Development of technical solutions for development of a commercial vehicle driver assistance systems

D M Porubov, A M Groshev, V P Mishustov, Y I Palutin, A V Tumasov

Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Minin str., 24, Nizhniy Novgorod, 603950, Russian Federation
2 Nizhny Novgorod State Agriculture Academy

E-mail: pavel.beresnev@nntu.ru

Abstract. As the world’s stock of cars is growing, the number of road accidents per each 100000 resident is going up as well. To avoid road accidents or to mitigate their consequences nowadays driver assistance systems are used. Pre-requisites and first steps of driver assistant systems development and integration in series-produced vehicles are presented in this article. Review of current solutions is given and technical regulation development trends in this field are considered. An option of driver assistance systems integration on the platform of GAZelle NEXT is offered. It has also been detected that current series-produced GAZelle NEXT vehicles provide no opportunity of external control over actuating devices. This factor hinders development of domestically made vehicles and reduces their export potential. Force and kinematic analysis of the steering system is presented in MSC ADAMS/View program package. Also a number of system designs is presented for further mounting on “GAZ Group” vehicle family, having a feature set of recognizing vehicles, road signs, pedestrians, road marking and traffic lights; warning of possible head-on clash and leaving the traffic lane. Field research of the developed driver assistant system has been carried out. Ways of further integration of driver assistant systems in series-produced “GAZ Group” vehicles are mapped out.

1. Introduction
Transport plays an important role in forming and functioning of the modern society. It helps to provide equal access to different objects and services. Transport and transport communications are one of the key factors providing development of industrial complexes, defence and state security. In this regard transport communications help to raise information awareness, stimulate science and innovations, economic activity, global character of different human activities including the country’s northern territories development.

A developed transport network ensures connection between all the country’s territories making them a single social, cultural and economic space. As soon as the Russian Federation occupies the first place in the world in terms of its territory, this is the country’s crucial parameter and a necessary condition of its territorial integrity.

Improving road traffic safety remains one of the basic conditions of transport network development in the Russian Federation. According to the Russian government statistics each year 20 deaths per 100 000 residents are registered in road accidents on average. In the USA, this number is 10-12 deaths per 100 000 residents and to Germany – 5-6 deaths. A relatively big number of road accidents involve commercial vehicles due to their operational specialty (minimal, simple, a big number of transport...
operations, haul length etc.). Herewith, one of the main causes of road accidents in Russia is the so-called «human factor» which is also characteristic of other world community countries. For example, in Europe over 90% of road accidents happen because of the drivers’ mistakes, in particular because drivers and motorists are distracted from the process of driving.

Research and development of driver assistance systems is carried out in order to minimize drivers’ mistakes and to improve road traffic safety for commercial vehicles inclusively. The basic algorithm of ADAS-systems operation is collection of sensor data around the moving vehicle, further information analysis, detecting emergency situations on the road and taking measures to avoid them or to mitigate their consequences. Nowadays a number of measures is being taken to alter the regulatory framework and implement the requirements to have series-produced vehicles equipped with driver assistance systems. These alternations encourage a breakthrough development of driver assistance systems as well as their further integration in series-produced vehicles in order to improve road traffic safety.

2. Technical regulation in driver assistance systems

Technical regulation is considered to equip commercial vehicles of N1, N2 categories with different driver assistance systems. Implementation of driver assistance systems in commercial vehicles is an essential task as it improves road traffic safety due to these vehicles operational specialty (minimal idle time, haul length etc.) and a big driver’s workload, especially when handling regular cargo-and-passerger hauls.

In the European Union countries nowadays there are requirements to equip vehicles of N2 category with driver assistance systems. Currently the following systems are obligatory: Automatic Emergency Braking, Lane Departure Warning; Automatic headlight control system.

Starting from 2022 new EU requirements are to be enacted to equip N1-category vehicles with such ADAS types as Automatic Emergency Braking (AEB), Emergency Braking Display; Intelligent Speed Adaptation; Safety Belt Reminders; Alcohol Interlock Devices; Crash Event Data Recorder; Tyre pressure Monitoring; Reversing Detection, Lane Keep Assistance; Driver Drowsiness and Distraction monitoring [1,2].

According to the EU requirements to equip N1-category vehicles starting from 2024, the following ADAS will be obligatory: Automatic Emergency Braking (AEB), Lane Keep Assistance; Driver Drowsness and Distraction monitoring.

Nowadays in the Russian Federation there are no obligatory requirements to equip vehicles of N1, N2 categories with driver assistance systems. However implementation of the requirements analogous to UNECE Rules is planned in normative legal documents of the Russian Federation, videlicet in Technical Regulation of Customs Union TRCU 018/2011 «On wheeled vehicles safety». For example, implementation of Automatic Emergency Braking (AEB) requirements is due in the period of 2019-2021 [3]. Analogous requirements are offered with respect to Forward Collision Warning System, road signs and traffic lights detection system, lane leaving system.

In Russia production and sales leader in LCV segment (about 70% of the market) is “GAZ Group” LLC [4]. The basic model in this class is GAZelle NEXT. Different design variants of the vehicle (cargo and passenger) are assembled on the basis of this chassis type. Nowadays this model has no driver assistance systems installed. However to keep and increase the market share in Russia as well as to increase “GAZ Group” production export potential it is necessary to install driver assistance systems complying with both UNECE and Russia’s normative legal requirements and meeting the needs of target customers.

3. Review of current solutions

As soon as normative requirements to equip commercial vehicles with driver assistance systems will first of all concern N1-category, light commercial vehicles manufacturers have already started to equip series-produced vehicles with different ADAS types. Benchmarking has been carried out in order to assess level of development of driver assistance systems installed in series-produced commercial vehicles of N1-category. The obtained data are shown in Table 1.
According to the table such carmakers as Volkswagen (car model “Crafter”) and Mercedes Benz (car model “Sprinter”) [7, 8] enjoy the highest rate of using ADAS in LCV. Basically the above commercial vehicles are equipped with the following systems: Hill Start Assist, Cruise Control, Downhill Assist Control, Parking Assistance и Automatic Emergency Braking system. Only Volkswagen, Iveco and Mercedes have active driver assistance systems of the second level according to SAE classification (affecting driving control units) [11]. Consequently, these systems allow the companies to give their competitors an edge in this market segment as well as to increase the rate of development of breakthrough technologies in the car industry, and driver assistance systems in particular.

However it is worth mentioning that in LCV segment renewal takes place once in 5 - 10 years. In the nearest future other global carmakers are likely to equip their vehicles with active driver assistance systems of such level, seeing their competitors produce next generation LCVs.

Analysis of normative documents of commercial vehicles market shows that development and equipment of “GAZ Group” with driver assistance systems, namely GAZelle NEXT, will help largely increase the safety level of competitive production as well as to expand export potential of commercial vehicles.

4. Driver assistance systems integration

To actuate control actions from the driver assistance system control unit it is necessary to provide external control of principle actuating mechanisms of the vehicle. At present series-produced GAZelle NEXT vehicles have no possibility of external control of actuating mechanisms, namely brake system and steering control system.

Within the framework of this project intelligent brake system and steering control system with the possibility of external control are being developed. Intelligent brake system with the possibility of external control will serve as an actuating mechanism for Automatic Emergency Braking system and will be able to respond to signals coming from electronic control unit of the vehicle showing the risk of collision with the vehicle in front. It will also activate braking mechanisms in order to slow down to prevent the collision or mitigate its consequences. At this, the system will give the driver the possibility to interrupt the emergency braking stage and will provide operation within the range of 15 km/h to the maximum speed of the vehicle except for the cases when it...
is manually switched off. At this stage of the project the structural components of the system have been developed and assembly operations have been carried out. Fig. 1 shows the components layout of the brake system under development in GAZelle NEXT vehicles.

![Intelligent brake system in GAZelle NEXT vehicles](image)

**Fig 1.** Intelligent brake system in GAZelle NEXT vehicles: 1 – hydraulic unit with external control function; 2 – steering wheel angle sensor; 3 – ABS sensor; 4 – front brake rotors; 5 – rear brake rotors; 6 – drive incorporating a vacuum booster; 7 – park brake; 8 – electric circuit; 9 – radar with an integrated control unit; 10 – brake system.

When developing the steering control system an analysis has been carried out of the current steering control systems used in series-produced vehicles equipped with driver assistance systems, directly influencing the steering control. The results of the analysis allowed to come to a conclusion that in order to successfully complete the above tasks it is necessary to use the steering control system with electromechanical power steering. On the first design stage technical specifications for the steering control have been determined, the structural components of the system have been developed and assembly operations have been carried out. Also on this design stage force and kinematic analysis of the steering control has been carried out using MSC ADAMS/View program package.

In the course of modelling turning of the wheels depending on the suspension vertical travel as well as the wheel turning kinematics were researched. Fig. 2 shows general view and model (MSC ADAMS) of GAZelle NEXT vehicle front suspension with steering control under development.
With the modelling results in view a comparative assessment of the steering control under development and the current series-produced steering control with a hydraulic booster was carried out. Kinematic analysis has shown that the amplitude of changing toes at the suspension vertical travel with the steering rack under development and a standard steering mechanism is similar. The amplitude of suspension with a standard steering mechanism was 0.031°, the one with the steering mechanism under development was 0.028°. Because of a smaller steering ratio and a bigger stroke of the steering mechanism under development, maximum wheel turning angles are larger than when using standard steering mechanism. Also this model of suspension with the steering control helped to determine a boosting ratio for the electric power steering. As a result, the electric motor torque dependence upon the steering wheel torque has been obtained. Basing on the modelling results it is possible to make a conclusion about acceptable force and kinematic specifications of the steering control under development. The modelling results will be further used to calculate electric motor specifications and to develop algorithms of the control system electronic unit operation.

5. Developing driver assistance systems
Alongside with developing brake and steering systems with outer control, operations are carried out to seek technical solutions for driver assistance systems. Basing on the former presented analysis of driver assistance systems for light commercial vehicles, an idea has been put forward to develop a number of systems for further mounting on “GAZ Group” vehicle family, with a specific feature for recognizing vehicles, road signs, pedestrians, road marking and traffic lights; warning of possible head-on clash and leaving the traffic lane.

The structural components of the traffic objects recognition systems and warning of possible head-on clash as well as the system of leaving the traffic lane are represented by calculation research module Nvidia Jetson TX2 and optical sensor Basler acA1920-50gc.

Field research of the system efficiency at recognizing road signs and road users with warning of possible crashes was carried out in city traffic with various traffic flow and weather conditions. It should be noted that nowadays the system is able to recognize a number of road signs having a great influence on the safety of traffic (pedestrian crossing, main road, STOP sign, speed limit, etc.). In future the functional of the system will be completed. A fragment of the system test in winter in high humidity is shown in Fig. 3. The system marks the vehicle in the way with red.
The system tests of head-on clash warning were carried out on a special restricted test area. A GAZelle NEXT vehicle having a system of crash warning was tested. The system algorithm is the following: The system recognizes the object in the way by a video camera and estimates the distance to it. Using travelling speed data from CAN-bus of the vehicle the approach speed to the object depending on safety distance to it is estimated at every moment. In case of exceeding the permissible limit, the driver gets a warning signal of a possible crash. It should be noted that the brakeage took place after the signal started. A fragment of successful brakeage in front of the pedestrian manikin is shown in Fig. 4.

![Fig. 4. Successful brakeage in front of the manikin.](image)

The criterion of correct system actuation was a timely signal warning the driver of possible clash with a pedestrian. The calculated accuracy of critical situation estimate was 0.95. The completeness showing the number of timely actuations of the total number of tests was 0.94. The system performance index was 95%.

The warning system operation when leaving the traffic lane is based on video camera data. Next, according to the system operation algorithm, the video image is processed and the system determines the value of deviation from the center of the lane.

The algorithm and evaluation of correct system actuation are shown in [12] There are 3 warning areas: the green one – the vehicle is in the center of the lane (Fig. 5a); the yellow one – deviation from the center of the lane within the range of 0.2 to 0.3 m (Fig. 5b); the red one – deviation from the center of the lane of more than 0.3 m (Fig. 5c). The yellow area is transitional, showing visual information when the driver finds himself in a possible emergency situation. When the red area is displayed, the system warns the driver of an emergency situation by an audio signal. A fragment of the system operation is shown in Fig. 5.

![Fig 5. A fragment of the warning system operation when leaving the traffic lane: (a) The green area, (b) – The yellow area (deviation of 0.2-0.3 m.), (в) – The red area (deviation of more than 0.3 m.)](image)

6. Conclusion
Increasing the traffic safety in the nearest future by implementing driver assistance systems will be an obligatory requirement for car makers according to the analysis of UN ECE normative documents and technical rules of the Russian Federation. Basing on market research of LCV, equipped with ADAS, it is possible to make a conclusion that some car makers are ready to equip vehicles with obligatory driver assistance systems in series.
To keep the market share of the Russian Federation and increase the export potential, the research team of NNSTU after R.E. Alexeev is working together with engineers of Joint Engineering Center of “GAZ” Group to prepare vehicles of LCV category for implementation of driver assistance systems, as well as direct development of ADAS.

Following the project the structural components of intelligent brake system and steering control system with outer control have been developed and assembly operations have been carried out. When developing the steering control force and kinematic analysis has been carried out. Basing on the modelling results it is possible to make a conclusion about acceptable force and kinematic specifications of the steering control under development. The modelling results will be further used to calculate electric motor specifications and to develop algorithms of the control system electronic unit operation.

Also driver assistance systems have been developed and tested with a special feature for recognizing vehicles, road signs, pedestrians, road marking and traffic lights; warning of possible head-on clash and leaving the traffic lane. According to the test the system of vehicle recognition has shown good results, “missing” on-coming, moving in the same direction and parked vehicles only in rare cases. A number of pre-set road signs are recognized satisfactorily but neural network training is necessary to recognize a bigger number of road signs.

Test results have shown that the system of obstacles recognition is efficient, but it can become more efficient when active sensors (radars) to estimate the distance to the obstacle are used. In future when operating intelligent brake system it will be become possible to set brake control action. This solution will automatically provide emergency braking in front of the obstacle thus largely increasing traffic safety.

Test results have shown that the system warning when leaving the traffic lane functions satisfactorily. However, in future it is necessary to consider completing this system with synchronization with turn indicators of the vehicle, the function of tracking the driver’s operating the steering wheel, i.e. the possibility to track if the driver’s hands are on the steering wheel. Also after developing the steering system with external control it is necessary to realize the steering control action to prevent unintended leaving the traffic lane.

Realization and integration of actuating mechanisms with external control and driver assistance systems, meeting UN ECE legal requirements, Russian legislation and customer needs on commercial vehicles GAZelle NEXT will allow to significantly increase traffic safety as well as to keep the Russia’s market share and boost export potential of “GAZ” Group.

Acknowledgments

This research has been carried out with the financial support from Ministry of Education and Science of the Russian Federation in the frame of the complex project "The establishment of the high-tech manufacturing of safe and export-oriented GAZ vehicles with autonomous control systems and the possibility of integration with the electric platform on the base of components of Russian production" under the contract №03.G25.31.0270 from 29.05.2017 (Governmental Regulation №218 from 09.04.2010).

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