DOI: 10.46299/ISG.2025.MONO.TECH.2.5.4

5.4 Software development road safety system

Every year, about a million people die on the world's roads due to car accidents and about 50 million more are injured. Such statistics are provided in [198] by the Organization for Economic Cooperation and Development (OECD). Moreover, such a level of road injuries is very expensive for the economy of any country, absorbing from 1 to 3% of GDP.

In Ukraine, the situation with vehicle accidents is also difficult. In 2017, Prime Minister V. Groysman announced: "According to the World Bank, economic losses due to road accidents on Ukrainian roads amount to 1.5-2.5% of GDP. We lose $4.5 billion from traffic accidents per year. Unfortunately, road safety issues in Ukraine have never been addressed systematically before" [199].

Road traffic injuries before the full-scale war were the main cause of mortality and disability and especially affected people of young and working age. Treatment of road traffic accident victims now places a great burden on the health and social protection services not only of Ukraine, but also of any country in the world, including the European Union.

But the most important thing is human lives and the grief of many families, which cannot be estimated in hryvnias or dollars.

The rapid increase in the number of vehicles and the increase in the intensity of road traffic leads to an increase in the number of road accidents and their negative consequences in our country as well. "Unfortunately, in Ukraine the level of mortality and injuries as a result of road accidents is one of the highest in the European region. Over the past six years, about 170,000 road accidents with victims have been registered, in which 26,500 people died and 209,000 were injured," noted A. Gavrilyuk, Deputy Director of the Medical Department, Head of the Department of Medical Care for Adults of the Ministry of Health of Ukraine [200].

For example, for the years before the full-scale war: "Since the beginning of this year, 54,500 road accidents have been registered. This is 12.1% more than last year.

Every eighth road accident involves victims: 723 people died, more than 8,000 were injured. The number of road accidents involving public transport drivers has doubled," said I. Prokhorenko [200], Deputy Head of the Department of Preventive Activities, Head of the Road Safety Department.

All of the above allows us to assess the importance and globality of the problem of reducing road transport accidents. The globality of the above-mentioned problem also determines the global level of efforts to solve it. This is being done by public organizations, national governments, and the largest international structures.

The OECD system includes the International Transport Forum, which is a global platform for policymakers in the transport sector.

Ukraine is a member of this body. In 2004, the OECD and the Transport Forum established the Center for Transport Research, whose specialists, together with specialists from the World Bank, the World Health Organization and the FIA (International Automobile Federation), in 2008, following three years of joint work, issued the report "The Pursuit of Zero: High Goals and a Systemic Approach to Traffic Safety"[198].

This 300-page work is the quintessence of the most interesting research, analysis, recommendations and forecasts for transport policy, which are worth studying separately, especially at a transport university. Since then, such global research has not been conducted, so we will rely on the data obtained. Let us dwell on one most important aspect of this research.

Having collected and studied data on road safety levels, current road safety strategies, costs associated with road accidents and costs of improving road safety, the experts concluded [198] that road safety can be improved in the short term by implementing a range of measures:

1) enforcing existing speed limits;

2) reducing drunk driving;

3) using seat belts;

4) making roads and roadsides safer;

5) making vehicles safer;

6) reducing risks for novice drivers.

The report examines these issues in great detail, which is beyond the scope of this work.

The Forum experts consider compliance with the speed limit on roads to be a key problem: "Speed is a central factor in road safety problems. It affects both the risk of getting into an accident and the consequences of an accident."

The correlation between accident rates and vehicle speed (Fig. 1) is studied in [198].

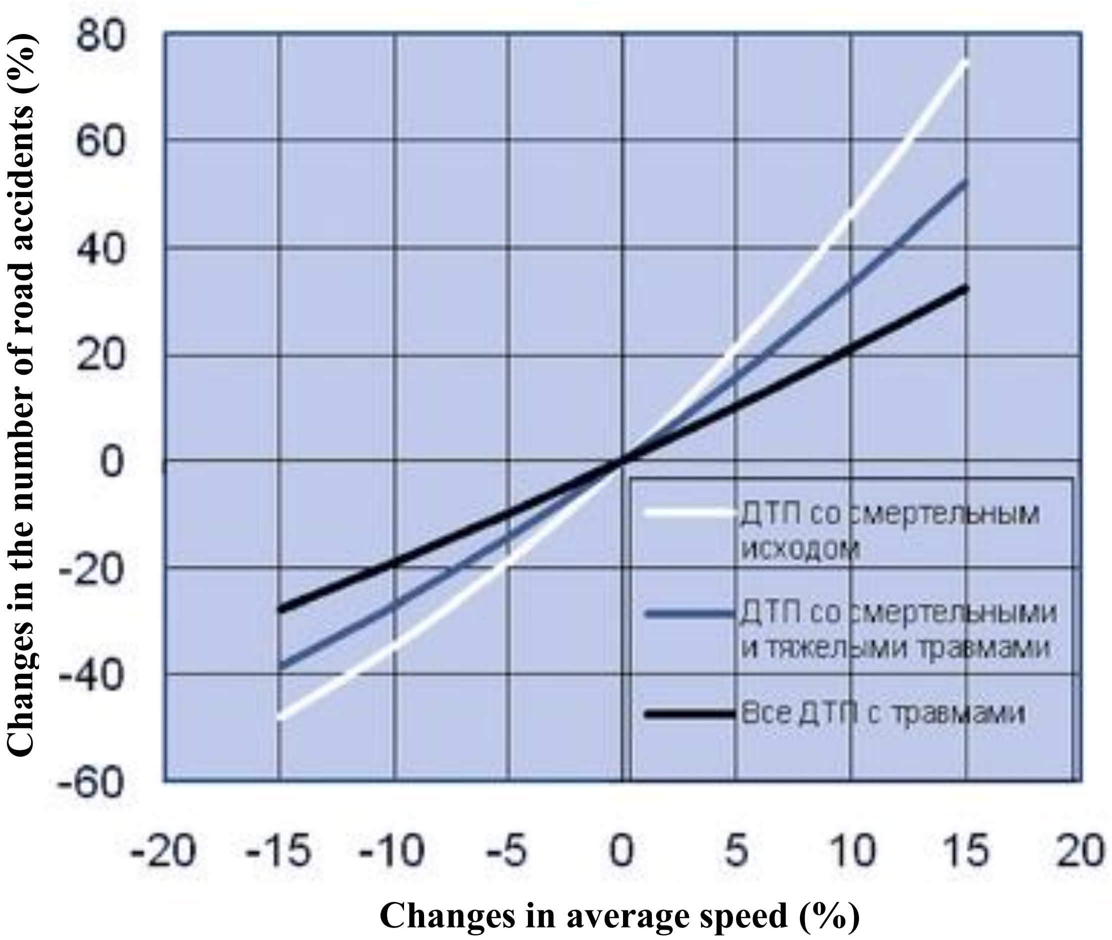

Figure 1. Correlation between accident rate and vehicle speed

According to this model, a 10% reduction in average speed leads to a reduction in the number of fatal accidents by almost 40%, which is confirmed by studies by many independent experts, references to whose works are given in [198].

According to the conclusions of the OECD report on speed management, an effective speed management program should, among other things, include improvements in vehicle design, including the use of information technology.

"Given the enormous positive potential of new technologies, their widespread implementation is strongly recommended," this is the conclusion of the experts, which is interesting for us [198]. In this area, they advise the following:

1) all new cars should be equipped with manually adjustable speed limiters and, where possible, with voluntarily installed Intelligent Speed Adaptation Systems (ISA);

2) to ensure the results of the application of ISA technologies, the state should create digital databases of speed limits with private partners that can generate electronic maps and distribute them to warn drivers about exceeding the permissible speed;

3) it is necessary to make the installation of ISA systems mandatory by law.

The ISA intelligent speed adaptation system should be installed in any vehicle (Vehicle) to ensure that the VHB complies with the established speed limit by reading the speed limits along the route.

Thus, experts from the International Transport Forum consider the main way to reduce accidents and fatalities on roads to be a reduction in vehicle speed, including mandatory ones.

Developing and implementing the recommendations of the Report [198], the European Transport Safety Commission (ETSC) plans to oblige automakers to equip all cars with a device that automatically and forcibly limits the speed (VV) in accordance with road signs from 2020 [201]. But we see that these plans were not implemented.

The above-mentioned device uses a video camera that recognizes speed limit signs, as well as navigation data, which prescribes the speed limit on different roads. The speed limit device (SLD) should learn about the location of the car using the global positioning system (GPS). The device will compare this data and will not allow the car to move faster than the permitted speed.

Presenting the European Commission’s future plans to the European Parliament in Strasbourg, then-Transport Commissioner Violeta Bulc called Intelligent Speed Assistance (ISA) a revolutionary technology. She also said that when the proposed safety measures are implemented, “the EU will become a leader in road safety” [202].

It is obvious that the EU is implementing the recommendations of the International Transport Forum on reducing road accidents, including by introducing mandatory speed reductions in accordance with existing restrictions. However, the specific implementation of this plan by road and automotive industry experts has not yet begun (with some exceptions). In addition, as far as we know, there are no plans to digitize our country's roads in terms of speed limits, which is a necessary condition for the implementation of the ISA system.

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), to which Ukraine has also joined, is a direct implementation of the recommendations of the Report [198]. In accordance with the strict technical requirements of these Rules [203], a vehicle transporting dangerous and explosive cargo is required to be equipped with a special system – a "Speed Limitation Device". In the UNECE regulations No. 89, paragraph 2.6, subparagraph 1, it says: "The Speed Limitation Device means a mechanism that in one way or another reduces (limits) the amount of fuel supplied to the engine. This leads to limiting the speed of the vehicle to a given regulated value."

Vehicles carrying dangerous goods and subject to these requirements for the presence of a vehicle speed limitation device are trucks (rigid frame vehicles, as well as tractors for semi-trailers) with a maximum mass of more than three and a half tons.

According to paragraph 9.2.5 of the ADR, the SLD device must be adjusted so that the vehicle speed does not exceed 90 km/h, taking into account the regulatory tolerances for the device, within 5 km/h in the direction of increase or decrease.

One more point should be taken into account. Modern cars (cars and trucks) are most often equipped with a factory device built into the engine control system, which limits the maximum possible speed. But this is not what the rules for the transport of dangerous goods require. The fuel cut-off valve should be a separate, independent mechanical and electrical system that mechanically blocks the fuel supply to the required limit.

The principle of operation of the fuel cut-off valve is based [199] on the operation of a solenoid valve on the fuel supply line, which limits the further speed gain of the vehicle. The MCU (microprocessor control unit) receives the corresponding signals from the speedometer or, depending on the vehicle, from the speed sensor on the gearbox. When the maximum set speed is reached, the MCU transmits a signal to the solenoid valve for controlling the fuel supply. When the signal is received, the valve closes, thereby limiting the fuel supply. The valve is set to exactly the amount of fuel supply that is necessary for a specific vehicle to achieve a given speed.

The use of a speed limiter on trucks carrying dangerous goods is also a direct implementation of the recommendations contained in the Report [198], but for a rather narrow category of cars. Of course, it is possible to equip all cars with such devices, including passenger cars. Without a doubt, this would significantly reduce the accident rate and mortality on the roads. So we can recommend that the state move in this direction.

But the speed limiter has a serious drawback: it is necessary for either the owner himself, or the driver of the car, or some authorized person to set the speed limit in the device. And this always leaves room for either error or deliberate violation. In addition, there is a difficulty in changing the permissible speed values, for example, when a car enters the city from a highway.

Manufacturers and dealers of conventional motor vehicles are unlikely to give permission to interfere with the car without voiding the warranty, which makes it practically impossible to use such technology in conventional cars.

Modern cars have been using continuous gasoline injection control systems or distributed systems for quite a long time, when fuel is supplied through a separate nozzle (injector) for each cylinder. With the development and miniaturization of microprocessor technology, it has become possible to control the process of fuel supply to the injectors using quite complex algorithms in accordance with the signals of numerous sensors (air flow, crankshaft position, exhaust gas temperature, and others). These algorithms take into account all possible requirements and limitations on the operation of the car engine in different modes and are implemented by engine control units or on-board computers. Fig. 2 shows a version of such a system developed by Bosch [205].

The system operates as follows: the air flow sensor measures the instantaneous air flow and uses its lever to control the plunger of the fuel metering device, which in turn directs to the injectors an amount of fuel that corresponds to the measured air flow. With a constant pressure in the upper part of the metering device, the pressure in its lower part is regulated by an electrohydraulic pressure regulator controlled by the controller.

The controller also receives signals from the coolant temperature sensor 11, the throttle potentiometer and switch, and from the ignition coil about the crankshaft rotation speed.

Based on these signals, the controller identifies the engine operation and changes the strength and direction of the current passing through the electromagnet winding of the electrohydraulic regulator, and by moving the spool, changes the cross-section of the through hole connecting the upper and lower chambers of the fuel metering device. If the spool fully opens the hole, the pressure in the upper and lower chambers will become the same, the membrane will abut against the seat of the distribution valve and the fuel supply will stop.

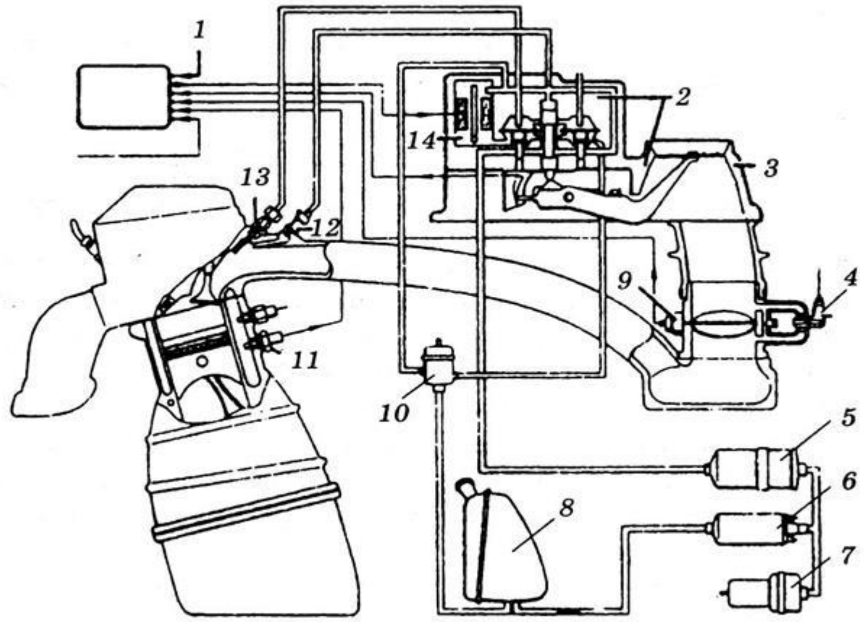

Figure 2. Functional diagram of the fuel supply control system to the engine of a car from the company "Bosch": 1 - electronic control unit; 2 - fuel dispenser-distributor; 3 - air flow meter; 4 – valve of additional air supply; 5 - fuel filter; 6 - fuel pump; 7 - fuel accumulator; 8 - fuel tank; 9 - throttle position switch; 10 - fuel pressure regulator in the system; 11 - coolant temperature sensor; 12 - starting nozzle; 13 - working nozzle 14 - electrohydraulic controlled pressure regulator

The coolant temperature sensor provides the controller with information about the thermal state of the engine, which is used to adjust the quantity and quality of the combustible mixture during cold engine start-up, during warm-up, in acceleration mode, etc. At the same time, an additional portion of air is supplied through the regulator 4 and an additional amount of fuel through the starting nozzle 12.

This system (like other similar engine control systems) allows, when operating according to a certain algorithm or if necessary, to reduce or stop the fuel supply to the nozzles and thus reduce the speed or completely stop the car. But it is not designed to automatically influence the speed of the car, and even more so to permanently limit the speed in accordance with traffic rules.

The analysis showed that at present the problem of limiting the speed of the vehicle so that it does not exceed the speed value permissible on a given section of the given road has not been solved. And this, according to experts of the Transport Forum [198], is in many ways the key to reducing accidents on highways. Although the prerequisites for performing such a task, as the analysis has shown, are. These are control systems for the operation of an automobile engine with microprocessor-based regulation of fuel supply to the engine injectors, and the rapid development of microprocessor and information technologies, and other achievements of science and technology.

Based on the analysis, we formulated the goal of the research, which is to create a method and device for remote forced speed limitation of cars on roads within the city and outside it in accordance with the speed limit adopted in a given place.

In order to implement the proposed method of remote forced speed limitation of a car (RFSL), it is necessary to solve a number of tasks:

1) develop a functional diagram of the device for RFSL;

2) develop a schematic diagram of the device;

3) assemble and test a full-scale model of the device in laboratory conditions to experimentally confirm the validity of the proposed method of remote forced speed limitation of a car;

4) test the device on a car using a reference signal;

5) resolve the issue of the possibility of using carrier frequencies of mobile operators to transmit a limiting signal;

6) investigate the possibility of using an existing or creating a special GSM transmitter to transmit a limiting signal;

7) in the case of using a special GSM transmitter or a transmitter of another type, develop a scheme for covering all roads in Ukraine with these transmitters.

Each of these tasks in itself is a separate serious research work. The author sees the tasks set as quite broad, especially in terms of implementation in real transport systems and conditions (on the streets and roads of the surrounding areas). These are the frequency of transmitters emitting a control signal, and algorithms for controlling fuel supply to the engine, and the safety of the car and the safety of the driver, passengers and cargo of the vehicle, and the transmission of a limiting signal, and much more.

Therefore, the task of this article is to formulate a concept for improving safety on Ukrainian highways in terms of reducing vehicle speeds to the maximum permissible values for these highways (the concept is outlined and substantiated above), as well as to develop a functional diagram of the RFSL device.

The method of improving road safety by means of remote forced speed limitation of vehicles on roads within the city and outside it in accordance with the speed limit adopted in a given place consists in the constant transmission of a signal via mobile or any other communication networks that carries information about the speed limit in a specific place on a specific highway. This signal, after reception, is processed in the microprocessor control system for fuel supply to the car engine according to a certain algorithm in order to maintain the speed of the car, which does not exceed the limit value.

Moreover, the driver of the vehicle could not even if he wanted to bypass such a restriction. For example, within the city limits 50 km / h, and on highways 90 km / h.

The formal and technical prerequisites for implementing the proposed method of increasing safety on the roads of Ukraine and, perhaps, any country in the world are the following:

a) huge moral and material damage from accidents on the roads and the desire to minimize it among the authorities, the expert community and civil society;

b) the development of microprocessor technology and mechatronics in transport;

c) total coverage of the roads of Ukraine with the GSM-telephony network;

d) the development of mobile telephony, including 4G and 5G technologies.

The functional diagrams of the RFSL device are designed for the main types of engine control systems in modern cars (with microprocessor control), which differ in some details. These are differences in the method of regulating the fuel supply to magnetoelectric injectors, in the types of control devices, which differ in speed and volume of operational and permanent memory, which entails a different approach to the algorithmization of car control processes, etc. In Fig. 3, a generalized functional diagram of the method of remote forced speed limitation of a car device is shown, which can become, in our opinion, universal for all types of modern cars.

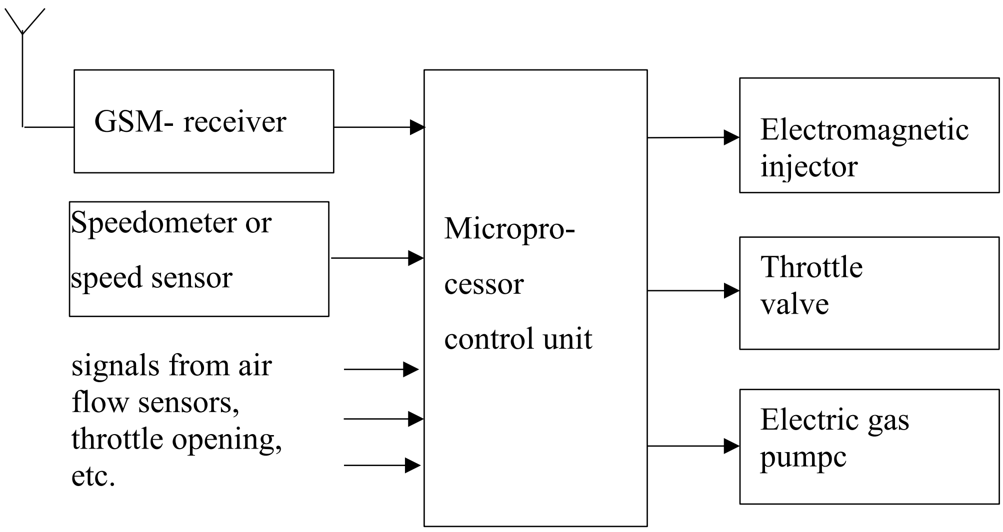

Figure 3. Functional diagram of a device for remote forced vehicle speed limitation

The method of remote forced speed limitation of a car works as follows. The GSM receiver (possibly another radio receiving device) constantly receives a signal that carries the speed value permissible on a given road. In the microprocessor control unit (MCU), this value is compared with the signal from a digital speedometer or speed sensor, which is the current value of the car's speed. The discrepancy between these two signals or the excess of the car's speed over the permissible speed value on a given road serves as the basis for recalculating the amount of fuel required to be supplied to the injector by the MCU block according to the programmed algorithm, as well as for reducing the duration of the injector opening. Reducing the fuel supply to the engine cylinders leads to a decrease in the car's speed to acceptable values. The described process of forced speed limitation of a car is quite complicated, because it is necessary not only to reduce the speed of the vehicle, but to do this without harm to all road users, without exception, for the economy of the driving cycle and other indicators. It will be necessary to take into account by the microprocessor control unit all the information coming from various sensors and to form, taking into account this information, a control effect on the electromagnetic injectors. And this, in turn, will cause some changes in other algorithms and programs embedded in the MCU.

Thus, a method for reducing accidents on highways in the part that depends on the speed regime of vehicles has been proposed and developed. The method and device that implements it remotely and forcibly limit the speed of vehicles depending on the value of the permissible speed on a given section of the road.

When creating a method for remote forced speed limitation of a car, an analysis of existing means and devices for forced speed limitation was carried out, which showed the absence of remote solutions to this problem at the moment.

Remoteness is carried out by receiving a signal on each car that carries the value of the permissible speed on a given section. Such a signal is transmitted either by mobile operator stations. The standard microprocessor control units on each car compare the value of the limiting signal with the current speed value, and if the latter exceeds the limit value, reduce the fuel supply to the engine cylinders.

We have developed functional diagrams of devices for implementing the proposed method on the main types of engine control systems in modern cars. As an example, a generalized universal functional diagram of a device for remote forced speed limitation of a car belonging to the economy class, i.e. minimally equipped with electronic means and devices, is given.

As a continuation of this research, the author is engaged in the manufacture of an experimental device RFSL and its full-scale tests with imitation of a limiting signal from mobile communication base stations. Of course, during martial law this is almost impossible, because the author lives in Kharkiv. All workshops in higher educational institutions are not functioning. Now we are testing the functioning of the device when interacting with a signal that will be emitted by real stations. Unfortunately, the full-scale war slowed down these works as well. You have to do this at your own expense in your own car. This requires interaction with the management of the mobile operator to allocate a small network resource for testing the device. Under martial law, this is impossible. In the future, the allocation of a frequency for transmitting a restrictive signal will need to be decided at the regional or state level, because this will allow us to offer our society and the state a way to radically improve road safety (of course, together with other measures in this direction), which will avoid huge human casualties and material losses.

Let's return to the study [198]. Having collected and studied data from a hundred countries on road safety levels, modern strategies for the latter, on the costs associated with road accidents and the costs of improving road safety, experts concluded that the level of road safety can be increased in the short term by solving two main problems:

1. Enforcing compliance with existing speed limits;
2. Reducing drunk driving.

We have already made some developments on the first problem, as discussed above. Now let's turn our attention to solving the second problem - making it impossible for drivers to drive while intoxicated.

The risk of a road traffic accident increases with the driver's blood alcohol content, and the higher the alcohol level, the greater the risk. Driving under the influence of alcohol, above the legal limit, is a registered factor in fatal accidents in most countries, and its share in all driver fatalities can range from relatively low, around 5% in countries such as Mexico, Bulgaria, the Czech Republic, Portugal and Romania, to high, between 30 and 40% in countries such as Canada, Slovenia, the

United States, France, Ireland and New Zealand [198]. Around 25% of all road deaths in Europe are alcohol-related.

In order to reduce the number of accidents caused by drunk driving, the installation of anti-alcohol interlocks on the cars of first-time but dangerous offenders and all repeat offenders has been introduced in the USA and some European countries, in combination with a driving skills improvement course and a medical counseling program in case of suspected alcohol dependence.

Interlocks have significant potential to reduce this problem, especially if they are installed almost immediately after the offense and if the installation is accompanied by medical counseling and treatment programs for alcoholism.

Experts [198] believe that there is a potential to completely eliminate drunk driving as a road safety problem if anti-alcohol interlocks are installed on all vehicles, and not just on cars of repeat offenders. However, in most countries, before introducing a mandatory requirement for the installation of such interlocks on all cars, it is necessary to convince the general public of its value and technical reliability.

A conscientious driver of a vehicle is not limited in his capabilities by anti-alcohol blocking, and he will probably be understanding of some possible inconveniences. After all, a drunk driver is a potential threat to any citizen of Ukraine, including family members of a conscientious driver.

But when developing methods for anti-alcohol blocking of cars and designing devices for their implementation, it is necessary to take into account all possible negative consequences of this intervention in the design of the car.

On the other hand, the design of such devices should ensure the unambiguous detection of drunk drivers and not allow these drivers to drive a vehicle.

A search in the Ukrainian information space for anti-alcohol blocking of vehicles did not yield any results - no information on this topic was found. A patent search in Ukraine also did not yield any results - no copyright certificates on this topic were found. In general, strangely enough, this problem (as well as the problem of forced compliance with existing speed limits by drivers of vehicles) is not addressed not only in Ukraine and Russia, but also in many other countries of the world.

Thus, the analysis showed that at present the task of making it impossible for drivers to drive vehicles while intoxicated has not been solved in Ukraine. And this is precisely what, according to experts of the Transport Forum [198], is largely the key to reducing the accident rate on highways.

The prerequisites for fulfilling such a task are, firstly, the desire of society to live in a safe environment, and, secondly, the rapid development of microprocessor technology and information technologies.

Based on the analysis, we formulated the goal of another study (for this work), which is to develop a method and device for making it impossible for drivers to drive vehicles while intoxicated.

In order to implement the proposed method of anti-alcohol blocking based on modern information technologies, it is necessary to solve a number of problems [202]:

1) formulate a concept for improving road safety in Ukraine in terms of preventing drivers from driving while intoxicated;

2) develop a functional diagram of a device for anti-alcohol blocking of vehicles;

3) develop an electrical schematic diagram of such a device;

4) assemble and test a full-scale sample of the blocking device in laboratory conditions to experimentally confirm the operability of the proposed method;

5) test the device on a car at reference values of the alcohol content in the driver's blood;

6) resolve possible issues regarding the use of a video camera in this device for driver identification.

It is possible that in the course of solving these problems, other problems will arise.

Solving each of these problems in itself is a separate serious research work. We see the tasks set as quite broad, especially in terms of implementation in real vehicles. This is the calibration of the sensitive element of the anti-alcohol blocker, driver identification, an algorithm for safely stopping the vehicle and stopping the fuel supply to the engine, the safety of the vehicle and the safety of the driver, passengers and the vehicle's cargo.

Therefore, the primary task is to formulate a concept for improving safety on the roads of Ukraine in the part caused by the driving of vehicles (Vehicles) by drunk drivers, develop a method for preventing such driving and design and test a device implementing such a method.

The method for improving road safety by preventing the driving of vehicles by drunk drivers is as follows.

In the cabin of the vehicle, in the immediate vicinity of the driver, there is a sensor that recognizes alcohol vapors in the air. The corresponding electrical signal from the sensor is sent to the microprocessor, which measures the signal level from the sensor and, in accordance with the action program, performs certain procedures.

The content of these procedures depends on many factors. Some countries (and even some states in the US) have laws that allow the use of ignition interlock devices as an alternative to punishment for drunk drivers. The US proposes the installation of ignition interlock devices (IEDs) with different installation thresholds. The criminal process thresholds for installation requirements vary from a minimum blood alcohol level (e.g. 0.2%) to a repeat offense, with about half of the states requiring installation on a first offense.

Most states have a “zero tolerance” level (set either at a level corresponding to cooking alcohol or measurement errors). In general, the US has developed and detailed legislation relating to anti-alcohol IEDs. Ukraine may borrow some of its provisions if it adopts the concept of using anti-alcohol interlock devices. But such measures are not even discussed in Ukraine today.

Some politicians in Sweden, Japan, Canada, the United States, and other countries are calling for such devices to be installed as standard equipment on all cars sold. Problems that need to be addressed, in addition to consumer and voter acceptance of such calls, include the difficulty of obtaining accurate measurements and the need to achieve high reliability so as not to interfere with the usability of the vehicle [198].

In Ukraine, the situation with accidents caused by drunk driving is no better. According to the Patrol Police, 1,400 road accidents due to drunk driving were recorded in the first 10 months of this year. This is 25.2% more than in the same period last year. As a result of these accidents, 1,360 people were injured and 78 died. For comparison, the number of people killed as a result of drunk driving in 2018 was 87 [201].

Therefore, in our opinion, it is necessary to introduce anti-alcohol ignition interlock devices by law in Ukraine. All increases in the amount of fines for driving a vehicle under the influence of alcohol for many years have not brought any results. At the same time, explanatory work with society is necessary regarding all aspects of the use of anti-alcohol ignition interlock devices.

The previous section concluded that it is necessary to introduce mandatory equipment of all cars in Ukraine with anti-alcohol interlock devices, which should make it practically impossible for drunk drivers to drive vehicles.

This section proposes the most optimal method of such blocking. The task is not so simple, because blocking the ignition, for example, while the vehicle is moving, can lead to unpredictable consequences not only for the blocked vehicle, but also for vehicles that are under the control of conscientious drivers.

Having analyzed several possible options for the functioning of anti-alcohol ignition interlock devices, we settled on the following method.

The sensor that diagnoses alcohol vapors is installed in the place closest to the driver's face. Since modern alcohol vapor sensors are small in size, the installation location can be both the steering wheel and the dashboard.

In the USA, devices containing such sensors have dimensions of approximately 100×50×, have an exhalation fitting and are connected to the dashboard with a hose 70-80 cm long. In our opinion, this design provides an opportunity for abuse. For example, the front passenger can exhale into the anti-alcohol blocking device instead of the driver. Thus, additional protective measures are required for the functioning of such a device.

In the anti-alcohol blocking method we propose, such a falsification is much more difficult, because the alcohol vapors exhaled by the drunk driver must inevitably reach the sensitive element of the sensor, mounted, for example, in the steering wheel rim.

If alcohol vapors are present in the air exhaled by the driver, the anti-alcohol blocking device must open the electrical circuits of the ignition and starter power supply, as a result of which the vehicle will not be able to move off.

To exclude other possible cases of driving a vehicle by drivers under the influence of alcohol, the alcohol vapor sensor must be periodically turned on when the engine is running, that is, while the vehicle is moving. Or imagine a situation when someone from the acquaintances of a drunk driver starts the engine, and then transfers control of the vehicle to the latter. Such cases must be taken into account and excluded by software.

On the other hand, the software of the blocking device must take into account the safety requirements of both the blocked and surrounding vehicles. When blocking, for example, there should be no sudden stop of the vehicle while driving. In this case, the car must smoothly reduce speed to a complete stop with the inclusion of sound and light signaling.

Fig. 4 shows a structural diagram of the developed method for reducing road accidents.

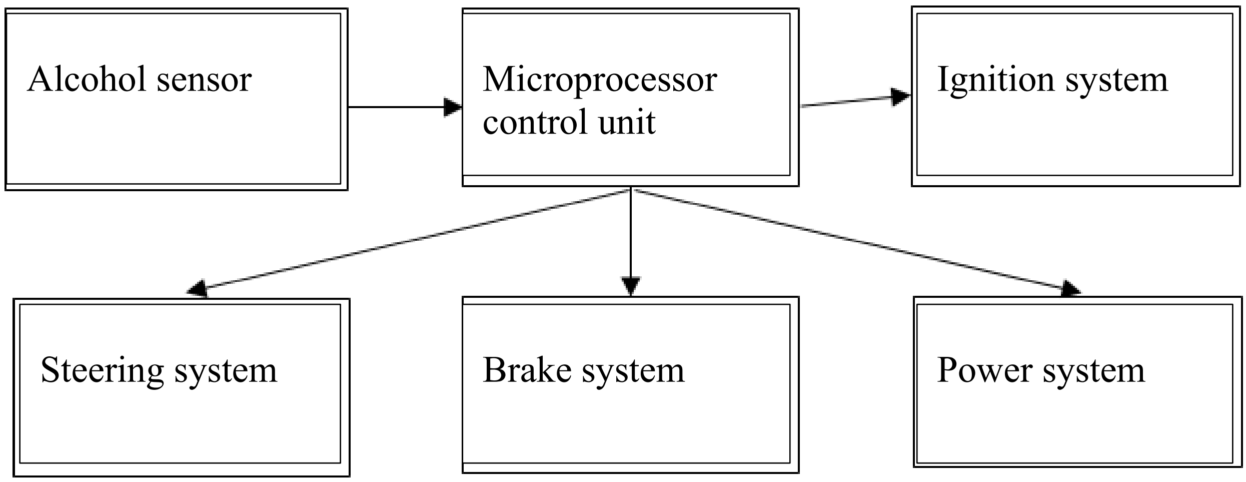

Figure 4. Block diagram of a method for preventing drunk drivers from driving vehicles

The above diagram is enlarged and consists of the main functional blocks. In case of receiving a signal from the sensor about the presence of alcohol vapors in the air exhaled by the driver, the microprocessor control unit generates a signal to open for the normally closed relay contacts that provide electrical power to the starter, ignition and electric fuel pump of the vehicle, which prevents the engine of the latter from starting, thereby preventing drunk driving with unpredictable consequences.

Thus, the method of anti-alcohol blocking of the vehicle proposed by us consists in unconditionally blocking the ignition and blocking the start of the vehicle engine according to the signal from the sensor about the presence of alcohol vapors in the air exhaled by the driver, in order to prevent the vehicle from being driven by a drunk driver. This will require some changes in the software of the microprocessor control unit of the vehicle.

The formal and technical prerequisites for implementing the proposed method of increasing safety on Ukrainian roads are as follows:

1) huge moral and material losses from accidents on roads and the desire to minimize them among the authorities, the expert community and civil society;

2) the development of microprocessor technology and mechatronics in general and in transport separately;

3) total coverage of Ukrainian roads with the GSM-telephony network and the Internet.

Thus, a method of reducing accidents on roads in the part that depends on the driving of vehicles by drivers in a state of intoxication has been proposed and developed.

The purpose of this section is to develop and design a device that implements the proposed method of reducing the accident rate of vehicles in the previous section by prohibiting drivers from driving them in a state of intoxication. This is about the mandatory equipment of all cars with such devices, which should be established at the legislative level. Such a device can be designed for any vehicle with varying degrees of interference with the vehicle's equipment. The legislators will decide which design option to choose and what level of interference there should be with the vehicle's design and software.

It is obvious that additional research and testing of the developed devices will be required in order to select their optimal design and minimize possible emergency situations associated with the use of such devices while the vehicle is moving.

There are enough open questions regarding the use of devices for anti-alcohol blocking of vehicles. This includes equipping already operated vehicles with such devices, and the algorithm for stopping a moving vehicle in which alcohol vapors are detected in the cabin air, and many other questions. The scope of this study does not allow us to dwell on these issues in more detail. This is a completely different volume of funds for research, equipment, and time for their implementation.

We have taken certain steps in this direction. We have begun developing software for an anti-alcohol blocking device for various depths of implementation into conventional factory software. Below is the development of an entry-level anti-alcohol blocking device. The developed device implements the above-described method of anti-alcohol blocking of a vehicle without interfering with the latter's software, therefore this device can be installed on cars that are already in operation, without interfering with their design, as well as on cars of outdated designs that do not have microprocessor control units.

Fig. 5 shows a structural diagram of an anti-alcohol blocking device that implements the above-proposed method of reducing accidents on highways. The device is developed on the basis of a microprocessor and is autonomous in relation to the vehicle on which it is installed.

The developed device works as follows. According to the signal from the sensor about the presence of alcohol vapors in the air of the vehicle cabin, the microprocessor generates a control signal for a relay with normally closed contacts, through which the starter electric current passes. The relay contacts open, making it impossible to start the vehicle engine. In the same way, for safety reasons, the electric current supply to the gasoline pump is made impossible.

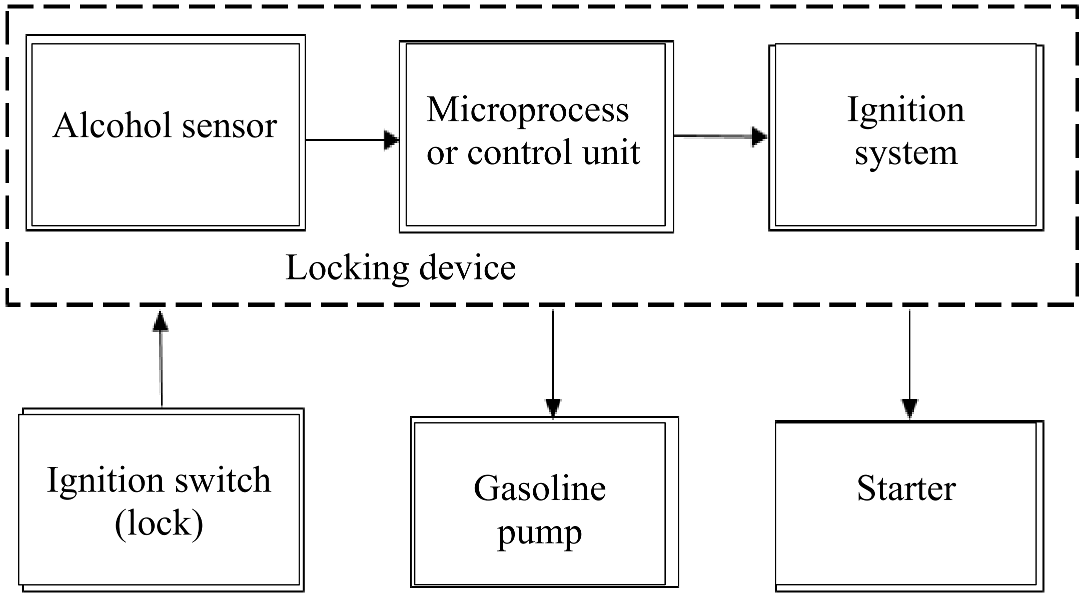

Figure 5. Block diagram of the anti-alcohol interlock device

The anti-alcohol blocking device was implemented by us on the basis of the Arduino microprocessor technology platform [203]. The choice of this platform is due to its wide distribution, the availability of a huge number of various sensors, microprocessors, various related radio electronic elements on sale, a relatively low price, the presence of a large library of programs, etc. The use of the C ++ programming language allows the developer of devices on the Arduino platform to create software for projects himself. Microprocessors are programmed using a special software environment.

In addition, this platform has been designed for convenient installation of radio elements without soldering contacts. This point is especially important for us, since in the future it is planned to use this development as a basis for laboratory work when studying, for example, the discipline "Information technologies in vehicle control" or the discipline .

The Arduino Uno microprocessor system version R3 was chosen for the developed device. This is a printed circuit board based on the 8-bit ATmega328P microcontroller [203] (Fig. 6). Thus, the Arduino Uno board is an expansion board or an ATmega328P developer board.

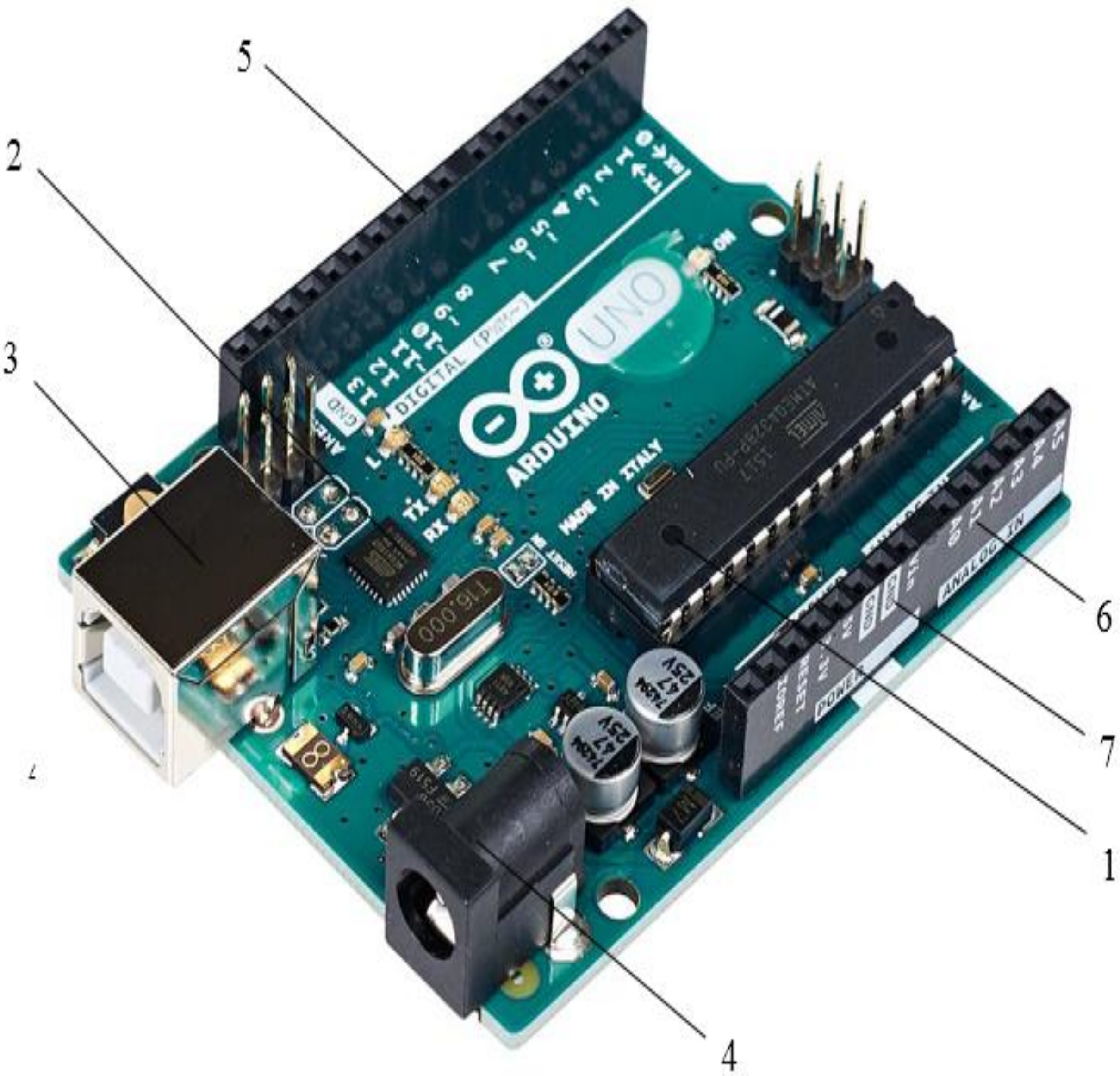

Figure 6. Arduino Uno microprocessor system version R3: 1 – ATmega328P microcontroller; 2 – ATmega16U2 microcontroller; 3 – USB port of the board; 4 – power connector; 5 – 14 digital outputs; 6 – 6 analog outputs; 7 – power outputs

There is another auxiliary microcontroller ATmega16U2 on the board. Arduino Uno has 14 digital and 6 analog inputs/outputs (pins) adapted for removable mounting, a 16 MHz quartz crystal resonator, a USB output, a reset button, an output for connecting a power adapter (7-12 V) or a 9 V battery, a connector for programming the controller. In addition, the board has three ground outputs (GND), one output for 5 V, one for 3.3 V and a Vin pin for connecting an external power source or for obtaining a voltage exceeding 5 V if the board is connected to an external power adapter (via USB, the power connection is limited to 5 V).

The ATmega328P microcontroller for Arduino Uno comes with a program loader, which allows you to download the program code without using an external programmer, but directly from a regular personal computer via the USB connector.

The MQ-3 gas sensor [204] was used as a sensor, designed to register and measure the concentration of alcohol vapor in the air (Fig. 7).

Figure 7. MQ-3 alcohol vapor sensor

For use as a starter power circuit breaker in the anti-alcohol interlock device, the HLS-13F-2 relay [205] (Fig. 8) was selected, designed for DC circuits with a voltage of 12 V and a current of up to 10 A with normally closed contacts. These parameters correspond to the currents and voltages that are possible when the device is operated in real vehicle conditions.

By combining the above components in accordance with the developed electrical circuit (Fig. 9), an anti-alcohol blocking device was developed for vehicles that do not have an electronic control unit.

The principle of operation of the anti-alcohol blocking device is as follows.

Figure 8. HLS-13F-2 relay

The basis of the device is the Arduino Uno printed circuit board with the ATmega328P microcontroller installed. The circuit (Fig. 9) shows only those contacts of the board (pin) that are involved in the operation of the device. They are easy to identify when installing the device by clearly visible marking (Fig. 6).

The MQ-3 sensor, placed in the car interior as close as possible to the driver's face and receiving 5V power from the GND and 5V contacts of the Arduino Uno board, constantly analyzes the composition of the air in the cabin. If alcohol vapors appear in the air, the MQ-3 sensor outputs a signal to pin A0 for the microcontroller.

Based on this signal, the microcontroller, in accordance with the program entered into it, generates a control pulse to operate the relay and transmits it to the digital output D10.

The relay operates and opens the starter power supply circuit, making it impossible for a drunk driver to start the engine. Along with the starter power supply circuit, the ignition coil power supply circuit may also be open.

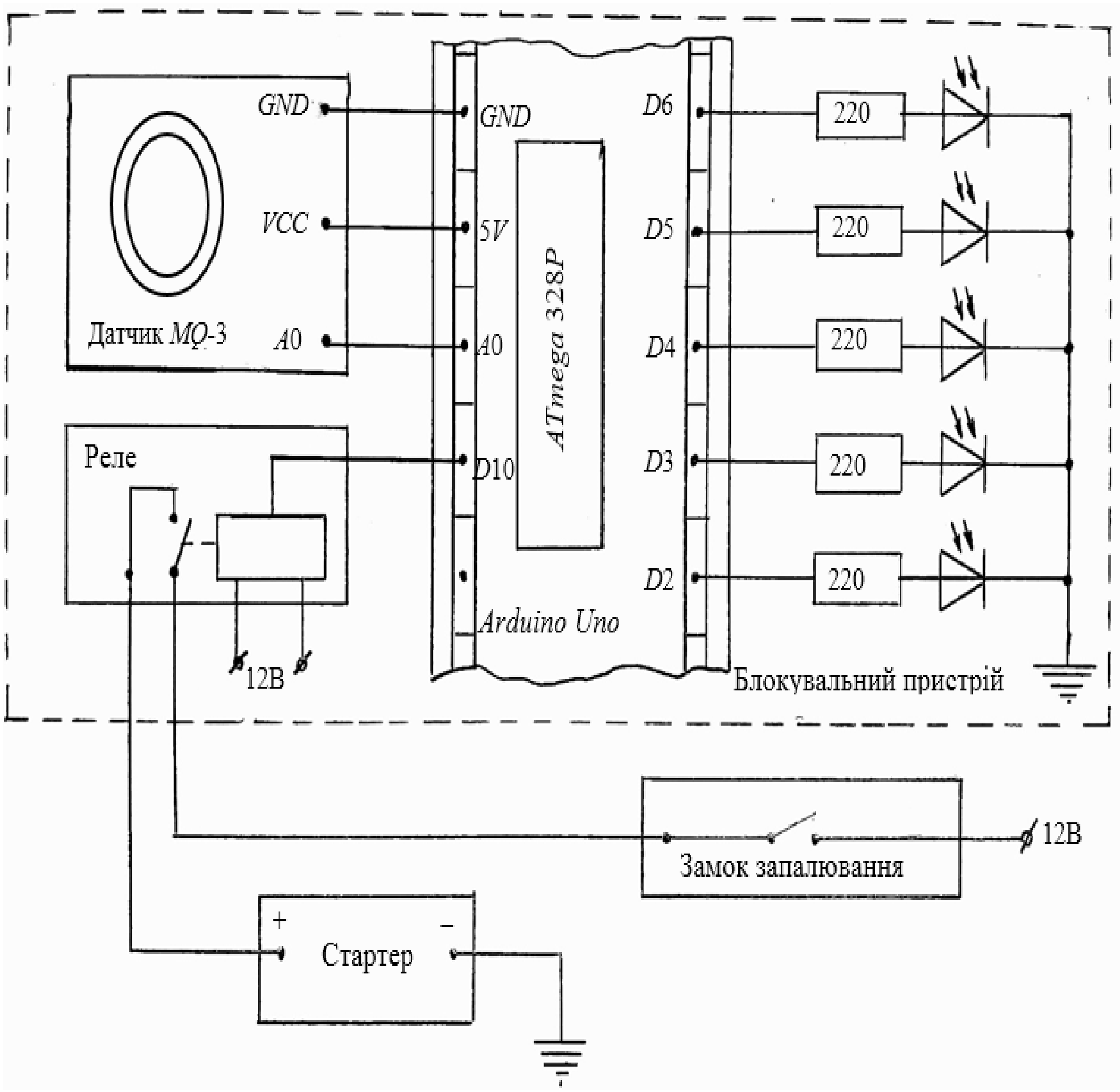

Figure 9. Electrical diagram of the anti-alcohol blocking device and its installation diagram on a car

In order for the created microprocessor anti-alcohol blocking device to perform its task of preventing drivers from driving while intoxicated, it is necessary to develop an algorithm for the operation of this device. Such an algorithm, on the one hand, must take into account the features of programming Arduino microprocessor systems, and on the other hand, the features of programming on-board computers of motor vehicles.

We have developed an algorithm that ensures the functioning of the anti-alcohol blocking device. In general, for modern vehicles, such an algorithm has a significant volume, since it interacts with the on-board software, and is also guided by the requirements for the safety of the driver and passengers.

In this work, we focused on the development of the algorithm that underlies the operation of the blocking device, the schematic electrical diagram of which is shown in Fig. 9. This blocking device has a simple design, operating principle and algorithm of operation, at the same time it clearly fulfills its purpose - to prevent a driver from driving a car while intoxicated.

Arduino microprocessor systems are programmed in the C ++ language. A program was developed that implemented the algorithm of the circuit (Fig. 9) for interrupting specified electrical circuits.

To enter the developed program into the microcontroller memory, the Arduino software environment in version 1.8.13 was used, which contains a text editor, an interface for communication with the microcontroller and a program debugger for the C ++ language. In addition, the monitor (a window on the screen that opens additionally) can display the values of the necessary variables (in our case, this is the alcohol content in the air near the MQ3 sensor.

The Arduino platform has significantly simplified the process of designing, programming and debugging microprocessor systems. The program developed for the designed device was loaded into a microcontroller connected to the computer using a regular USB cable. After correcting several spelling errors, the microprocessor system was debugged. More details about the experimental part of this study are described below.

For experimental testing of the anti-alcohol blocking device, it was mounted in full accordance with the developed electrical circuit (Fig. 7).

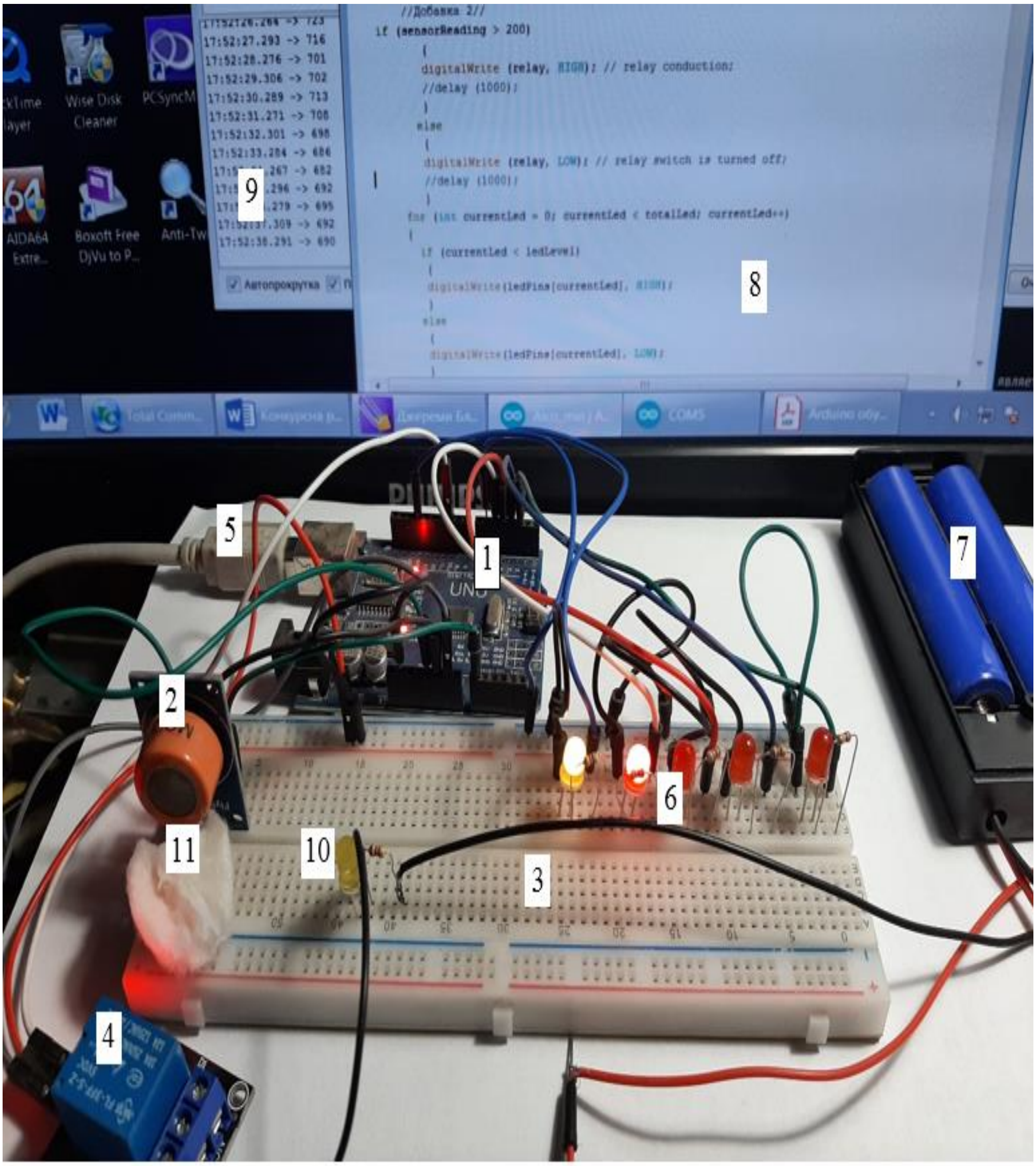

Fig. 10. Experimental verification of the device for anti-alcohol blocking of vehicles: 1 – Arduino Uno board; 2 – MQ3 sensor; 3 – breadboard; 4 – relay module; 5 – USB cable for connecting to a computer; 6 – five LEDs for indicating the value of the MQ3 signal; 7 – batteries; 8 – Arduino program window; 9 – monitor with signal values; 10 – signal LED; 11 – cotton wool with alcohol

LEDs 5 and resistors are connected to the Arduino Uno board 1 using conductors. The number of lit LEDs qualitatively indicates the degree of alcohol content in the air.

For assembly, a special breadboard for the Arduino 3 platform was used, which allows for detachable assembly. This is very important, because on the basis of the Arduino platform we are developing laboratory work for the discipline "Information technologies in vehicle control", and all elements of the circuit will be used several times.

When debugging the program and the device, the Arduino JQC-3FF relay module 2 was used for convenience. The relay of the module, according to the microcontroller signal, should interrupt the electrical circuit of the LED power supply from an autonomous source, which was used for greater reliability of the experiment.

The experiment was successful. Program 8 was entered into the microcontroller and configured using the Arduino software environment. After starting the program, cotton wool with alcohol 11 was brought to the sensor-sensor. LEDs 5 lit up in turn, indicating the presence of alcohol in the air. In addition, the current values of the alcohol content in the air were constantly displayed on the computer screen in a special monitor window 9. If the cotton wool with alcohol was moved away from the sensor, these values decreased almost to zero, and the LEDs gradually went out.

The developed program provides for entering a threshold value of the alcohol content in the air to turn on relay 4, that is, to open the power supply of the signal LED 10. The developed blocking device was tested for several threshold values. The relay always worked, and the signal LED went out when a given amount of alcohol was present in the air.

For a more reliable test of the blocking device, a circuit was assembled with a real car battery, relay and starter (Fig. 11).

Figure 11. Experimental verification of the blocking device with a car battery and a starter: 1 – Arduino Uno board; 2 – MQ3 sensor; 3 – breadboard; 4 – relay module; 5 – USB cable for connecting to a computer; 6 – five LEDs to indicate the value of the MQ3 signal; 7 – car battery; 8 – Arduino program window; 9 – monitor with signal values; 10 – starter; 11 – cotton wool with alcohol

In this circuit, the control signal from the microcontroller is sent to the car relay, which, if alcohol is present in the air, opens the electrical circuit of the starter power supply from the car battery, thus making it impossible for a driver who is in a drunken state to start the vehicle engine.

The HLS-13F automotive relay is designed for a voltage of 12 V and a current of up to 25 A, which significantly exceeds the parameters of the Arduino JQC-3FF relay and fully complies with the real operating conditions of the device in a vehicle.

The experiment was successful. The program was again entered into the microcontroller and configured using the Arduino software environment 8. After starting, cotton wool with alcohol 11 was brought to the sensor. LEDs 5 lit up, indicating the presence of alcohol in the air. The current values 9 of the alcohol content in the air were constantly displayed on the computer screen. When the threshold value of the alcohol content in the air was reached, the car relay was triggered, but the starter did not start. Thus, experimental testing of the anti-alcohol blocking device in conditions as close as possible to the real conditions of a motor vehicle showed the possibility of using such a device to prevent driving a vehicle while intoxicated.

The purpose of this study was to improve the safety of vehicle operation by developing a method based on modern information technologies to prevent drivers from driving vehicles while intoxicated and implementing such a method of an anti-alcohol blocking device.

We propose to introduce anti-alcohol blocking devices for the starter and ignition in Ukraine by law. Increasing the fines for driving a vehicle while intoxicated for many years has not yielded any results. At the same time, explanatory work with society on all aspects of the use of anti-alcohol UBZ is necessary.

When developing a method for disabling the control of a vehicle and a blocking device, an analysis of existing methods and devices for forcibly restricting the ability to drive vehicles by drivers in a state of intoxication was conducted, which showed the absence of solutions to this problem in Ukraine at the moment.

We have developed a method for increasing transport safety, based on the unconditional disabling of driving a vehicle by drivers in a state of intoxication, and its structural diagram has been developed. A functional diagram of an anti-alcohol blocking device has also been developed for implementing the proposed method on modern cars, which requires changes in their software.

The implementation of the blocking device on cars without computer control is described, because on such vehicles this does not require reprogramming of the control unit. In this case, questions may arise regarding traffic safety, which will require additional research. An electrical circuit of such a device for vehicles has been developed, which involves the use of the Arduino microprocessor platform. Using Arduino allows the developer to assemble the device with the necessary properties and independently program the microprocessor to perform the necessary actions in a given sequence.

Thus, an anti-alcohol blocking device was designed, assembled, programmed with a specially developed program and experimentally tested. Experimental testing in conditions that are as close as possible to real ones (car starter and battery) showed that the developed device disconnects the starter from power supply in the presence of a given amount of alcohol in the air.

The price of the developed device, even taking into account taxes and deductions, is not an obstacle to equipping vehicles with anti-alcohol blocking devices. The cost of components as of May 1, 2025 is about 1000 UAH.

A continuation of this research may be the manufacture of a pre-production sample of the blocking device and its full-scale testing with reprogramming of on-board computers.

In general, the authors proposed and implemented two methods with devices to improve road safety (of course, together with other measures in this direction), which will avoid huge human casualties and material losses. These methods are associated with the software of the corresponding microprocessor equipment. The first of them is more difficult to implement in laboratory conditions, so we have made a more detailed description of the second method.

To solve the above problems of safe operation of vehicles, we have proposed a system for ensuring road safety (BDR).

This system consists of separate parts (Fig. 12), each of which can act independently, but the positive effect of implementing the BDR system when these parts interact is significantly enhanced when they are used together due to the exchange of information on road traffic.

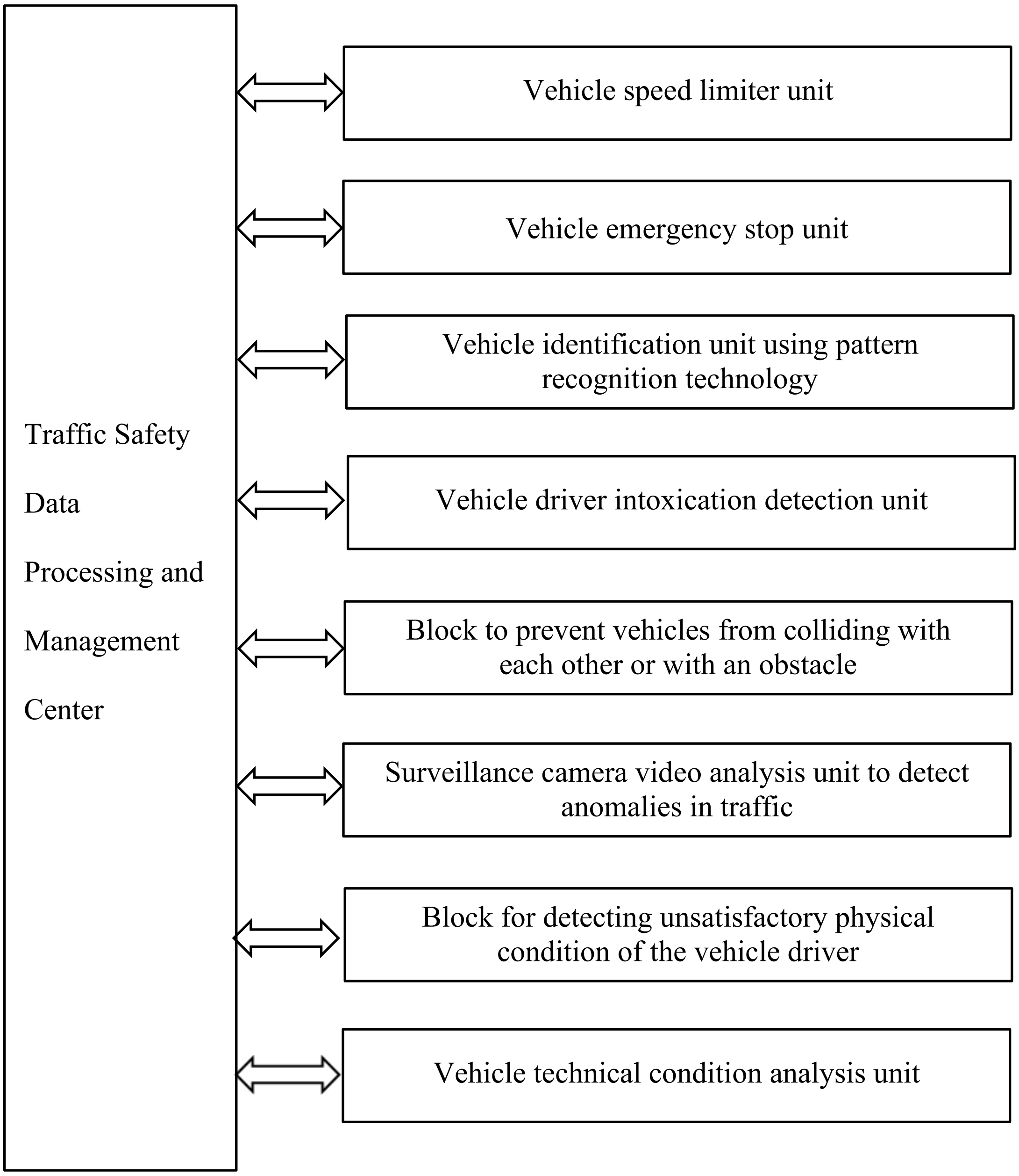

Figure 12. Functional diagram of the road safety system

The traffic safety system shown in Fig. 12 can be implemented at any level of transport systems, starting from the simplest ones. Additional blocks can be added to it, for example, a block for analyzing the technical condition of the vehicle. Each block is the result of the interaction of software and microprocessor hardware, both individual, i.e. installed on the vehicle, and general, i.e. implemented at the server level.

The BDR system is currently implemented in the form of software algorithms that control the interaction of individual blocks, and its individual parts have a finished form and are almost all implemented on the basis of microprocessor technology. The concept of operation of most blocks (forced speed limit of the vehicle, forced stopping of the vehicle, detection of drunkenness of the driver of the vehicle, analysis of video footage from surveillance cameras in order to detect anomalies in road traffic) was proposed by the author of this study and is based on the use of information technologies.

It was noted above that the method of remote forced speed limit of the vehicle [201] works as follows. The GSM receiver (possibly another radio receiving device) constantly receives a signal that carries the value of the permissible speed for a given road or street. In the microprocessor control unit, this value is compared with the current value of the vehicle speed. Exceeding the vehicle speed above the permissible speed value on a given road is the basis for reducing the amount of fuel required to be supplied to the injector according to the programmed algorithm, as well as for reducing the duration of the injector opening, which leads to a decrease in the vehicle speed to acceptable values. Such devices should be installed on all vehicles (Vehicles), but at the first stage these may be public transport, vehicles of speeding violators and vehicles transporting dangerous goods.

Such an algorithm is also used by the vehicle forced stop unit. This function may be needed, for example, by patrol police officers pursuing violators or criminals. Other situations may arise when it is absolutely necessary to stop the vehicle. But this requires a database of vehicles in a large city or the entire country, containing passwords or access codes to the vehicle control system for the purpose of forced stopping of this vehicle. By the way, safe forced stopping of a vehicle on city streets or on a country road is not such a simple matter.

The vehicle identification block works on the basis of image recognition technology [206], which is based on the use of artificial intelligence. The operation of this block of the proposed traffic safety system is based on the use of state license plate recognition systems AutoTRASSIR, which are designed to automatically identify vehicle numbers that have fallen into the field of view of video cameras. In addition to performing functions for detecting traffic violators and others, this block is needed to find information about the vehicle registered in the corresponding database. Including the access code to the forced stopping system of this vehicle.

The second most important factor causing the occurrence of a road accident is the drunken state of the driver of a motor vehicle [198]. The author once proposed a solution to this problem using information technologies and microprocessor technology [202].

This concept will be appropriate to apply in the created road safety system in the unit for detecting the drunken state of vehicle drivers.

Another important component of the proposed safety system is the unit for analyzing the video series of surveillance cameras in order to detect anomalies in road traffic [207]. Such an anomaly in the course of transport processes is any deviation from the usual state, for example, the carriageway of streets, intersections, suburban highways. For example, this is the appearance of a stationary vehicle where cars usually move or the appearance of a person on the carriageway of the street outside the pedestrian crossing zone. The search for anomalies in video series is an ultramodern scientific direction using neural networks.

Unfortunately, the limited scope of the article does not allow discussing the tasks and features of other blocks shown in Fig. 1. Thus, the proposed road safety system should significantly increase the level of safety in transport by reducing cases of vehicle speeding and cases of drivers driving in a state of intoxication. The developed road safety system can be supplemented with other functional blocks that solve tasks related to the safety of vehicles, passengers, cargo, other road users and pedestrians.

To illustrate, let us consider point 5 of the recommendations of the experts of the Transport Forum [198], which deals with increasing the safety of vehicles in the part that depends on the technical condition of these vehicles. So far, we have dealt with the human factor and its impact on the safety of passengers, the driver or drivers and the cargo and tried to minimize these impacts in every possible way. Now, at the end of this work, we will pay attention to factors related to the technical condition of the vehicle. Of course, here too, the participation of the human factor in various emergency situations can be found, but this is of a more indirect nature than in the cases considered above.

A characteristic feature of modern engine building is the desire for a comprehensive improvement in the efficiency, environmental friendliness and reliability of internal combustion engines (ICE). In addition, a mandatory condition for the development of new ICEs is the reduction of material and time costs for their design. The high complexity of modern engines and strict requirements for the timing of design and engineering work conflict with existing design methods, which can only be resolved using an adequate mathematical model of the processes occurring in the ICE.

To solve the problems of analyzing and optimizing the working processes of the designed engine at the required power and speed modes, the main problem is the identification of the mathematical model of the ICE. Identification of the mathematical model consists in determining both the structure of the model and its unknown parameters. With such a model, engine designers could develop optimal design solutions much faster, cheaper and more successfully. Currently, there is no single solution for a team of developers of a new ICE with specified characteristics. The problem is solved in different ways. Large companies and design bureaus finance the creation of the above-mentioned mathematical models of varying degrees of approximation or conduct a large number of full-scale tests to fine-tune the designs being developed. Those organizations that do not have such funds are practically deprived of the opportunity to create new engines with an optimal combination of efficiency, environmental friendliness and reliability.

At present, the known mathematical models of internal combustion engines do not fully reflect both the thermodynamic processes in the combustion chamber, in the intake and exhaust manifolds, and the features of the interaction of the mixture formation and ignition systems, and the kinematic connections between various units and assemblies, as well as other processes occurring in the engine.

The choice of optimal parameters for the engine operating process and its design elements during experimental design work is extremely difficult. Therefore, many leading automobile companies and scientific organizations use the method of mathematical modeling of the real operating cycle of the engine and its systems, which reduces dependence on the manufacture of prototypes of internal combustion engines and their fine-tuning by trial and error. Designers, developers and researchers use mathematical models of individual processes and units of internal combustion engines in their practical activities, focusing on the aspects of engine operation that interest them in modeling. At the same time, the methods for solving the equations that make up such models are very complex. It seems important and possible to create a mathematical model of an internal combustion engine that would describe as fully as possible the entire diversity of processes occurring in the engine. In this case, first of all, methods for identifying the proposed mathematical model should be developed, which is a very difficult task. Moreover, the use of such a software product should be unambiguous and not cause difficulties for the creators of internal combustion engines.

Having studied several modern software packages for calculating internal combustion engines, the authors came to the following conclusions: The use of methods of mathematical modeling of working processes for fine-tuning the design of modern diesel engines and assessing their parameters at the stage of creating new modifications is a promising direction.

The use of modern software packages for CFD modeling (CFD - computitional fluid dynamic) of diesel working processes has a number of advantages, both in terms of the accuracy of describing the combustion chamber configuration and in describing the in-cylinder processes themselves. The combination of numerical methods implemented in specialized software packages for modeling processes in internal combustion engines with an in-depth study of in-cylinder parameters of a diesel engine with CFD modeling methods allows achieving the best result with minimal time expenditure.

The model is described by the following system of differential equations:

- the equation of balance of thermal energy in the zone of the unburned part of the charge;

- the equation of state of the unburned part of the charge; – the equation of balance of thermal energy of combustion products and a dozen other equations that take into account and describe in sufficient detail almost all processes occurring in the internal combustion engine.

The authors developed a mathematical model of the working cycle of the internal combustion engine with spark ignition in the form of a set of submodels consisting of an intake submodel, a compression submodel, a combustion and free expansion submodel and an exhaust submodel, as well as a submodel describing the main chemical reactions in the cylinder of the internal combustion engine, leading to the formation of NOx, CO, CH, etc. In addition, each submodel includes algebraic equations describing the dependence of the thermodynamic parameters of the working fluid on its temperature.

As a result, the mathematical model of the working cycle of the internal combustion engine takes the form of a matrix differential equation, linear with respect to derivatives and solved using numerical integration methods.

It is not possible to provide an analysis of other sources, although there are very interesting studies and the results of their application.

Quite complex chemical, thermal, mechanical and electrical processes occur in an internal combustion engine. As a result, even the most complex engine models (nonlinear, non-stationary and with delay) are approximate and reflect the engine behavior only with a certain degree of accuracy. In addition, many engine parameters and characteristics cannot be accurately calculated analytically, but are established experimentally or must be evaluated by a control algorithm during its operation.

The block nature of the functional scheme 12 of the road safety system provides opportunities for adapting this scheme for various safety needs, adding certain blocks.

At the moment, for example, judging by the figure, there is one block that can be devoted to analyzing the technical condition of the vehicle.

The author proposes a subset of this block (additional blocks can be added depending on the need) to determine the technical state of the operating transport means. For whom will the results of the simulation of installations for the analysis of the technical parameters of the transport department be selected by means of a comprehensive selection of current methods of parametric identification and mathematical modeling of the technical systems of the transport department. As a result, this recommendation is transmitted to ensure the possibility of safe transportation at a specific moment to a specific transport facility.