Improving the emergency system for a traffic accident

Georgy Rembalovich¹, Vyacheslav Terentyev¹, Konstantin Andreev¹, Nikolay Anikin¹, Vladimir Teterin²

¹Ryazan State Agrotechnological University by P.A.Kostychev (RSATU), 1, Kostychev Str., Ryazan, Russia
²Institute of Agricultural Technical Support, FSBI FNCC VIM, 38/11, Schorsa Str., Ryazan, Russia
E-mail: kosta066@yandex.ru

Abstract. The problem of high traffic loads of vehicles is typical for most countries of the world. The current situation leads to significant delays in vehicles due to traffic jams, which negatively affects the efficiency of cargo and passenger transportation. In addition, the environmental burden is increasing due to increased emissions of harmful substances into the atmosphere. An increase in the number of road traffic accidents and an increase in the severity of the consequences of accidents is another sad factor caused by the increase of cars. In order to reduce the negative aspects associated with reducing road safety in most countries of the world, emergency assistance systems have been developed and are constantly being improved in a case of a car accident. Such systems include the European ECall, NEXCO Central, developed in Japan, ERA-GLONASS, deployed in the Russian Federation and a number of other modern developments. These systems allow real-time monitoring of the traffic situation using GPS navigation and in the event of an accident, timely inform the relevant services. The introduction of an automatic system for reporting a traffic accident can reduce the response time of emergency services and reduce the severity of the consequences of accidents. The article considers the possibility of expanding the functionality of the ERA-GLONASS system by installing additional sensors for shock, moisture, flame and the vehicle’s spatial position after the accident, which will provide emergency services with extended information about the condition of damaged cars after a road accident. Equipping vehicles with such sensors will allow the contact center operator to assess the severity of the consequences of the accident correctly and coordinate the activities of rescuers even before arriving at the scene. Improving the ERA-GLONASS system will have a positive impact on the efficiency of the first aid for victims of a traffic accident and will qualitatively increase its level.

1. Introduction
The level of motorization in most countries of the world has been growing steadily over a long period. At the beginning of 2019, the Russian fleet of motor transport amounted to 51.8 million units, of which 84% were cars. There are about 330 cars per 1,000 people in Russia, which is about 10% higher than the same indicator recorded in 2017. The fleet of light commercial vehicles amounted to a little over 4.1 million vehicles. About 3.8 million units of trucks and 0.4 million units of buses were registered in the country. The average age of a vehicle in operation does not exceed 5-7 years. Every year, the requirements are growing in the dynamic and operational characteristics of the car, its ergonomics and systems that ensure traffic safety. Such an increase in road vehicles negatively affects road safety, since there is a long time interval between the increase in transport units and the...
reconstruction of the existing network of roads, the construction of new roads that meet modern transport and operational characteristics [1]. For example, the length of public roads in Russia at the beginning of 2019 was 1,531,475 km. During 2018, this figure increased by 21.6 thousand km, which corresponded to an increase of 1.4%. In 2019, road works were started in Russia in accordance with the plans of the national project “Safe and high-quality roads”. According to these plans, by 2024 it is planned to expand the network of roads significantly and modernize existing routes, minimizing their accident rate. The national project provides for financing in the amount of 100 billion US dollars. The amount compared with the cost of building roads, for example, in European countries is small, but roads in Russia (in any case, their construction) are cheaper than in Europe. So this amount of investments will allow to form and put into operation another 5 thousand km by of highways by 2024. At present, their combined length in Russia is a little over 2 thousand km.

The accident problem associated with road transport has recently become especially acute due to the mismatch of road transport infrastructure, the needs of the society and the state for safe road traffic, the insufficient efficiency of the road safety system and the extremely low discipline of road users. Infrastructure is currently unable to provide unhindered traffic flow, which leads to unproductive waste of time and increased transport costs in the economic sector [2].

According to the State Inspectorate for Road Safety of the Russian Federation for 2016-2018, 511,225 car accidents occurred on Russian roads. This is about 3-4 times higher than in Europe. For three years, 57,610 people died and 651,367 people were injured as a result of car accidents (Table 1) [3]. According to the NHTSA’s National Center for Statistics and Analysis in the United States for the same period, these figures were 18,340 dead and more than 220 thousand people were injured. As we see road traffic injuries in the United States as well as in Europe are much lower than in Russia [4].

Table 1. Car accident rates in the Russian Federation for 2016-2018.

| Year | Number of car accidents | Indicator change, % | Killed, persons | Indicator change, % | Injured, persons | Indicator change, % |
|------|-------------------------|---------------------|----------------|---------------------|-----------------|---------------------|
| 2016 | 173,694                 | - 5.6               | 20 308         | - 12.1              | 221,140         | - 4.3               |
| 2017 | 169,432                 | - 2.5               | 19 088         | - 6.1               | 215,374         | - 2.7               |
| 2018 | 168,099                 | - 0.8               | 18 214         | - 4.6               | 214,853         | - 0.3               |

According to statistics, the majority of deaths (64%) with victims of traffic accidents occur from the moment of the accident itself to the provision of qualified medical care [5]. This indicates the need of an effective system for informing emergency services about accidents on the roads to be introduced in motor vehicles, as well as improving the system for initiating the occurrence of technical malfunctions of cars and detecting other emergency.

2. Discussion

In connection with the constantly growing fleet of vehicles with almost unchanged transport infrastructure, there is a need not only to optimize the transport process, but also to increase the level of security of its participants. Car manufacturers are constantly improving the design of passive vehicle safety features. At the state level, legislative acts aimed at regulating traffic are adopted. Modern systems for informing emergency services about emergency situations on highways are being developed.

Some scientists [6] provide an analysis of the work of the European telecommunication system eCall, designed to provide automatic notification of a traffic accident, based on accurate GPS positioning and ensuring the prioritization of eCall in a mobile communication network. The importance of the eCall service as the ICT solution for traffic and public safety enhancement is emphasized. Various aspects of the functioning of the eCall system are presented in [7], [8], [9] and [10].

P. Nitsche, J. Olstam et al. [11] consider the possibilities of the PRIMA (ProActive Incident Management) project in the field of improving modern measures to deal with incidents such as traffic accidents, technical malfunctions of cars and obstruction of traffic due to development of proactive
recommendations. Assessment of eCall, C2X or xFCD technologies is carried out in terms of reducing response time to unforeseen traffic situations. Based on microscopic modeling of traffic conditions, its effectiveness is determined. Practical recommendations for managers of road maintenance services are also provided in [11].

S. Hu, T. Wey, M. Lin and N. Hu [12] propose an improvement in the traffic accident data output system. In order to visualize the location of the emergency call signal trigger point, the possibility of using an LCD screen is considered, on which the coordinates of the call will be displayed in real time via GPS, GSM and GIS. Using the GPS protocol data, the construction of the shortest route to the emergency site will be available on the screen. This system will accelerate the terms of assistance to victims by optimizing the route of delivery of necessary rescue equipment.

One of the promising areas of research in the field of development of emergency assistance systems in emergency situations is the use of IP-telephony - Voice over Internet Protocol (VoIP). The results of research are presented in [13], [14], [15] and [16]. The European Union has developed the next generation emergency communications project (EMYNOS). EMYNOS has the aim of designing and implementing the next generation emergency communication system, which allows receiving multimedia calls combining voice and text messages, as well as a video signal. This platform will provide coordination of communication between victims, call centers and rescue services. EMYNOS also provides for call routing, which will ensure redirection of information to the nearest available call center, the location of the call and prevention of erroneous calls.

In [17] and [18], the authors presented the results of testing the performance of emergency services, whose work is based on the use of VoIP. Experts note that the main advantage of using IP-telephony is the ability to combine various types of communication, such as voice, video and text in real time, which will optimize the processing speed of emergency information. Additionally, this platform allows to integrate information received from social networks. As a result, a more complete and detailed informational characteristic of an emergency, based on data from various sources, increases the speed of response and the chances of saving human life in general.

To ensure the prompt transfer of information about a vehicle during a traffic accident to emergency operational services in an automatic mode and in order to reduce the consequences of causing serious harm to life and human health, the Russian technical regulation establishes requirements for the mandatory equipping of vehicles in circulation with a device (system) of emergency services call. In January 2015, the State Automated Information System “ERA-GLONASS” (hereinafter - GAIS “ERA-GLONASS”) was put into commercial operation. The main goal of creating the GAIS “ERA-GLONASS” is to reduce the time of emergency information delivery to emergency services. According to experts, the system allows to save about 4 thousand people every year by reducing the response time to accidents.

At the moment of operation of GAIS “ERA-GLONASS”, a message about a traffic accident is sent to the emergency dispatcher control panel via wireless communication channels in the call prioritization mode via the network of mobile communication operators.

If the communication signal of any of the operators is unstable, the generated data packet will be delivered to the addresssee by SMS message. It is also possible to “call” from your car yourself, without triggering automation, by pressing the SOS button. In this case, the incident card will be generated and transmitted, as in the case of automatic operation, but at the same time voice communication will be established with the operator of the ERA-GLONASS contact center. During the conversation, the operator finds out the details of the incident and, if necessary, transfers the call to emergency services.

OnSatr Corporation, USA has developed a vehicle monitoring system that uses a CDMA communication channel. To determine the coordinates of the scene of a traffic accident, GPS navigation is used. Information from sensors (mainly shock sensors or airbag deployment) is automatically transmitted to call centers. This allows quick informing the rescue and law enforcement agencies about the accident. This system provides voice communication with drivers.
In 2012, Japan launched the NEXCO Central Traffic Management System, developed by Japan Highway Public Corporation. The traffic control center is located in Tokyo. It processes a huge amount of data received from road sensors at minute intervals. This allows to get an actual picture of the traffic situation in real time. On the roads, specialized access points have been installed that provide emergency telephone channels and sensors for transmitting traffic information. For data transmission, a global IP network is used, with the help of which information from sensors is transmitted to the monitors of the traffic control center. Global data transfer is ensured through fiber optic communications, which allows quick processing of phone calls and incoming information.

A number of the main telecommunication systems used in the world and presented in the review inform emergency services about emergency situations on highways. Each system has its own advantages and a number of limitations. In order to expand the functionality of the emergency response system and form the most complete informational picture of the consequences of a traffic accident, it is necessary to additionally equip the vehicle with a set of special sensors.

3. Improving the efficiency of ERA-GLONASS system

As noted in the second section the response mode in most emergency response systems is based on information received from the shock sensor when a collision of vehicles or the operation of the vehicle's passive safety system (usually airbags). Practice shows the high efficiency of this principle of the emergency system, but at the same time the information that is given to the operator of the emergency service is extremely limited. Often a traffic accident is accompanied by other negative aspects, besides the impact itself. As a result of a road accident, the car may catch fire or, if there is a body of water, be flooded with water, as well as tip over on its side or roof. Timely informing the emergency service about the consequences of the accident and about the condition of the damaged vehicle will allow the contact center operator to assess the situation correctly and, if necessary, send a specialized rescue team to the scene.

Figure 2 shows the current arrangement of sensors about accidents and the ERA-GLONASS block.
Figure 2. The arrangement of sensors and the ERA-GLONASS block.

Figure 3 shows the current FORT-112 EG terminal.

Figure 3. Terminal “ERA-GLONASS” FORT-112 EG.

FORT-112 EG terminals fully comply with Order No. 285 of the Ministry of Transport of the Russian Federation and also support the requirements of the ERA-GLONASS system. All terminals on the FORT-112 platform support operation in the EGTS protocol. FORT-112 EG terminals included all the necessary functionality that meets the latest requirements of the regulatory and legal framework.

To increase the efficiency of work, it is proposed to equip the ERA-GLONASS system with additional sensors for shock, moisture, flame, and the position of the vehicle after an accident, which will determine the state of the car after the moment of the accident.
Additional sensors will allow to get more accurate and complete information about the state of the car after an accident, which will lead to a reduction in response time by about 10%.

Suggested additional sensors are as follows:

- fire sensor;
- impact sensor;
- moisture sensor;
- the position of the vehicle sensor.

A fire in a car most often occurs in the engine compartment, as in this zone the highest temperature conditions are achieved. Fires start at the injector or carburetor. In case of a prolonged fire, these units may become deformed, which entails an increase in fuel supply to the burning center. Fire can also occur due to malfunctions in the fuel supply line, injection system and gas tank.

To inform about the fire on time, it is proposed to use a fire sensor. Such sensors are triggered when a bright flame occurs at the initial moment of the fire. Typically, fire sensors also respond to infrared or ultraviolet radiation in case of a fire.

The proposed fire sensor is shown in Figure 4.

![Fire sensor](image)

**Figure 4.** Flame sensor.

When a fire occurs in the engine compartment, the fire begins to spread in all directions the characteristic radiation, which is detected by the sensor. Depending on the model (infrared, ultraviolet), the sensor will determine the type of radiation and send the signal first to the navigation terminal, from where information about the vehicle’s ignition will go to the information collection and transmission unit. The sensor will reduce the response time of special services, since the main damage from vehicle ignition occurs within 15 minutes from the moment of ignition.

The impact sensor (Figure 5) is used in emergency response systems in case of an accident to record the moment of the accident and then recreate what has happened. This sensor is fixed in front of the vehicle. At the time of impact, the sensor processes information about the strength of the external influence and sends the corresponding information to the information collection and transmission unit.

![Impact sensor](image)

**Figure 5.** Impact sensor.

The moisture sensor (Figure 6) will allow obtaining information about the flooding of the car and its quick transfer to the special services, which will reduce the response time and increase the chances of rescue.
The sensor is a small circuit fixed in the car at a height of 20 cm from the floor level. The front surface of the device is its sensitive element. As soon as water enters it, the contact of two media automatically changes the potential difference in the internal circuit, and when a certain value is reached, an appropriate signal will be sent to the unit for collecting and transferring information that the vehicle’s interior is being flooded.

Sensors of the vehicle’s position after the accident (Figure 7) allow to determine the position in which it is located. The sensor recognizes the following vehicle positions: on the roof, on the side, normal position.

As a result of an accident, the impact sensor is primarily triggered, due to which a signal that an accident has occurred goes to the FORT-112 terminal. This device also determines the strength of the impact received by the vehicle as a result of an event. After that, the vehicle’s position sensor is triggered, allowing to obtain information about its location, namely, to determine whether the car is on the roof, on its side or in a normal position. Next, sensors that respond to the ignition of a vehicle or to its immersion in water are triggered.

After analyzing the consequences of an accident, its results are sent to the navigation GLONASS/GPS terminal FORT-112, where they are processed and sent to the collection and transmission unit. The data collection and transmission unit is planned to be used on the basis of the “black box” principle, which is capable of recording and storing data for a period of more than a month, with their subsequent unloading.
In this block, an SMS-message is generated, which is sent to the call-center using cellular or GPS communications. The dispatcher transmits the received traffic accident information to special services. The data generated in the collection and information block are also duplicated and sent to the special services, which will significantly increase the response speed. Therefore, the mortality rate due to road accidents will decrease.

The data collection and transmission unit (Figure 8) must be installed under the hood of the car. During an accident, the unit will be disconnected from the vehicle body according to the principle of airbag deployment.

![Figure 8. Information collection and transmission unit.](image)

A solid fuel gas generator consists of a body, a pyrotechnic squib and a charge of a mixture of sodium azide, potassium nitrate and silicon dioxide. Ignition of a fuel charge comes from a pyrotechnic squib with the release of nitrogen gas. A hybrid gas generator consists of a body, a pyrotechnic squib, a charge of solid fuel and a charge of gas under high pressure (compressed nitrogen or argon).

A bright colored bag is attached to the information collection and transmission unit. After the mechanism is triggered, it will be filled with gas, which will allow to determine the location of the unit or the car quickly, provided that it sank in a pond. Activation occurs upon impact and depends on its strength. If the impact force exceeds a predetermined level, the impact sensors transmits a signal to the control unit. After processing the data of all sensors, the control unit determines the need and response time and provides an electrical signal to turn on the gas generators.

The modernization of the response mechanism of the ERA-GLONASS system will provide the dispatch center with more complete information about the accident that will reduce the response time and the severity of the consequences.

4. Conclusion
The rapid growth of the world fleet is the reason for the emergence of a number of negative aspects associated with the operation of vehicles. The discrepancy between the pace of construction of new roads and the increase in the rolling stock is one of the causes of difficulties in driving both in large megacities and on highways. In addition to increased material costs for the transportation of goods and passengers caused by delays in vehicles on the way, the load on the environmental component of life is increased due to increased emissions of exhaust gases into the atmosphere and the safety of the transport process is reduced.

The issues of improving road safety and reducing the severity of the consequences of road traffic accidents are relevant in most countries of the world. To solve them, automatic emergency response systems have been developed and implemented that allow getting the real-time information about traffic accidents and, if necessary, providing the necessary assistance in a short time. The principle of operation of such systems is almost identical and is based on the operation of sensors when a collision of vehicles or hitting an obstacle with the subsequent transfer of information to emergency services. As practice shows, the amount of incoming information does not allow to fully assess the severity of the consequences of the accident and make the right decision to reduce them.

The modernization of the ERA-GLONASS system proposed in the article by installing additional sensors for monitoring the fire and moisture, as well as the position of the vehicle after the accident, will provide information on the degree of damage and even before rescuers arrive at the accident site, make decisions on how to eliminate its consequences and provide first aid for victims. The installation
of such sensors does not require significant changes in the design of the car and significant material costs, and in the event of a critical situation it can be invaluable in saving lives and reducing the severity of injuries.

References

[1] Dorokhin S, Terentyev V, Andreev K 2017 World of transport and technological machines 2(57) 67
[2] Andreev K, Terentyev V 2019 E3S Web of Conferences 135 02013 DOI: 10.1051/e3sconf/201913502013
[3] https://gibdd.ru/
[4] Terentyev V, Andreev K, Anikin N, Morozova N, Shemyakin A 2020 E3S Web of Conferences 164 03042 DOI: 10.1051/e3sconf/202016403042
[5] Zelikov V, Denisov G, Dorokhin S, Razgonyaeva V, Zelikova N 2019 Studies in Computational Intelligence 826 1081 DOI: 10.1007/978-3-030-13397-9_111
[6] Filjar R, Vidović K, Britvić P and Rimac M 2011 Proceedings of the 34th International Convention MIPRO, Opatija
[7] Pinart C, Calvo J, Nicholson L, Villaverde J 2009 VTC Spring 2009 - IEEE 69th Vehicular Technology Conference, Barcelona DOI: 10.1109/VETECS.2009.5073518
[8] Werner M et al 2009 VTC Spring 2009 - IEEE 69th Vehicular Technology Conference, Barcelona DOI: 10.1109/VETECS.2009.5073434
[9] Cabo M, Fernandes F, Pereira T, Fonseca B, Paredes H 2014 Procedia Computer Science 27 104 DOI: 10.1016/j.procs.2014.02.013
[10] Geuens C, Dumortier J 2010 Computer Law & Security Review 26(4) 385 DOI: 10.1016/j.clsr.2010.03.009
[11] Nitsche P et al 2016 Transportation Research Procedia 14 3360 DOI: 10.1016/j.trpro.2016.05.287
[12] Hu S, Wey T, Lin M, Hu N 2011 Second International Conference on Innovations in Bio-inspired Computing and Applications, Shenzhen DOI: 10.1109/IBICA.2011.62
[13] Manso M et al 2016 IEEE First International Conference on Internet-of-Things Design and Implementation (IoTDI), Berlin DOI: 10.1109/IoTDI.2015.21
[14] Sdongos E, Bolovinou A, Tsogas M, Amditis A, Guerra B, Manso M 2017 14th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, NV DOI: 10.1109/CCNC.2017.8015368
[15] Markakis E, Lykourgiotis A, Politis I, Dagiuklas A, Rebahi Y, Pallis E 2017 IEEE Communications Magazine 55(1) 139 DOI: 10.1109/MCOM.2017.1600284CM
[16] Markakis E, Politis I, Lykourgiotis A, Rebahi Y, Mastorakis G, Mavromoustakis C, Pallis E 2017 Communications Magazine IEEE 55 92 DOI: 10.1109/MCOM.2017.1700345
[17] Subudhi B, Catal F, Tcholtchev N, Chiu K, Rebahi Y, Boerger M, Lämmel P 2020 Journal of Ubiquitous Systems & Pervasive Networks 12(1) 01 DOI:10.5383/juspn.12.01.001
[18] Subudhi B, Tcholtchev N, Chiu K, Rebahi Y 2019 Procedia Computer Science 151 287 DOI: 10.1016/j.procs.2019.04.041