Driver Assistance Systems: State-of-the-Art and Possible Improvements

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***Abstract*–Today, modern vehicles are equipped with various complex systems. Systems related to the class of Advanced Driver Assistance Systems (ADAS) are aimed to assist drivers. Depending on the purposes, these systems can have different architectures and ways of communicating with the driver, e.g., they can use external sources and/or on-board sensors, have different sets of indicators or influence upon other on-board systems. The goals of this paper is to analyze the state of the art in the area of ADAS, develop a comparison based on the analysis and propose possible ways of improvement and future development of such systems.**

I. INTRODUCTION

Modern vehicles are equipped with various complex systems. Some of them can be related to the class of Advanced Driver Assistance Systems (ADAS) [1] aimed to support drivers in different aspects of car control. One of the key purposes of ADAS is safety. ADAS are aimed to ensure safe driving and to reduce the number of accidents.

Depending on the purposes, these systems can have different structures and architectures, e.g., they can be autonomous or use external sources, can be based on on-board sensors and/or cloud services [2]. ADAS can help with various types of problems from parking to more complex tasks, like reduce accident rate.

Besides, the issues of information processing in ADAS and their mode of interaction with the driver are worth to be studied along with their ability to interact with external information sources and technologies, to determine which sensors and instruments they use for their purposes.

The paper presents a systematic review and discusses the issues related to the research and development in the field ADAS. Its main purpose is to reveal the major ADAS concepts and study the possible prospects of this class of systems.

The structure of this paper is as follows. The introduction is followed by the research method description. The ADAS are described in section II. Section III presents the comparative analysis of active driver assistance systems. Then, the generalized usage scenario and its possible improvements are proposed. The final section is devoted to conclusions.

II. RESEARCH METHOD

A. Research approach

The research approach used in this paper is the "Structured Literature Analysis" (SLA) [3] The idea of SLA is to deliver a summary of activities in a given scientific field. It aims to be transparent and repeatable as well as to present evidence for all conclusions that have been drawn.

B. Research questions

The presented review is aimed at finding which of the below listed functionalities are supported by various ADAS:

- Possibility to communicate with driver's smartphone,
- Ability to integrate with external services,
- Implementation of navigation,
- Vehicle diagnostics,
- Auto search,
- Parking assist,
- Notice of collisions,
- Warning of an attempt of theft,
- Making a call.

The choice of the above questions is motivated by a required definition of availability of technologies related to future planned research in the area of ADAS.

C. Pre-search

The pre-search was first conducted to select the source list. In the process of deepening in the subject, the following keywords were highlighted: *Driver system, Driver Support, Driver.*

D. Literature sources

The following sources were selected for the structured literature analysis:

- http://link.springer.com
- http://www.sciencedirect.com

The sources included into the review were published during the period between 2006 and 2016.

E. Paper selection and Data Collection

During the work on the review, the sources that describe driver support systems were selected based on the above sources and keywords. The decision if a source should be included in the review was made after preliminary reading.

Unfortunately, the sources, which were not accessible during the review (for example, due to charges imposed by the publisher, or those, which were not covered by the available university subscription) were excluded from the review.

III. DESCRIPTION OF ADAS

A. *Introduction*

ADAS [4] usually includes a set of subsystems aimed at passive or active interaction with the driver. These subsystems affect different aspects of the driving process and include:

- autonomous cruise control system,
- adaptive high beam,
- automotive navigation system,
- collision avoidance system,
- driver monitoring system,
- intelligent speed adaptation,
- traffic sign detection and recognition,
- intelligent car.

Below, these subsystems are described in detail.

B. *Autonomous cruise control system*

Cruise control is a system that automatically controls the speed of a motor vehicle. Autonomous or adaptive cruise control system adjusts the vehicle speed to maintain a safe distance from the vehicle ahead. The process is based on the usage of sensors that are installed on the car. These sensors can be two types [4]:

- laser lights (unreliable, because of the triggering in bad weather conditions and in cases when covered with dirt);
- indicators using infrared radar (widely used as a part of the collision prevention system).

This advanced driver assistance technology is especially useful on highways, where drivers otherwise have to constantly monitor their cruise control systems for safety reasons. Most of these systems automatically shut off below a certain speed threshold, but others can even be used in “stop and go” traffic.

C. *Adaptive high beam*

These systems are designed to help drivers to better and further see in the darkness. This advanced driver assistance technology allows the headlights to swivel and rotate to better illuminate the roadway through corners and in other circumstances and automatic adjustment of brightness beams depending on the external environment. It allows the driver to achieve maximum visibility range (in the case of bad weather or night time driving) without dazzling other drivers. The source of information is usually a camera mounted on the rear-view mirror [4].

D. *Automotive navigation system*

The systems of this class receive information from external sources in order to detect the location of the car and construct the optimal route to the destination. Satellite-based location definition (through GPS or GLONASS) is based on the usage of sensors mounted either in on-board computer or through an external connected device (e.g., smartphone) [5].

GPS navigation systems effectively replace bulky, cumbersome paper maps. These systems are often capable of providing vocal directions as well, which saves the driver from the necessity of looking at the screen. Some GPS navigation systems also provide live traffic data for traffic jam avoidance, which drivers previously had to obtain by listening to news radio stations.

E. *Collision avoidance system*

This class of systems has received a wide range of designs, because it is directly related to the driving safety. The system aimed at improving the driving safety that is better known as «pre-crash system» [6] use a wide range of means (radar, laser lights and cameras, etc.) to detect imminent collisions. In the event of a possible collision, the system warns the driver either to take the vehicle under control in order to prevent a collision or if prevention is not possible to carry out a collision with minimal damage [7] (this system is used in the Tesla Model S 2015).

Collision avoidance systems use a variety of sensors to determine whether a vehicle is in danger of colliding with another object. These systems can typically sense the proximity of other vehicles, pedestrians, animals, and various roadway obstructions. When the vehicle is in danger of colliding with another object, the collision avoidance system will warn the driver. Some of these systems can also take other preventive actions, such as precharging the brakes or applying tension to the seat belts.

An example of these systems may be the LDW (Lane Departure Warning) [8]. Lane departure warning systems use a variety of sensors to make sure that the vehicle does not leave its lane accidentally. If the system determines that the vehicle is drifting, it will sound an alarm so that the driver can take a corrective action in time to avoid hitting another car or running off the road. Lane keeping assistance systems go a step further and they are actually capable of taking small corrective actions without any input from the driver. This system ensures that the car moves in one lane. The system uses three kinds of sensors [4]:

- video detectors (next to the rear view mirror),
- laser sensors (front part of the car),
- infrared sensors (for a windscreen or a car).

It should also be noted that the promising trend for this class of systems is the automatic creation of a "model" of the driver, i.e., the system analyzes the driver's typical behavior and automatically adjusts to it [9].

F. *Driver monitoring system*

It is a relatively new class of systems aimed at monitoring the behavior of the driver. They have various cameras installed in the car. A striking example of the system is following the driver's fatigue.

Also new is the prototype of a system that ensures that the driver does not use a mobile phone while traveling. The system uses the sensors of the headrest, and transmits the data to the computer center (research laboratory was at the time of the experiment center) [10]. The system can then be used to generate automatic fines.

Driver drowsiness or awareness detection systems can be example of these systems. Driver drowsiness or awareness detection systems use a number of different means to determine if a driver’s attention is starting to wander. Some of these systems look for the driver’s head to nod in a telltale motion that indicates sleepiness (e.g., [11]), and others use technology similar to lane detection warning systems.

Distraction occurs when drivers divert their attention away from the driving task to focus on another activity instead. Two types of inattentive driving are monitored. In the first type, the output of the face direction classifier based on head movements and head position is tracked. If the driver’s face is not facing forward for longer than three seconds while the car is moving forward (i.e., while a positive speed is reported by the accelerometer) and not turning as reported by the turn detector (which is based on the gyroscope readings) then a dangerous driving event is inferred. In the second type, we trace a vehicle movement and determine whether the vehicle made a turn or not [12].

G. *Intelligent speed adaptation*

This advanced driver assistance system depends on a variety of information types to help the driver maintain a legal speed. Since these systems monitor the current speed and compare it with the local speed limit, they only function in certain areas.

The system analyzes the vehicle speed and the speed limit on this stretch of road. The system comes in two types: active and passive. In the first case, the system automatically reduces the speed to the allowed on this stretch of road, in excess of the permitted limit. In the second system displays trip computer over speed warning [13].

H. *Traffic sign detection and recognition*

Traffic Sign Detection (TSD) and Traffic Sign Recognition (TSR) may be an important part of ADAS [14]. TSD deals with identifying the Regions Of Interest (ROI) and the boundaries of the traffic signs in a given image. A good TSD algorithm is supposed to find all relevant traffic signs in an image while producing as few false detections as possible. TSR deals with the classification of a given image patch. A good TSR correctly classifies a given image patch within a pre-formed set of traffic sign classes while making as few false recognitions as possible.

Sign detection in digital images is traditionally divided into two categories: color-based methods and shape-based methods. Color-based detection methods aim to segment a given color image in order to provide a ROI for further processing. The biggest problem of such methods is the difficulty to correctly assess the color information in an image due to light intensity variations and illumination changes because of day-night variations and weather conditions (rain, fog, snow, etc.). With color-based methods, researchers choose different color spaces and thresholds, and eliminate what they consider to be non-traffic signs. HSI (hue, saturation, and intensity) color space, which is less affected from illumination changes and different weather conditions, is very commonly used for segmentation. It uses the normalized RGB (red, green, and blue) color space with fixed thresholds in which the red component was chosen as a reference.

In shape-based TSD methods, the usage of Hough Transform (HT) is quite common. Although the methods using HT may offer satisfactory performance, their main disadvantages are high computational complexity and large storage requirements. Some shape-based methods make use of the corners in the image. Distance Transform (DT) is one of these methods. In this method, the corners are found first. DT feature vector image is then obtained by computing the distance of each pixel to the nearest corner.

TSR methods found in the literature are traditionally divided into two categories: template-based techniques and classifier-based techniques. Template-based approaches involve pixel-based cross-correlation template. This technique is simple, yet very useful when the tested image and the template images are well aligned. However, geometrical alignment is usually difficult to achieve by automatic sign detection systems, especially when the image is seen against a cluttered background or when it is affected by geometrical distortion.

Classifier-based approaches are based on machine learning techniques. In these approaches, a feature vector is first extracted from the image to reduce computational complexity. Then, the class label of the feature vector is obtained using a classifier, fuzzy regression tree frameworks or a random forest based classification method.

I. *Intelligent car*

To consider the concept of intelligent car, i.e. a car that can be seen as a driver support system, the following examples can be given to simplify the understanding of the concept.

ZF Advanced Urban Vehicle. This vehicle includes a range of systems to support the driver [15], allowing to solve various problems, for example:

- Intelligent networking of individual suspension systems, drive and driver assistance programs.
- ZF Smart Parking Assist provides fully automatic parallel and transverse car parking. Unlike regular Smart Parking Assist, ZF Smart Parking Assist enables smartphone usage for car parking control Parking system receives the necessary information from the 12 ultrasonic and two infrared sensors located in the front, rear and side parts of the vehicle and can detect a suitable parking place. In this case, the driver can

control the process through the display of the dashboard or activate the function of parking, having already left the vehicle, in the corresponding application on the mobile device, for example, Smart Watch.

- PreVision Cloud Assist technology takes into account not only the topographical data and information about the permitted maximum speed, but also stores the data of each trip, including the coordinates of the location of the vehicle, as well as lateral and longitudinal acceleration in the "cloud." When a passage of the same route is repeated, on the basis of these data, the system calculates the optimum speed of passage of the upcoming turn. Then the program assistant in advance reduces the torque to a value that allows to enter into the turn, without resorting to mechanical braking.

The interaction with the driver can be carried out via the on-board computer, smart phone, smart watch and through the steering wheel (a multifunction steering wheel was mounted by ZF specialists in Advanced Urban Vehicle, equipped with OLED-display).

BMW also has an interesting experience in the field of intelligent cars. In this case they are transferred to the new E / E (Electric / Electronic) architecture [16]. This architecture enables an analysis of the situation through a variety of sensors and provides multiple developers an opportunity to offer various products aimed at solving different tasks. This might result not only in a wide range of solved tasks but also in a wide choice for the user when selecting a product. The architecture consists of five units:

- I & C (Information and Communication) systems;
- D & S (Driver and Safety) systems such as airbags, anti-lock braking system, etc.;
- driving, engine, and transmission control system;
- B & C (Body and Climate control) function;
- “iSense”, a new for BMW functional block that entails the capturing of environmental information using sensor systems such as ultrasonic and various cameras and laser scanner technologies.

Systems with this architecture will allow to solve problems of driving adaptive adjustment, i.e. driver's experience of developing autonomous support of specific driving situations to a holistic, adaptive functionality, which is responsible, both for the driver and for the environment.

Taking all of the recent changes in ADAS-systems into account, it should be noted that the increasing role is played by the interaction with external sources of information (traffic information for navigation, high-speed mode for intelligent systems to adapt speed etc.). In this case, the increasing popularity acquire ADAS systems based on ATIS (Advanced Traveler Information Systems) [17], the objectives of which are: dynamic re-routing; predicting traffic jams; delivering information about the vehicles around, attractions, etc.

IV. GENERALISED USAGE SCENARIO OF ADAS

A. *Comparison of ADAS solutions*

To conduct a comparative analysis, the systems that directly communicate with a driver have been taken into account. The following systems were chosen: *OnStar, Volvo on Call, Peugeot Connect SOS, Car-Net (Volkswagen), FordPass, BMW Remote*

The following series of test questions have been pointed in II.B section.:

As it was already mentioned, the reason for the choice of the above questions is related to definition of availability of technologies related to future planned research in the area of ADAS.

The result of the comparison is presented in Table I. As it can be seen, all active driver systems have positive results in the following questions:

- possibility to communicate with driver’s smartphone,
- ability to integrate with external services,
- implementation of navigation,
- vehicle diagnostics.

Peugeot Connect SOS and *FordPass* do not have abilities of Auto Search and Warning of an attempt of theft. Only *Car-Net* and *FrodPass* have a Parking assist. *OnStar* and *Volvo on Call* can sent notice of collision to driver. Only *OnStar* have opportunity to make a call.

Based on the comparative analysis we can consider that *OnStar* has the largest number of positive answers. *Volvo on Call* and *Car-Net* also have good results. These systems have seven from nine positive answers. Peugeot Connect SOS show the worst result and has only four positive answers. This result can be explained by the fact that the system has a purpose of notifications about various incidents.

B. *Scenarios of ADAS functioning*

Based on section IV.A, a set of activities that are used in ADAS systems can be defined. Data analysis activities allow construction of a generalized scenario of ADAS functioning.

The scenario can be divided into two parts:

- scenario executed at the time of driving,
- scenario executed in certain moments.

The scenario of the first category includes the following activities: navigation, parking assist, making calls.

The second category includes the following activities: auto search, vehicle diagnostics, notification of collisions, and warning of a theft attempt.

TABLE I. COMPARATIVE ANALYSIS OF ACTIVE DRIVER SYSTEMS

	OnStar	Volvo on Call	Peugeot Connect SOS	Car-Net	FordPass	BMW Remotes.
Possibility to communicate with driver's smartphone	+	+	+	+	+	+
Ability to integrate with external services	+	+	+	+	+	+
Implementation of navigation	+	+	+	+	+	+
Vehicle diagnostics	+	+	+	+	+	+
Auto Search	+	+	-	+	-	+
Parking assist	-	-	-	+	+	-
Notice of collisions	+	+	-	-	-	-
Warning of an attempt of theft	+	+	-	+	-	-
Making a call	+	-	-	-	-	-

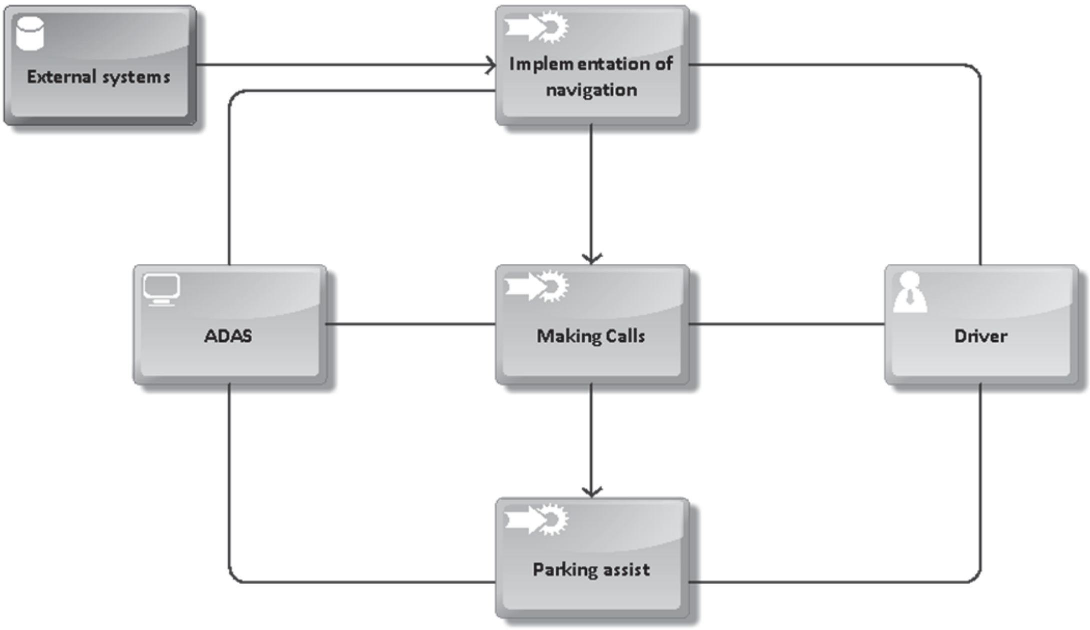

Fig. 1. ADAS functioning scenario, comprising a set of activities undertaken at the time of driving,

Communication with driver's smartphone (or other personal device) and integration with external services appear to be external elements for ADAS.

Fig 1 shows a scenario of ADAS functioning, comprising a set of activities at the time of driving. The driver sets the destination and ADAS navigation subsystem defines the route. Information can be taken from various external systems (e.g., Google Maps). While driving, the driver can receive and make calls using the ADAS. At the same time, ADAS monitors the car movement in order to engage another scenario when necessary. Upon reaching the destination, ADAS provides assistance when parking.

Fig 2 shows the scenario ADAS functioning, comprising a set of activities in certain moments. If you attempt theft of the vehicle and / or vehicle collision ADAS sends an alert to driver's smartphone (other smart devices). With the help of a smartphone (other smart devices) the driver can locate his/her car (e.g., in a large parking lot). ADAS provides diagnostics for vehicle damage severity (data about car's regular condition from the vehicle manufacturer may be used for analysis). The diagnostics results are sent to the driver's smartphone (other smart devices) and (in some systems) to the authorized service as well.

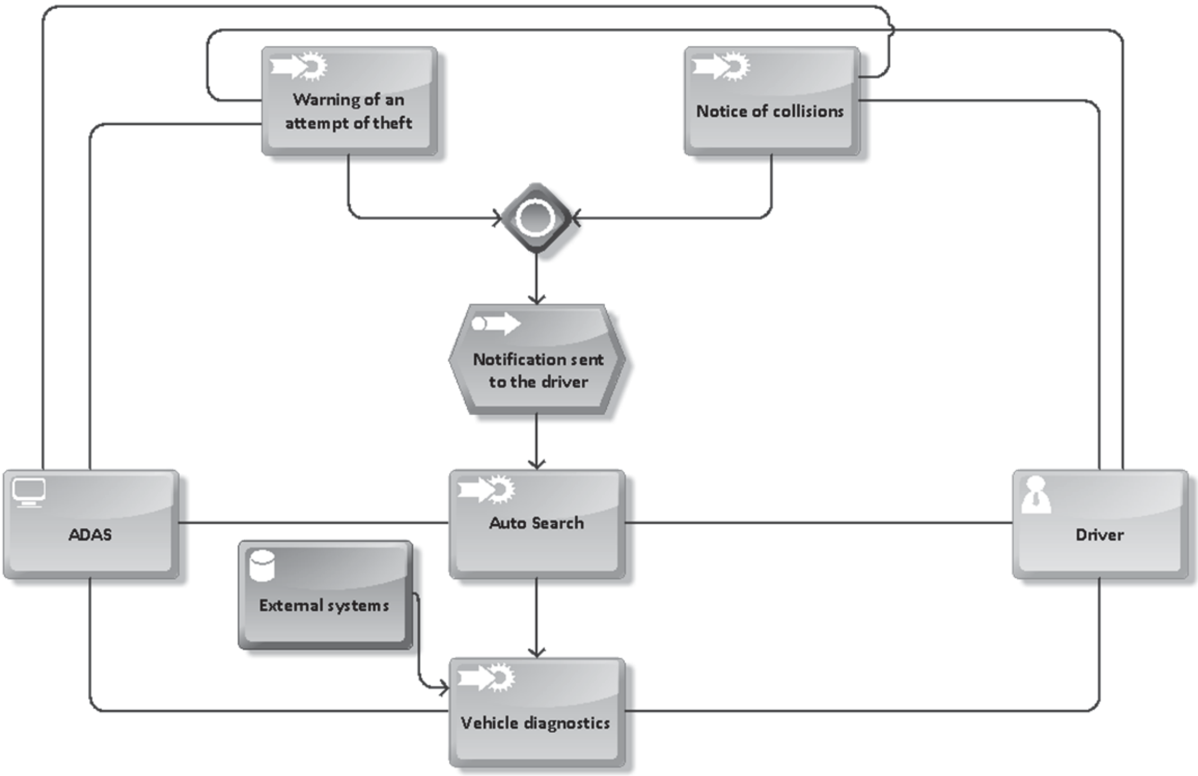

Fig. 2. ADAS functioning scenario, comprising a set of activities undertaken in certain moments

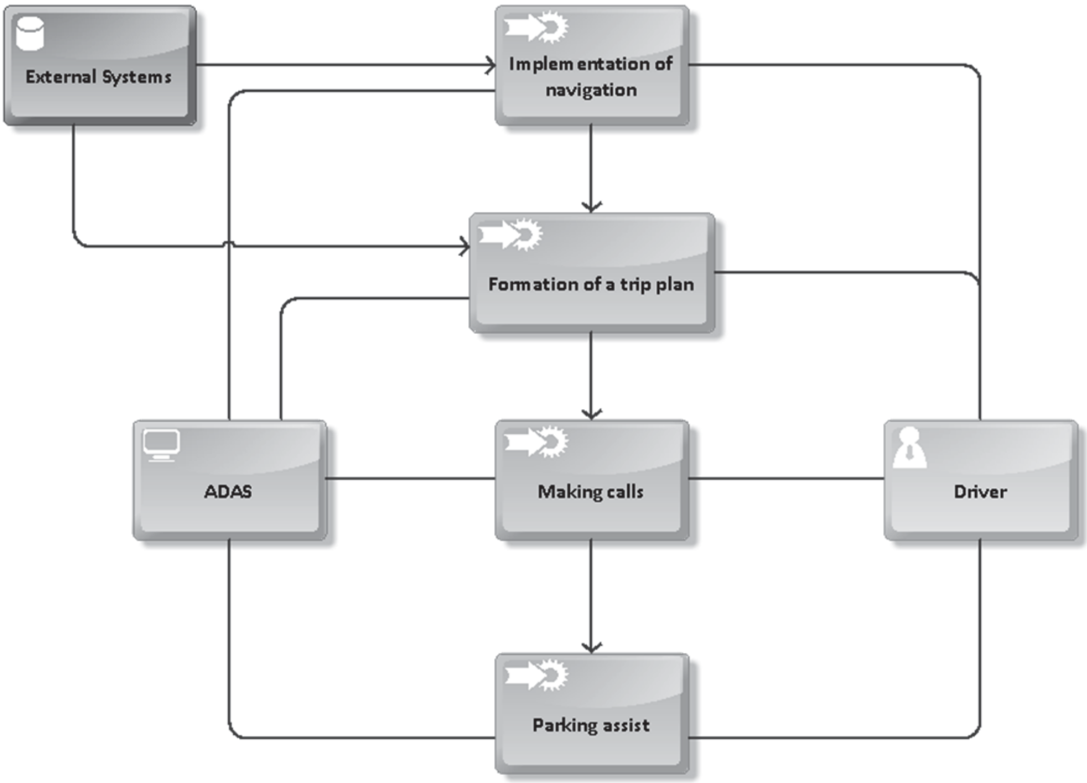

Fig. 3. ADAS functioning scenario with modification

During the implementation of these scenarios, an improvement of the system was suggested. The improvement involves the scenario of interaction with the ADAS, comprising a set of activities undertaken at the time of driving. An activity responsible for the definition of a trip plan based on personal preferences and information from various sources was proposed. This trip plan may include a wide range of different aspects information sources (for example, the trip plan can formed on the calendar, information about sightseeing, parking, traffic and etc.).

Thus, modified scenario would be like follows. Car sets the route to the destination of the proposed options for ADAS. At the request of the driver's route can be changed for different purpose. ADAS suggests different options about the trip plan and shows all information about them. While driving, the driver can receive and make calls using the ADAS. Upon reaching the destination, ADAS can provide assistance for parking. The modified scenario is shown in Fig 3.

V. CONCLUSION

In the course of this paper, the analysis of research papers addressing issues related to ADAS was implemented. This class of systems is currently developing fast in different areas, ranging from adaptive lights to create prototypes of cars that are kind of driver support systems. It can be concluded that the research topic of improving ADAS in various ways can be very promising and is open to new developments on the basis of this analysis.

Comparative analysis of several ADAS and building a generalized scenario of ADAS functioning was carried out. This analysis allowed to identify trends in the development of specific manufacturers and suggest tentative vector of development of these systems. It is worth noting the increasing role of external services for ADAS.

In constructing the scenarios potentially promising improved driver support systems were considered. The future research is planned in the area of a new service development, the main purpose of which will be the formation of a trip plan based on information from various sources and individual interests of the driver.

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