integration of mobile resources to a regional infrastructure, involving continuous connection of a vehicle with the traffic control services, manufacturer's service centers, and also communicating directly with the neighboring vehicles in a given radius without access to the global data transmission networks. Integration of mobile resources implies the development and widespread usage of compatible networking equipment.

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