

SAFETY RISKS OF USING AN ALTERNATIVE PROPULSION VEHICLES

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Abstract. *The concept of Traffic Safety implies not only strategic thinking about the level of road safety, but also the use of modern technologies in the transport sector through means of alternative propulsion, hybrid and electric vehicles. As a result of the use of alternatively powered vehicles, safety risks related to specific operating and maintenance conditions inevitably occur. The paper gives a brief overview of the traffic safety situation in the Republic of Serbia followed by the issue of safety and maintenance of alternative propulsion vehicles in terms of their use, and a special reference to the components of alternative vehicles that differ from the conventional ones. Also, the safety risks of using electric and hybrid electric vehicles (EV/HEV) due to the increasing mass use in traffic, as well as the safety of alcoholic fuels (ethanol and methanol), biodiesel LPG and CNG fuels were analyzed.*

Key words: *traffic safety, alternative propulsion vehicles, safety risks*

1. INTRODUCTION

Traffic safety is one of the biggest challenges of modern society. The concept of Traffic Safety implies not only strategic thinking about the level of road safety, but also the use of modern technologies in the transport sector through means of alternative propulsion, hybrid and electric vehicles.

Traffic safety, condition and prospects

As it is given, the problems referred to the Traffic safety are one of the largest problems in modern society. According to world statistics, more than 1.3 million people die each year and 50 million are seriously and lightly injured in road accidents [1-4]. In our country, the

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situation is worrying, because according to the data of the Traffic Safety Agency of the Republic of Serbia in the period from 2016 to 2020, 2760 people died in traffic accidents, 16489 were seriously injured and 84030 were slightly injured (Table 1) [6,7,8].

Table 1 Some of the indicators of traffic safety in the Republic of Serbia (2016-2020)

Year	Number of traffic accidents	Death toll	Number of seriously injured	Number of lightly injured	Total number of injured
2016	35.972	607	3.362	17.308	20.670
2017	36.475	579	3.514	17.849	21.363
2018	35.818	548	3.338	17.508	20.846
2019	35.770	534	3.322	17.068	20.390
2020	30.718	492	2.953	14.297	17.250
In total	174.753	2.760	16.489	84.030	100.519

A large number of dead, permanently disabled and severely injured people, as well as the huge material damage, require that traffic safety be substantially and significantly increased, that is, to take deliberate measures to ensure:

- appropriate behavior of drivers and other road users,
- high-quality vehicles and
- high quality of roads and traffic infrastructure.[1-5]

Figure 1 s shows the traffic safety division scheme with special reference to vehicle safety.

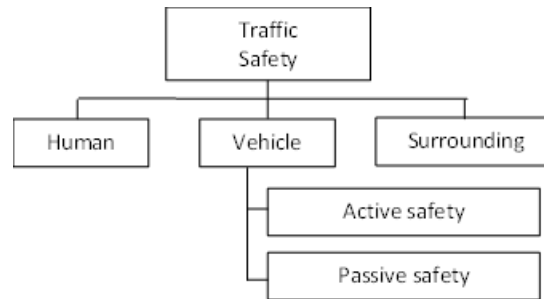


Fig. 1 Traffic safety structure [5]

Each country strives to raise the quality of life and strategically considers the level of vehicle safety on the roads. There is no single answer to the question of what a safe vehicle is, although most countries are signatories to the Vienna Convention on Minimum Conditions for the Technical Safety of Vehicles, in order to mutually recognize the inspection of tech proper technical functionality [9,10].

When it comes to alternative propulsion vehicles, it is necessary to ensure the high-quality performance in traffic safety, both active (driving safety, conditional safety, observation safety, steering safety, etc.) and passive safety (deformation behavior bodywork, body shape, bumpers, road surface strength, passenger restraint system, steering system, passenger escape capability, fire protection, etc.), and then in terms of proper technical functionality and reliability properties, regarding the probability of proper operation and adequate reacting in

critical situations. In order to achieve that, it is necessary to have adequate technical regulations. [11-14]

Technical regulations, prescribing the requirements that vehicles must meet to participate in public transport are regulated at two levels [1]:

- The first level consists of requirements in terms of vehicle equipment and performance, the fulfillment of which can be examined relatively easily and quickly, with the help of simple measuring devices and installations,
- The second level consists of requirements related to the design features and performance of vehicles that require significantly more time to determine and verify and often very complex measuring and experimental installations.

Compliance with the requirements at the first level is checked, as a rule, on each vehicle by regular or extraordinary inspections, on the spot, or at appropriate technical inspection stations.

These requirements include:

- Basic vehicle performance from the point of view of active safety (braking characteristics, lighting devices, tires, steering system, etc.),
- Equipping the vehicle with devices and equipment important for traffic safety (seat belts, tachograph, etc.),
- Obligation to regularly check the technical correctness, ie to perform regular inspections.

Regulations with requirements of the second level refer to various types of homologation, approval of vehicle type, attestation and other types of tests performed on a sample of one specific type of series-produced vehicle. It is assumed, that all vehicles of that type are equal, i.e. compliant with the tested sample (which in certain cases is periodically checked). Regulations at this level are significantly wider than the regulations at the first level and include a range of vehicle performance from the point of view of passive safety (body strength, design, and arrangement of external surfaces and interior of the vehicle, etc.), and also in terms of environmental impact, noise level, radio interference, etc.) [7,11-15].

Homologation and other similar tests are carried out in line with special instructions, regulations and rules, with the help of complex experimental and measuring installations. This part of the technical regulations is mostly regulated at the international level. The most important regulations for our country are the UN Economic Commission for Europe, i.e. the so-called ESE Regulations, and also the relevant European Community regulations, i.e. the EES Directive. The development of these Regulations and Directives has been underway for many years so today there are already hundreds of these regulations. A part of the ESE regulations is included in our positive regulations in accordance with the relevant interstate agreements (on mutual recognition of homologations) and is applied in our country as well [13-16].

However, the efforts for our country to become an equal member of the European Union require the necessity to transpose the overall technical regulations of the European Union into our legislation. This is an extremely large and complex task. Even greater problems will certainly arise in connection with the implementation and satisfaction of these very sophisticated regulations [4].

It is necessary to point out that all regulations within the framework of technical regulations, at both levels, contain or should contain the following basic elements [1]:

- required performance (minimum braking coefficient, highest nitrogen oxide content, etc.),
- method of verification, i.e. testing methodology, including requirements regarding space, environment and other elements important for conducting measurements, verification or testing,
- measuring devices, instruments and installations for checking, i.e. for testing, the required technical validity of these devices and the manner and deadlines for their examination (calibration),
- the required qualifications, work experience and other important criteria for the persons performing these examinations or tests.

Therefore, Regulations from this wide domain of technical regulations not only determine what kind of performance it should have and what requirements the vehicle should meet but also determine how it should be checked, i.e. tested, by which methods, by which measuring devices and installations, as well as who has the right to perform these tasks and the conditions that the appropriate testing center or laboratory should satisfy.

From this very general and concise presentation, it is easy to conclude that the regulations from the framework of technical regulations are extremely complex and that meeting all the requirements for alternative vehicles is a very difficult task.

Therefore, two important questions arise:

1. Does it make sense to have detailed technical regulations on the requirements for the quality of vehicles in public transport, and does it make sense to make huge investments in the development of appropriate measuring equipment, devices and laboratories, as well as investments in conducting tests and quality control, bearing in mind that vehicles are the cause of 3 to 5% of the total number of accidents worldwide?

2. Does such detailed standardization and prescribing of all important characteristics and characteristics of safety vehicles not negatively affect the development of alternative propulsion vehicles, i.e. faster application of the results of new technologies and new constructions, which may be of interest for motoring development and increase traffic safety?

When it comes to the impact of existing, extensive and detailed technical regulations on traffic safety, vehicles are rarely the cause of accidents, since quality requirements are usually detailed and precise and vehicle quality checks are given great attention. The fact is, however, that even 30 years ago when there were practically no homologation and related tests and technical inspections were not performed regularly in many countries, the vehicles were rarely the cause of traffic accidents. So, if we start from that, it could be claimed that such detailed and increasingly complex technical regulations have not, at least so far, significantly contributed to greater traffic safety.

In Serbia, as well as worldwide, motor vehicles, regardless of their age (over 16 years), are very rarely the cause of traffic accidents (less than 0.5%).

However, although the vehicle is very rarely the direct cause of traffic accidents, it is not difficult to conclude that the existing, detailed technical regulations are necessary and useful. It reflects the intensive technological development in this area and regulates all issues related to the vehicle as a factor of traffic safety, at the level of today's knowledge and technological capabilities. Due to the number and complexity of these issues, it is inevitable that these regulations be comprehensive, set out a large number of individual requirements and be formulated in the form of documents that have different legal effects and impose different responsibilities.

It should be noted that the elaboration of certain requirements may go too far in some details, and some regulations may be unnecessarily detailed and irrational, but it is indisputable that in general, the existing technical regulations are very necessary and important from the point of view of traffic safety and environmental protection.

As for the answer to the second question, it is quite logical that technical regulations must follow the development of vehicles. Vehicles have changed so much in recent decades, nowadays, vehicles look much different than just 10 years ago. In that sense, present regulations are much broader and they also regulate the characteristics of vehicles that were not even thought about before. As vehicles continue to evolve rapidly, there is a constant need for improved and expanded technical requirements. Hence, the development of technical regulations is something that international expert teams regularly work on, especially the experts in the developed countries, and teams in ESE UN, the European Commission and other organizations worldwide

However, despite the efforts to ensure that technical regulations follow the development of alternative propulsion vehicles, it sometimes happens that certain regulations hinder or at least delay the introduction of new technical and technological solutions. Although this is not often the case, legislators and expert teams working on the development of technical regulations must take this into account.

2. SAFETY RISKS OF USING VEHICLES ON ALTERNATIVE FUELS

The safe use of alcohol fuels (ethanol and methanol) and biodiesel is similar to the use of gasoline. This is reflected in the fact that these fuels, as well as gasoline, are stored in vehicle tanks in a liquid state and they are prone to create flammable vapors under ambient conditions of use [11,18].

Unlike gasoline, pure methanol burns with a colorless flame that cannot be seen in daylight and can pose an accident hazard to both passengers and firefighters. This problem is solved by adding gasoline to the mixture, so with the M85 fuel blend, this danger could be eliminated. Methanol, unlike ethanol and biodiesel, is extremely toxic, so the amounts of about 110 grams, if taken, can be deadly. A small amount of methanol can cause blindness or pass through the skin and cause neurological damage [18].

Maintenance of vehicles powered by alcohol fuels and biodiesel is similar to the maintenance of gasoline vehicles, except that alcohol fuels and biodiesel are more aggressive on fuel pipes and gaskets, therefore, it is important to try to use suitable material and avoid leakages. From the maintenance point of view, especially when using biodiesel, it is very important to use biodiesel of the quality standard (EN 14214) in order to avoid damage or destruction of the diesel engine.

Regarding the safety use of LPG on vehicles, there are prejudices and beliefs that LPG is a very dangerous fuel. The manipulation, distribution and storage of LPG are indeed riskier and more difficult than diesel fuel and gasoline. It requires knowledge of the basic characteristics of propane/butane mixture and strict application of safety measures. With measures applied, the risk could be completely eliminated, because the working pressure in the tank is in normal circumstances slightly higher than the pressure in the hot water boiler.

LPG tanks are made of sheet steel 3÷4 mm thick and have very rigid construction, so they practically represent additional reinforcement of the vehicle in the event of a collision. In this

respect, LPG tanks are significantly safer than standard petrol tanks. The tanks are filled with gas up to 80% of their volume. The remaining 20% of the volume is a necessary reserve in case of gas spread at elevated outdoor temperatures. Also, if the gas pressure in the tank is around 10 bar, all tanks must be certified at a gas pressure of 30 bar. Tanks used in LPG vehicles must have an appropriate plate confirming that the certification has been performed. There must be a safety valve on the tank that releases gas from the tank outside the vehicle when the pressure in the tank exceeds the permitted level. Gas flow through this valve is limited. In the event of a fire, when the LPG tank is heated, there will be no explosion, but the gas will gradually leak out, unlike the gas tank, which explodes very easily at elevated temperatures due to the presence of gasoline vapor. When the LPG tank is emptied, care should be taken that a certain amount of gas always remains in the tank and, therefore, the tank valve must be closed to prevent air diffusion into the tank and an explosion.

The validity period of an LPG installation compliance Certificate, in Serbian legislation, is in line with the validity period of the tank certificate (10 years). As we know that the tank is one of the most important elements of LPG installation, neglecting other elements of equipment by perhaps, inadequate inspection, vehicle maintenance or some other cause, raises the necessity to introduce periodic inspections of equipment that would prevent vehicle accidents during the validity of the certificate. Moreover, it is urgent to legally regulate periodic inspections of equipment, and associate them with annual inspections of vehicle technical functionality.

An explosion of LPG is possible only at a gas concentration of 2 to 9% of the relative volume space, which is practically impossible to reach in the open space where the car is moving. If the gas pipeline is damaged, this volatile and flammable fuel tank leaks unhindered, unlike LPG, because there is a built-in ventilation safety that will prevent gas leaks in the event of a motor vehicle. Also, LPG leaks can be easily saved by condensation of moisture on the installation near the place of burning. This phenomenon occurs due to the sudden evaporation of technical gas, during which heat is removed from the environment, and the surrounding air is cooled, resulting in the condensation of water vapor. Particular care should be taken that LPG does not come into contact with the skin because, due to intense evaporation on the skin, it will cause frostbite.

It should be noted that an explosive mixture of LPG and air can be created in a slightly enclosed space where fuel-based vehicles are parked (especially in underground garages). This danger is successfully eliminated with only two openings for natural ventilation in the lower part of the above-ground garages or by installing newer generation electric valves that will prevent gas loss when the engine is turned off.

In 1987, an agreement was reached at the UN level, within the framework of the International Agreement on the Approval of Vehicles, Equipment and Parts (1958 Agreement), to enter into force ESE Regulation no. 67 which prescribes the homologation of equipment on vehicles using LPG and the homologation of vehicles in relation to the installation of such equipment. De facto, this set the first safety requirements for motor vehicles that use LPG in their propulsion system.

Today, the installation of LPG propulsion systems should be performed by several professional and authorized services. The requirements to be met by LPG vehicle propulsion devices from the point of view of safety are given in ESE Regulation no. 67/01 and ESE Regulation No. 115.

ESE Regulation no. 67/01 - Uniform provisions concerning the approval of:

- specific equipment of motor vehicles with LPG drive,
- vehicles equipped with specific LPG propulsion equipment in terms of installation of that equipment.

ESE Regulation no. 115 provides uniform regulations on specific LPG replaceable systems that are installed in vehicles for the use of LPG in the propulsion system. In Serbia, six organizations are responsible for testing individually produced vehicles, i.e. vehicles that have been modified (which includes testing vehicles with LPG propulsion).

Unfortunately, the technology used so far has not been unique, but a unique testing methodology needs to be developed in interlaboratory cooperation. Respecting the guidelines of ESE Regulation no. 67/01, authorized laboratories dealing with vehicle testing should soon harmonize the unique procedure for testing vehicles with LPG propulsion, all in order to organize the conditions for lighting technical issues.

Proper functionality of the installation as well as the reliability of the LPG installation equipment that is installed on vehicles in our country is still not satisfactory. It is encouraging that services (services that rely mainly on the world's most famous manufacturers of equipment for LPG installations) have recently appeared in Serbia, which with their evident quality of installation significantly contribute to raising the level of reliability of LPG-powered vehicles. Also, the origin of LPG equipment in the Serbian market is highly debatable. Illegal import (equipment without the necessary supporting documentation), as well as the existence of equipment of suspicious origin (counterfeit), has significantly contributed to this situation.

As proof of the current state of installed LPG equipment in vehicles in Serbia, we will give the results of testing 530 vehicles conducted by the laboratory of AMSS - Center for Motor Vehicles. This analysis shows that 58% of vehicles had no objections to the installation or equipment (so they received a certificate), while for the remaining 42% of vehicles there was at least one objection that required mandatory correction.

The observed faults are as follows:

- The tank is not homologated in 1.35% of vehicles
- Inadequate tank fixing in 22.95% of vehicles
- LPG leaks in the tank area of 1.35 vehicles
- The multivalve is not homologated in 0.4% of vehicles`
- Multi-valve mounting angle incorrect for 13.5% of vehicles
- There is no measurement of LPG in 0.4% of vehicles
- Malfunctions of the multi-valve armature in 5.4% of vehicles
- Improper ventilation in 27% of vehicles
- Improperly laid or fixed pipes in 30.6% of vehicles
- Inadequate low-pressure LPG pipes at 10.3%, vehicles
- Defective coolant hoses in 3.6% of vehicles
- Incorrect installation of some of the elements in 38.7% of vehicles
- Leaking gas into the engine compartment in 1.7% of vehicles

Some of the above faults are shown in the following figures.



Fig. 2 The angle of the multivalve is not 30° **Fig. 3** Ventilation passage closed



Fig. 4 No multi-valve ventilation **Fig. 5** Pipe near the exhaust manifold



Fig. 6 Mechanically damaged pipe during installation **Fig. 7** Larger hose diameter than the connection leading to LPG leakage

There are even greater fears of potential users when applying CNG from the aspect of security than when applying LPG. The reason lies in the fact that CNG is always in a gaseous state and is stored in tanks under higher pressure.

The reason for concern about the use of CNG is unjustified because the tanks are made of very solid material and are protected by safety valves and other safety devices. Also, the tanks pass a large number of strict tests such as fire resistance, impact, mechanical damage, etc.

CNG is safer than traditional liquid fuels such as gasoline and diesel for several reasons:

- In the event of a fuel leak, CNG will disperse rapidly upwards, while liquid fuels accumulate on the ground creating a potential fire hazard.
- CNG has a much higher ignition temperature than liquid fuels (580°C versus 220°C for gasoline), so there are many fewer potential sources of ignition in the event of a gas leak.
- CNG has a narrow flammability range and is non-toxic.
- The process of refilling CNG at the distribution pump is very safe because the whole system is airtight, thus preventing any leakage or spillage of CNG.

Installation of CNG drive systems should be performed by professional and authorized services. The requirements to be met by CNG vehicle propulsion devices from a safety point of view are given in ESE Regulation no. 110 and ESE Regulation no. 115.

ESE Regulation no. 110 - Uniform provisions concerning the approval of:

- specific equipment of motor vehicles with CNG drive,
- vehicles with regard to the installation of specific equipment of the approved type for CNG propulsion.

ESE Regulation no. 115 provides uniform regulations on the type-approval of specific CNG interchangeable systems to be installed in vehicles for the use of CNG in the propulsion system. In addition, the required maintenance of CNG vehicles is similar to that of LPG vehicles [26].

3. SAFETY RISKS OF USING ELECTRIC VEHICLES

In this paper we have examined the safety and maintenance of electric and hybrid electric vehicles (EV/HEV), as they have experienced their exploitation while other vehicles are in the development and testing phase. Electric machines (electric motor and generator) EV/HEV operate in extreme conditions during operation. When it comes to the safety and maintenance of EV/HEV, extreme conditions can lead to a number of problems and risk situations, as well as shorten the life of these vehicles.

Particular problems can be expected due to the extreme temperatures at which the vehicle is used, as well as the penetration of foreign bodies and moisture into the interior of the electric machine. It is certainly worth mentioning the possibility of overheating of the electric machine in the case of exploitation at high altitudes (due to poor cooling), the harmful effects of salt and other chemicals, vibration and the like. For HEV, it is important to mention fire protection, which should be given special attention due to the existence of electric machines and gasoline. Due to all this, it is difficult to talk about general indicators of safety and maintenance of EV/HEV because the conditions of exploitation can differ significantly.

HEV traffic accidents pose new challenges to rescuers. The electrical component of the hybrid vehicle runs at 500 V, which is about twice as much as the electricity from the home electrical network or about four times more than a 12-volt battery. In the event of a serious accident and crumpling of the HEV, there is a danger of high voltage on the metal parts of the car (there should be no high voltage on the body, but it cannot be guaranteed that he will get there in case of an accident). For their own safety, in countries where this type of vehicle is widely used, firefighters receive detailed technical instructions during interventions involving electric and hybrid cars. Firefighters - rescuers usually do not have time for all safety tests and procedures, so in the case of removing passengers trapped in the wreck of HEV, the victims are approached by cutting the roof, and HEV is declared a live object.

Differences in maintenance and operation are particularly prevalent between EVs and SUS-powered vehicles. Hybrid vehicles also have an electric motor, so at first glance, it may seem more difficult to maintain such a vehicle than a classic one.

Electric motors are mainly made with ball bearings that do not require a lubrication system. It is one subsystem less than classic cars. This is especially important because it is a subsystem that requires constant attention during maintenance.

It is quite common for an electric traction motor to be cooled by water. This means that the subsystem must be taken into account during operation and maintenance, as with conventional vehicles. The pump of the cooling system, as well as other auxiliary devices in EV, are driven by an electric motor, which does not require any special maintenance, unlike belt power transmissions (belts), which are used in classic cars.

Periodic maintenance of EV is reduced to checking the liquid in the cooling system and the tightness of that system. In addition, with EVs powered by conventional lead-acid batteries, it is necessary to take into account the level of electrolytes in the cells and the state of the account.

CONCLUSION

The safe use of alcohol fuels (ethanol and methanol) and biodiesel is similar to the use of gasoline. It should be noted that an explosive mixture of LPG and air can be created in a slightly enclosed space where fuel-based vehicles are parked (especially in underground garages). This danger could be successfully eliminated with only two openings for natural ventilation in the lower part of the above-ground garages or by installing newer generation electric valves that will prevent gas loss when the engine is turned off.

As proof of the current state of installed LPG equipment in vehicles in Serbia, we gave the results of testing 530 vehicles conducted by the laboratory of AMSS - Center for Motor Vehicles. This analysis shows that 58% of vehicles had no objections to the installation or equipment (so they received a certificate), while for the remaining 42% of vehicles there was at least one objection that required mandatory repair.

There are even greater fears of potential users when applying CNG from the aspect of security than when applying LPG. The reason lies in the fact that CNG is always in a gaseous state and is stored in tanks under higher pressure. CNG is safer than traditional liquid fuels such as gasoline and diesel for several reasons, in the event of a fuel leak, CNG will disperse rapidly upwards, while liquid fuels accumulate on the ground creating a potential fire hazard. Furthermore, CNG has a much higher ignition temperature than

liquid fuels, it has a narrow flammability range and is non-toxic, and also the process of refilling CNG at the distribution pump is very safe because the whole system is airtight, which prevents leakage or spillage of CNG.

When it comes to the safety and maintenance of EV/HEV, extreme conditions can lead to many problems and risk, as well as shorten the life of these vehicles. Particular problems can be related to the extreme temperatures at which the vehicle is used, as well as the penetration of foreign bodies and moisture into the interior of the electric machine.

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BEZBEDONOSNI RIZICI KORIŠĆENJA VOZILA NA ALTERNATIVNI POGON

Koncept bezbednosti u saobraćaju ne podrazumeva samo strateško promišljanje o nivou bezbednosti na putevima već i upotrebu savremenih tehnologija u transportnom sektoru kroz transportna sredstva na alternativni pogon, hibridna i električna vozila. Kao rezultat upotrebe vozila na alternativni pogon neminovno se javljaju bezbednosni rizici vezani za specifične uslove eksploatacije i održavanja. U radu je dat kratak pregled stanja bezbednosti u saobraćaju u Republici Srbiji, a zatim je razmatrana bezbednost i održavanje vozila na alternativni pogon sa aspekta upotrebe i posebnim osvrtom na komponente alternativnih vozila koje se razlikuju od konvencionalnih. Takođe, analizirani su bezbednosni rizici korišćenja električnih i hibridnih električnih vozila (EV/HEV) zbog sve masovnije upotrebe u saobraćaju, kao i bezbednost primene alkoholnih goriva (etanola i metanola), biodizela LPG i CNG goriva.

Ključne reči: bezbednost saobraćaja, vozila na alternativni pogon, bezbednosni rizici