What About the Infrastructure?

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Abstract What once started as Advanced Driver Assistance Systems (ADAS) has evolved into vehicle control systems that partly or completely take over the driver's task. In doing this, many assumptions are made on the design of the infrastructure that the car will have to deal with. Infrastructure, users and cars should not be looked at separately but in combination. Road operators are faced with these new developments, a larger variety of cars, different user behaviour and are restricted in budget. The areas where infrastructure providers and the car industry should work together more closely are explored in this paper.

Keywords Infrastructure · User understanding · Road operator · Legislation · Controlled road · Electronic data recorder

1 Variation in Vehicles

First of all, the majority of all vehicles driving around today will still be on the road in 2025 [1]. Advanced vehicles have to deal with the existing cars but also with an increasing variation in vehicle design. First of all there are differences in physical shape and performance. The variation in size and weight is increasing as new vehicle concepts are being developed. Small electrically powered 2, 3, and 4 wheel vehicles are being developed. Their shape will be smaller than the present car or motorcycle. It could also result in vehicles driving very close together. These vehicles will show different behaviour, accelerate extremely fast or drive very slow to save energy on a low battery. These new designs will introduce new challenges for the existing automated functions.

Another big challenge is vehicle reliability. Old or badly maintained cars can suddenly break down and present an unforeseen danger [2]. But modern cars with

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more than 30 electronic modules of various suppliers and million lines of code can also break down. The records of the National Highway Traffic Safety Administration (NHTSA) Office of Defects Investigation show that all brands have experienced some issues in this respect. Due to the scale of the automotive industry an issue with one major supplier has its effects on many different brands, remember the Takata airbag inflator call back [3]. Automated systems are heavily dependent on the correct functioning of the whole car. For instance, a fluctuating voltage due to an old car battery could have an unexpected effect on other systems. Influence of the government is limited to vehicle type approval, Periodical Technical Inspection (PTI) and driver's licenses. Standardization and regulation by the Government could help the industry to advance.

2 Evolution in Car Systems

2.1 *Introduction*

Traditionally Road Operators see it as the responsibility of the manufacturer that the car they produce can cope with whatever comes up its way. The infrastructure is not the same across a country let alone across Europe. The maintenance state also varies considerably concerning faded or missing lines and traffic signs. We see that the function of automated systems is enhanced from cruise control with fixed speed to Adaptive cruise control (ACC). Further development has resulted in Forward Vehicle Collision Mitigation Systems (FVCMS) and Full Speed Range Adaptive cruise control (FSRA) systems. Furthermore, Lane warning systems have evolved in active steering systems. All this is merging into partly or fully automated cars. How these systems 'see' the world and what they need to drive around safely is largely unknown to road operators. Car owners are informed by their dealer and the owner's manual on working and basic limitations. However, users that get used to high levels of automation will soon start to trust on their systems to work wherever they go and could easily forget these limitations.

To prevent a mismatch between infrastructure and car it should be known to Road Operators what expectations are programmed into the systems and when these cannot be met.

2.2 *Lateral Assistance Systems*

Camera-based lane change warning systems rely on visible lane markings; faded, missing, or incorrect lane markings can present a problem. Temporary line markings during road work could also be an issue. Harsh vibrations could potentially prevent the correct working of the system. These vibrations could occur due to a defect to the tires, the vehicle stability system or an uneven road surface. The issue with visibility of the lane markings and temporary lining has risks, for both the user as well as road workers.

Advanced Lane Change Decision Aid Systems (LCDAS) do not always require lane markings. They also provide blind-spot warning and closing-in vehicle warning. Research by the AAA in 2014 [4] confirms that:

- Blind-spot monitoring systems have had difficulties detecting fast-moving vehicles—such as when merging onto a busy highway. Alerts were often provided too late for evasive action.
- Road conditions have often been a problem for lane-departure warning systems. Worn pavement markers, construction zones and intersections can cause the lane-departure warning system to lose track of lane location.
- The litany of alerts and warnings could be confusing. Auditory, visual or haptic responses—or a combination between these—could be similar to other advanced driver assistance features that deliver the same warnings.

The ISO 17387 LCDAS standard requires that the following statement is included in the owner's manual: "This system may not provide adequate warning for very fast moving vehicles approaching from the rear."

The dimensions that are used in the test seem to be barely sufficient to detect a small electrical vehicle such as the Renault Twizy with its height of 1.4 m, width of 1.2 m and length of 2.3 m.

The systems are tested under the optimal environmental conditions: The test takes place on a flat, dry asphalt or concrete surface. The ambient temperature during testing shall be within the range of 10 °C and 30 °C. The horizontal visibility range shall be greater than 1 km. Although the user receives instructions, other road users may not be aware of the fact that passing an equipped vehicle with high speed could result in a risk. Furthermore, users of vehicles smaller than the defined test target may not be aware of any extra risk.

2.3 Longitudinal Assistance Systems

Since the introduction of the classic Cruise Control system (CC) that set a fixed speed, major progress has been made. The first step was Adaptive Cruise Control (ACC) which allows the user to set a minimum gap with the target vehicle by controlling the power train and optionally the brake. Further development has resulted in Forward Vehicle Collision Mitigation Systems (FVCMS) and Full Speed Range Adaptive cruise control (FSRA) systems. A FVCMS can warn the driver for a potential collision with another vehicle in the forward path. It could also use a Speed Reduction Braking (SRB) or Mitigating Braking (MB). In this case automatic braking is applied if a collision seems inevitable. The system should operate between 30 and 100 km/h. The system should work with a target vehicle that travels at least 30 km/h.

The validation methods define the target as a representative passenger's vehicle or representative motorcycle. Since the performance is dependent on the sensor technology, the validation method makes a difference between lidar, radio wave radar and passive optical sensor. It is unclear how these differences affect the performance. Lidar needs a much smaller reflective area than radar. Once more, the driver shall be informed about the systems limitations in the owner's manual.

Full Speed Range Adaptive cruise control (FSRA) systems are intended to provide longitudinal control while travelling on highways (roads where non-motorized vehicles and pedestrians are prohibited) under free-flowing and congested traffic conditions. FSRA provides support within the speed domain of standstill up to the designed maximum speed of the system. The system is not required to react to stationary or slow moving objects.

The system will attempt to stop behind an already tracked and stopping vehicle within its limited deceleration capabilities. The specifications of the test target depend on the type of sensor technology used. The minimum width of the automatic "stop" capability test vehicle is 1.4 m, which is the size of the Renault Twizy. Its lateral displacement should be no more than 0.5 m to the subject vehicle. The familiarity of the daily user with the limitations of the system is unknown.

It is optional to design FSRA systems to respond to the presence of stationary or slow moving targets. In practice, unexpected features of the road system can cause problems. A previous version of the Lexus Pre-collision System (PCS) reacted to metal on bridge parts and started an emergency brake action [5]. It is unclear if this could happen with other systems and if Road Operators have any role in this.

If a given implementation is not intended to respond to stationary or slow moving targets, the driver shall be informed at least by a statement in the vehicle owner's manual. For instance, the Mercedes owner's manual warns the driver that the system might not react to very narrow vehicles or vehicles that are not in the middle of the lane. As the implementation of these systems varies between brands and even between models of the same brand users could get confused when changing cars.

2.4 Automated Cars

Further development and combination of advanced systems brings us highly or fully automated vehicles. For definitions see SEAJ3016 [6]. Depending on the design, these systems display vulnerability towards irregularities like road works, incidents, debris, weather conditions, and disturbances of communication. In the present road systems these disturbances have a great likelihood of occurring. The user has to be able to realize this and regain control in time, should this occur. A minimum standard for robust design of automated cars would make the issue more manageable. Such a standard should be technology independent.

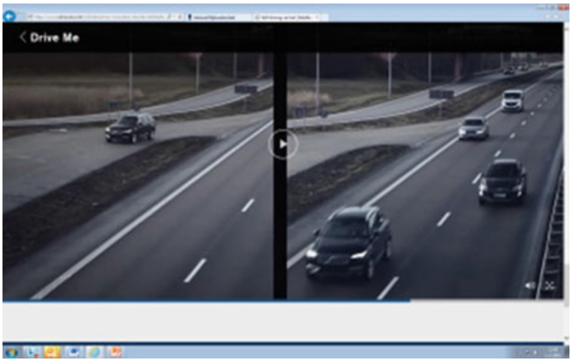

Fig. 1 Safe stop area in Gothenburg, Sweden

Furthermore, the standard for the road design would have to go up and roads should be able to communicate with the car. This requires cooperation between car industry and road operators.

A good example of such cooperation can be observed in Gothenburg, Sweden. The design of the motorway has been altered to accommodate automated driving. Where automated drive is no longer possible the driver is alerted to take back control. If the driver is not responding, the car automatically slows down and leaves the road for a safe stop area next to the highway [7] (Fig. 1).

2.5 Fleets

Systems like ACC that perform satisfactorily when used by an individual car, give problems when they are used by a row of cars. In a row of cars using ACC the last one hardly has any reaction time left to avoid an incident. Using V2V communications all cars can directly react on the first car. ACC and communication together enable platooning. While the platoon itself can be safe there is an issue with the interference with the other road users. The length of the platoon makes it harder for them to enter or leave the road. This is why, on some stretches of road, truck platooning is not permitted by the Road Operator. Communication between cars and trucks and Infrastructure would solve this problem.

2.6 Location, Communication, Maps

The autonomous car needs information from the outside world. Communication between vehicles (V2V) and between the vehicle and the infrastructure (V2I) is expected to resolve many issues such as ACC, detection of road works and incidents and could automatically resolve possible special conflicts on highways and

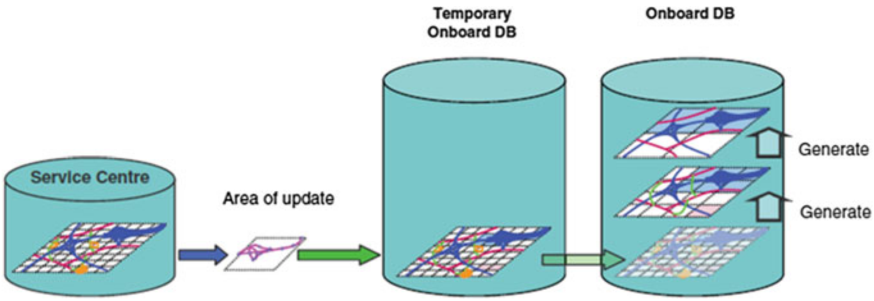

Fig. 2 Map services

intersections. Localization provided by GNSS systems plays an essential part in all this. All communication is sensitive to disturbances. Sources could be jammers, used by drivers that try to fool tracking systems, electromagnetic storms from solar flames or even other users in the same band.

If detected and tracked down, the use of jammers will be fined. This, however, will not solve the problem. The applications have to be resilient and warn users when they are experiencing problems that make save operations impossible.

A special use of GNSS services is "the map as a sensor" development. The needed detail of the map often exceeds the quality of the data that is present with the road operator. The number of lanes, for instance, as well as lane width, position and type of lane marking, traffic signs, special use lanes and traffic rules. Map updates and weather as well as road closures are sent as updates (Fig. 2).

To get the needed information to and from a car in a reliable way close cooperation or maybe even integration on technical and organizational levels between road operators and private parties such as the car industry and map providers is needed.

3 Involved Parties

3.1 The User

The user is being seduced by new functions that can make his journey safer, less tiring and that have a popular hype around it. At the same time he is supposed to know when the functions are not able to take over for him and in such cases he has to be able to quickly regain control over the vehicle. Clear information and education of the user are a necessity. To avoid misinterpretation, a standardization of the user information is desired.

Drivers of conventional cars are confronted with cars that react differently to manoeuvres as opposed to cars with a human in control. Although these differences can be seemingly small, they could result in dangerous situations. Eye contact during a manoeuvre is not possible, making it harder to predict the other car's reaction. This issue needs more attention than it presently gets.

3.2 Road Operators

Even with automated cars driving around, road operators will still have to deal with broken down cars, incidents, road works and bad weather. Road Operators are confronted with a greater variety of vehicles, partly and highly automated cars. User behaviour also changes due to smartphone addiction.

The road operator's first job is to maintain a safe road system within a tight and, in most cases, decreasing budget. The existing users expect that they travel safely and that any new and allowed system does not put them at risk. On the other hand the road operator is asked to facilitate the development and admit new functions, new behaviour and even automated cars to its roads. In some cases it is clear to the road operator that the use of a system can cause problems. For navigation and cruise control various creative solutions regarding road signs have arisen already (Fig. 3).

This is not manageable for all the new functions since their number is too big, they differ too much and their sensitivity to unexpected circumstances varies too much. Road operators can not anticipate this. Radar systems might not be able to recognise traffic cones used by emergency services, putting them at extra risk.

These issues are hard to tackle. Can the Road Operator expect or demand that all partly automated systems can detect traffic cones as used by emergency services? Should they only allow automated vehicles that are equipped with V2V and V2I communication capabilities to warn for road works by traffic information and V2I communication? By doing so the Road Operator would define the minimal abilities an autonomous vehicle should have.

One other way to go is to define a minimal level of service for roads suited for the use of automated driving systems. This could lead to the definition of a 'controlled road' where radar sensors continuously inspect the road surface for broken down cars, debris, animals and incidents and if these obstacles are detected the oncoming traffic and navigation providers will immediately be informed using road side V-I communications. As most road operators still have the opinion that it is up to the automated car to scan its surroundings, a common minimal standard is not yet foreseen. As a first step car makers should be clear about the limitations of the automated functions and then get together with road operators to determine what it is needed to make real progress in the traffic system. Technically there are also

Fig. 3 How road operator deals with present on-board systems

some hurdles to make the road smarter and more communicative, as the equipment needed is not even defined yet.

3.3 Law Makers

Governments are facilitating trials with (partly) automated cars. To make new applications work in all places the same rules will have to apply everywhere. These rules will lead to new laws and new agreements between countries.

Areas of interest are:

- Definition of quality and performance of new vehicle systems within type approval
- Information and education involving the drivers, possible additions to the driver examination
- Information to other drivers on the reaction of automated cars
- Standardization of the information exchange between road and vehicle
- Definition of suited highways with a minimal level of service
- The use of Electronic Data Recorder (EDR) that contains all relevant data for accident investigation.

In case of an accident with a (partly) automated vehicle there will be uncertainty about the situation before the crash. To help fix operational mistakes and design flaws all relevant information such as the speed, acceleration and positioning data should be directly available for the accident investigation. In this way the interest of the public is served, and the technology can evolve further as well. Incidents should be investigated and serve as input for improvement. The aircraft industry can serve as an example in this respect.

4 Conclusion

The properties of automated cars are largely unknown to Road Operators. System designers should be more aware of the limitations of the users and the position of the road operator. The technological development of cars proceeds much faster than the development of the road. As the diversity of applications increase, the consequences are not clear.

Some road operators hope that the smart cars will take away all their problems. They foresee an empty road. Since the existing cars will still be around for many years, it is time to switch to a more realistic view where smart cars are serviced by an intelligent road. In order to get there, the automated car should be developed with both the user and the Road operators in mind and involved in the dialogue.

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