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RISKS ASSOCIATED WITH INTERVENTIONS IN ROAD TRAFFIC ACCIDENTS INVOLVING ELECTRIC VEHICLES

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Resumen: La motorización del futuro da paso a vehículos con sistemas de propulsión eléctrica e híbrida. Durante esta transición, impulsada desde las más altas instituciones de la Unión Europea, convivirán vehículos con las nuevas motorizaciones, con vehículos con motores de combustión interna.

La irrupción del vehículo eléctrico e híbrido trae consigo una serie de riesgos específicos, por lo que la realización de un rescate por parte de los equipos de emergencia puede convertirse en un riesgo si no se tienen en cuenta determinadas premisas antes y durante la actuación.

La garantía de una atención rápida y eficaz a la víctima de un siniestro vial vendrá pareja a la seguridad del personal de intervención y, ésta a la dotación de los necesarios equipos de protección, a una adecuada formación de los mismos y a la existencia de protocolos de actuación específicos para los intervinientes.

"Abstract": The motorization the future gives way to vehicles with electric and hybrid propulsion systems. During this transition, promoted by the highest institutions of European Union, vehicles with the new engines will coexist with vehicles with internal combustion engines.

The irruption of electric and hybrid vehicles brings with it a series of specific risk, so that carrying out a rescue by emergency teams can become a risk if certain premises are not taken into account before and during the action.

The guarantee of rapid and effective attention the victim of a road accident will go the intervention personnel and, this, the provision of the necessary protective equipment, adequate training for them and the existence of safety protocols, specific actions for the participants.

Palabras clave: Vehículo eléctrico, siniestro vial, servicio de rescate, protocolo de actuación, formación.

Keywords: Electric vehicle, road accident, rescue service, action protocol, training.

1. INTRODUCTION

One objective of the Road Safety Strategy is to "improve the post-accident response activation mechanisms for coordination between the various services involved to reduce the response times of the emergency services", which requires giving "impetus to protocols and mechanisms for coordination between the various services responsible for rescuing and assisting victims", guaranteeing fast and efficient care, focused on reducing the risk of death or serious injury to people involved in an accident, as well as the safety of the responders and road users. (Observatorio Nacional de Seguridad Vial, 2022)

However, the appearance of electric and hybrid vehicles brings with it a series of specific risks, meaning that the work of emergency teams can become hazardous if certain aspects are not considered before the intervention, since any injury suffered by the intervening responders will result in poor, delayed or non-existent care for the road accident victim.

This study analyses the emergency response training level of responders with regard to handling electric vehicles, and whether they have the necessary protective equipment, safety information and a comprehensive methodology for unified action to equip them with a safety framework for intervention in road traffic accidents that eliminates the concern of first responders due to the appearance of electric vehicles in motorisation.

The specific hazards of handling electric or hybrid vehicles are analysed and a comparison is made between national and international regulations regarding formal training and intervention protocols, as well as an assessment of the current situation and any shortfalls in terms of safety measures and equipment.

The study includes other groups involved as second responders, since they also intervene in both road traffic accidents and breakdowns and removals of vehicles from the road.

2. THE APPEARANCE OF ELECTRIC VEHICLES IN MOTORISATION

For more than a hundred years, the predominant propulsion system for vehicles has been the internal petrol or diesel powered combustion engine. In the last 20 years, natural gas, hydrogen and biodiesel, among other alternative fuels, have emerged, with the *Battery Electric Vehicle (BEV*) as the dominant alternative energy vehicle on the market.

The Stockholm Declaration recommends "speeding up the shift toward safer, cleaner, more energy efficient and affordable modes of transport", and the *European Union (EU) Transport White Paper* has among its objectives for the next decade to "halve the use of 'conventionally fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO2-free city logistics in major urban centres by 2030". (Organización Mundial de la Salud, 2020)

Apart from the controversy triggered by Germany and Italy over the inclusion of e-fuels and the proposal to allow sales of new cars with internal combustion engines after 2035 if they run on carbon neutral fuels, the European Commission's proposed Euro 7 regulation ending the production of CO_2 emitting cars and vans from 2035 onwards has been given the green light, with the aim of achieving climate neutrality in the EU by 2050.

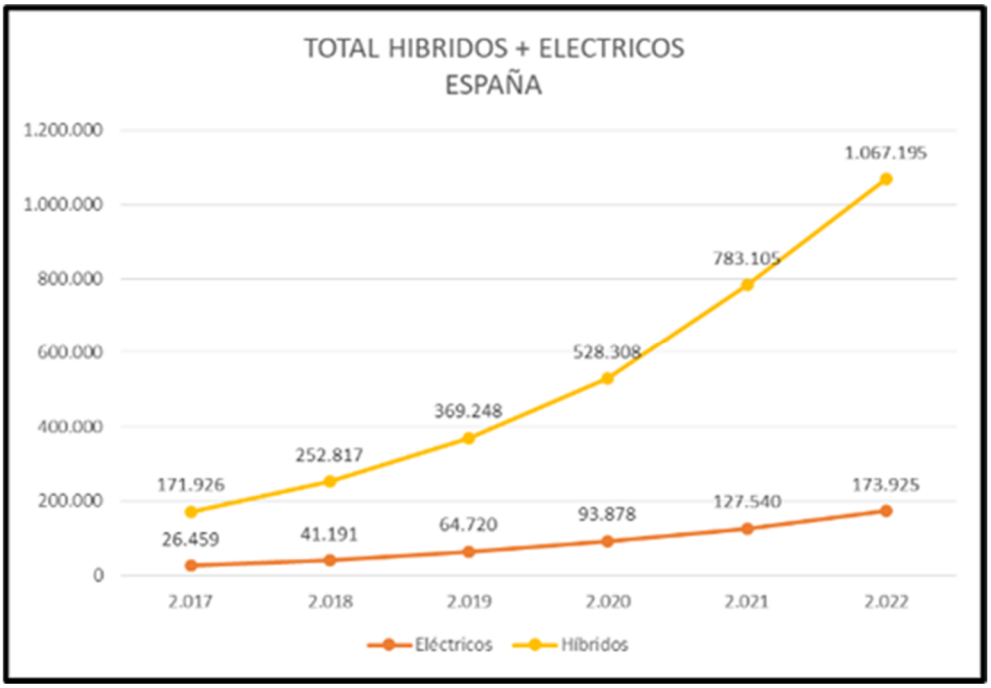
In the opinion of Pérez de Lucía, Director General of the Business Association for the Development and Promotion of Electric Mobility (AEDIVE), given the level of improvement in terms of autonomy, safety and availability of new materials and chemistry, the uptake of electric vehicles will grow significantly in the coming years.[1]

The increased number of hybrid and electric vehicles is notable and unstoppable, and they will gradually replace traditionally fuelled vehicles. An orderly transition is needed, during which vehicles with new electric and hybrid engines will coexist with traditional petrol, diesel and liquefied gas engines, without forgetting the appearance of the hydrogen powered fuel cell electric vehicles once their production and storage problems have been overcome. In addition, the batteries will have a higher capacity and will be smaller, allowing longer journeys without the need to recharge. Faster charging systems and more availability of these on the road network, coupled with longer ranges, are considered the most important factors for the wider deployment of electric vehicles.

The rise of electric and hybrid vehicles has been exponential. According to information from the Vehicle Register of the Directorate-General for Traffic (DGT), the active vehicle fleet in Spain as of December 2022 was 36,269,824. The hybrid and electric fleet consisted of 1,241,120 vehicles[2], with the number of hybrid vehicles considerably higher than the number of electric vehicles.

Figure 1

Hybrid and electric vehicle fleet in Spain (2017-2022)



[1] Telephone interview on 14 March 2023.

[2] The number of vehicles includes *Battery Electric Vehicles (BEV + Range Extended Electric Vehicles (REEV)* and *Hybrid Electric Vehicles (HEV + Plug-in Hybrid Electric Vehicles (PHEV)* and *Plug-in Hybrid Electric Vehicles (PHEV)*.

By vehicle segment, passenger cars hold a leading position in terms of the number of both electric and hybrid vehicles. Electric vehicles are followed by vans, motorbikes and mopeds, whilst those heavy vehicles (trucks and buses) in this segment is irrelevant with respect to the total fleet. In the case of hybrid vehicles, the fleet consists almost entirely of passenger cars and to a lesser extent, vans. Table 1 shows the figures and evolution over the last six years.

Table 1

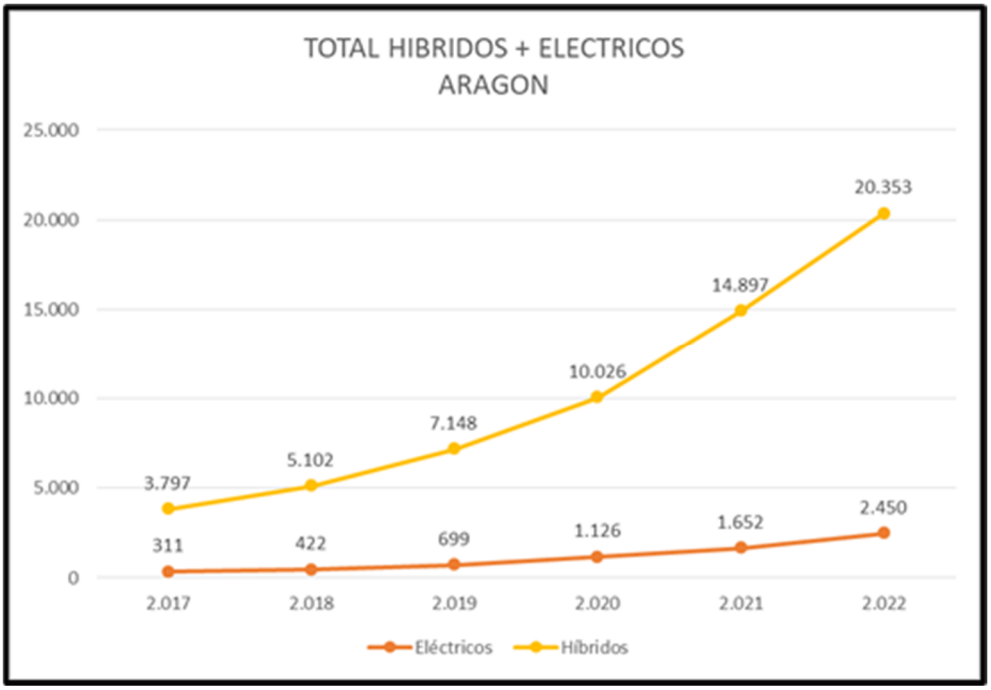
Number of hybrid + electric vehicles in Spain by vehicle segment.

	2017	2018	2019	2020	2021	2022
Vans	3457	5564	12865	25439	46693	70055
Lorries	1337	1933	2706	4203	5936	8290
Buses	436	643	1168	1490	2100	2613
Passenger cars	179549	265045	384630	547794	803906	1094741
Motorbikes	8264	11423	17926	24907	29047	38185
Mopeds	3686	7145	11621	14647	18599	21977
Other vehicles	1656	2255	3052	3706	4364	5259
Total	198385	294008	433968	622186	910645	1241120

In Aragon, the geographical area studied, Figure 2 shows the evolution and growth of the hybrid and electric vehicle fleet, which has been exponential over the last six years, with the number of hybrid vehicles outnumbering electric vehicles, in a similar way to national trends.

Figure 2

Hybrid and electric vehicle fleet in Aragon (2017-2022)



In terms of the number and evolution of the vehicle fleet in Aragon, mirroring national trends, most electric and hybrid vehicles are passenger cars, followed by vans, with more

hybrid than electric vehicles. Table 2 shows the figures and evolution of the fleet by vehicle segment.

Table 2

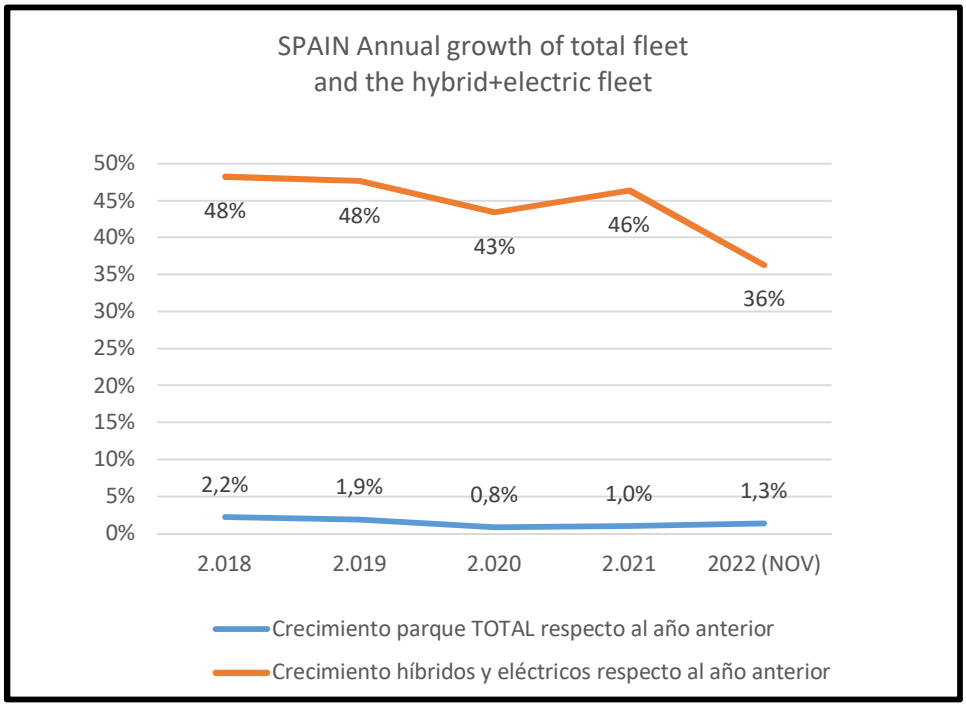
Number of hybrid + electric vehicles in Aragon by vehicle segment.

	2017	2018	2019	2020	2021	2022
Vans	44	65	152	338	750	1051
Lorries	26	31	49	60	85	102
Buses	4	6	45	62	62	75
Passenger cars	3860	5224	7285	10265	15034	20675
Motorbikes	81	87	118	172	266	455
Mopeds	44	54	122	152	194	235
Other vehicles	49	57	76	103	158	210
Total	4108	5524	7847	11152	16549	22803

In terms of annual growth, the fleet of electric and hybrid vehicles has grown significantly over the last few years in relation to the active fleet. Around 48%, with the exception of the year of the Covid pandemic, although there was only 36% growth over the last year. This could be due to user uncertainty resulting from EU policies with the approval of the Euro7 regulation and the controversy unleashed by some member countries regarding the moratorium on the permanent elimination of combustion vehicles in 2035 and the appearance of synthetic fuels known as e-fuels.

Figure 3

Growth of the total fleet and hybrid + electric vehicles.



If we look at electric vehicle registrations in several European countries in 2022, particularly in passenger cars, which account for most of the fleet, there are significant differences between countries. While in Norway, electric cars account for almost 80% of

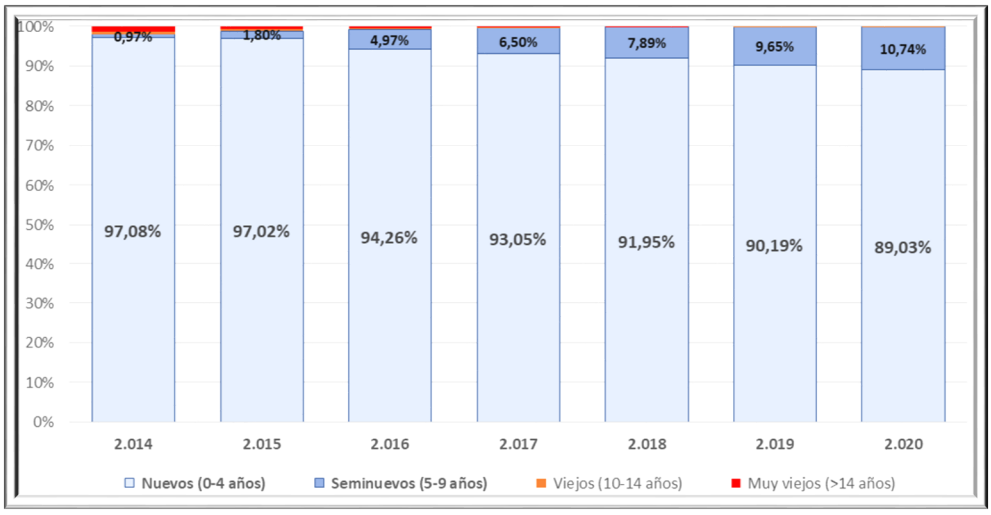
sales and the number of electric vehicles in Sweden is increasing by more than 100%, Spain is trailing far behind other EU countries like Germany, the United Kingdom and France in terms of electric vehicle deployment, and is one of the slowest countries to move towards electric mobility.

As for the age of the fleet, electric vehicles, in the range of new passenger cars, i.e. between 0 and 4 years old, have fallen from 97.08% in 2014 to 89.03% in 2020. Conversely, pre-owned passenger cars (5 to 9 years old) now account for 10.74%, compared to 0.97% in 2014. The number of passenger cars classed as old (10-14 years) and very old (more than 14 years) has declined since 2014 and has become virtually irrelevant today.

If the fleet of electric passenger cars, the most numerous by vehicle segment, ages in a similar proportion to that of petrol and diesel vehicles, this could pose an additional problem, since although electric cars require less maintenance than traditional fuels, the situation is quite different if the battery is damaged, even slightly, after an accident, because these defects are more difficult to repair and batteries are currently expensive to replace.

Figure 4

Age of the fleet of passengers cars with electric motors.



Note: evolution of the age of the electric passenger car fleet between 2014 and 2020. Source: Vehicle Research Institute Centro Zaragoza.

As the electric vehicle fleet grows, so do the new challenges we have to address. This applies not only to drivers, but also other stakeholders such as insurance companies, repair workshops, roadside assistance services and Authorised End-of-Life Vehicle Treatment Centres (ELVTCs) and, of course, emergency services.

On the other hand, there is some controversy about the safety of these new vehicles. While Euro NCAP considers electric cars to be as safe, if not safer, than combustion cars, in the United States, the National Transportation Safety Board (NTSB) considers electric

cars to be a driving hazard, mainly because they are heavy and the consequences of collisions with lighter vehicles.

Álvaro Gómez Méndez, Director of the DGT's National Road Safety Observatory (ONSV), believes that although some scientific work has already been published, more research based on real accident data is needed, as there is uncertainty about the differences between electric and traditional combustion vehicles in terms of the risk to vehicle occupants and pedestrians and occupants of other vehicles, because although, a priori, the greater mass of the electric vehicle means less risk to its occupants and greater risk to third parties, differences in driving styles can compensate for the mass effect.[3]

It is not that electric vehicles are more dangerous to traffic per se, but when a heavier vehicle collides with a lighter vehicle, the lighter vehicle bears the brunt of the collision because it absorbs more kinetic energy. The fact that they are so heavy, more than 2,000 kg in most cases, combined with the absence of noise, means that EVs pose an additional risk of pedestrians being run over. Not to mention the fact that they have power outputs of over 400 hp, which makes driving these vehicles more complex, as they accelerate faster than expected. The insurance company AXA claims that electric cars are involved in a higher number of accidents, 50% more than conventional cars, to be precise. (Franco, 2022)

From an analysis of information collected with data on the national and Aragonese level vehicle fleet, and the main accident and injury figures on the involvement of electric vehicles on interurban roads and in urban areas in the two territorial areas, we observe that a priori, it would appear that the number of accidents involving electric vehicles on interurban roads in Aragon is greater in the case of electric vehicles with respect to the active fleet than the accident rate with respect to the fleet of other vehicles, although in terms of accidents involving victims, it is similar in both cases. Similar results are obtained from the national comparison.

This is not the case in urban areas, where the situation is reversed, with a similar accident rate for the respective fleet, but a higher rate of accidents with casualties when electric vehicles are involved.

[3] Telephone interview on 1 April 2023.

Table 3
Vehicle accidents in Aragon and Spain on interurban and urban roads.

			Electric vehicles	Rest	TOTAL
INTER URBAN 2022	ARAGON	Fleet	22,803	949,477	**972,280**
	SPAIN		1,241,120	36,269,824	**37,510,944**
	ARAGON	Accidents	220	5,832	**6,052**
	SPAIN		4,032	99,917	**103,949**
	ARAGON	% of the	0.96%	0.61%	**0.62%**
	SPAIN	Fleet	0.32%	0.62%	**0.28%**
	ARAGON	Accidents	34	934	**968**
	SPAIN	with casualties	1,039	22,698	**23,737**
	ARAGON	% of	15.45%	16.02%	**15.99%**
	SPAIN	Accidents	25.77%	22.72%	**22.84%**
URBAN 2022	ARAGON	Accidents	99	3,473	**3,572**
	SPAIN		4,962	106,533	**111,495**
	ARAGON	% of the	0.43%	0.37%	**0.37%**
	SPAIN	Fleet	0.40%	0.29%	**0.30%**
	ARAGON	Accidents	95	1,187	**1282**
	SPAIN	with casualties	4,786	41,826	**46,612**
	ARAGON	% of	95.96%	34.18%	**35.89%**
	SPAIN	Accidents	96.45%	39.26%	**41.81%**

3. SPECIFIC RISKS ASSOCIATED WITH ELECTRIC AND HYBRID VEHICLES.

Changes in propulsion technology lead to changes in risks, which although neither greater nor lesser, are different. Due to their characteristics, both electric vehicles and hybrid vehicles entail a series of associated risks, among which we are electrical, chemical, fire and explosion risks, all three of which are equally dangerous.

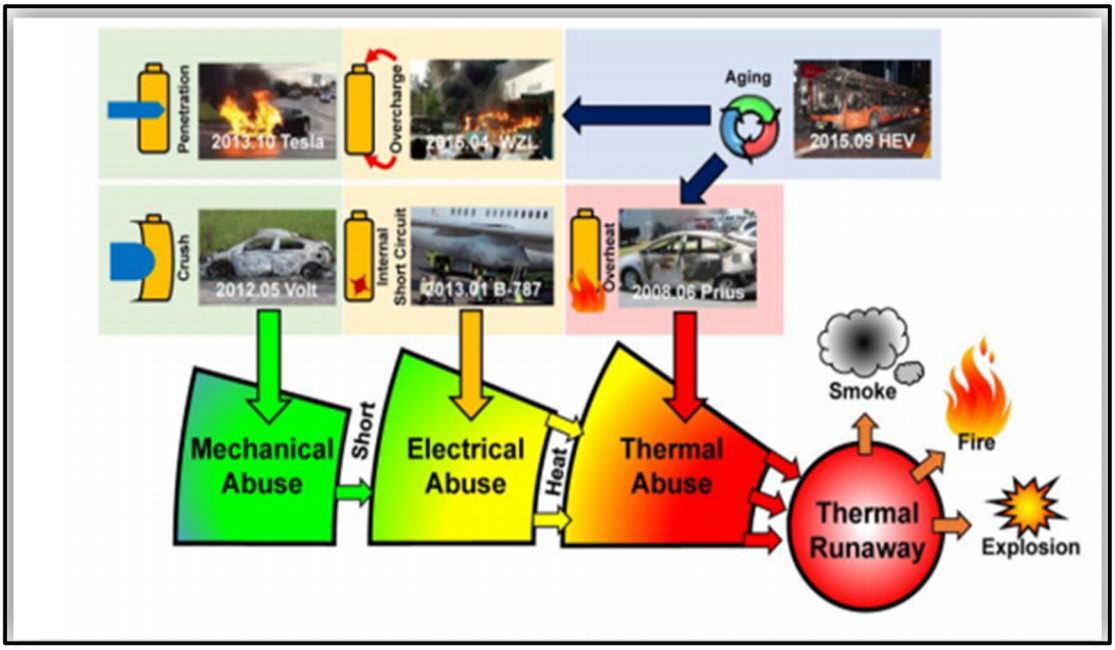
Researchers have concluded that the flammable solvents in lithium-ion batteries are just as dangerous as the petrol or diesel solvents used in conventional vehicles. (Sthephens, y otros, 2017)

The main safety problem of these batteries is due to a phenomenon called thermal runaway, which follows a mechanism during which the materials of the battery components undergo a chain decomposition, flammable gases are released, causing a build-up of pressure and temperature inside the battery that can eventually trigger a difficult-to-control fire or an explosion.

Feng summarises the abusive conditions that can lead to thermal runaway, which include mechanical abuse, electrical abuse and thermal abuse, with internal short-circuiting being the most common characteristic. (Feng, y otros, 2018)

Figure 5

Specific risks associated with handling an electric vehicle.



Source: Vehicle Research Institute Centro Zaragoza, retrieved from (Feng, et al., 2018, pp. 246-267)

Thermal runaway may be due to mechanical or thermal failure inside the battery. A faulty charging system or a vehicle collision resulting in crushing or penetration of the battery pack can cause overcharging or excessive discharge leading to high temperatures and thermal runaway.

Electrical risk is the risk caused by electrical energy, including not only the probability of suffering an electric shock, but also the risk of suffering burns due to electric shock or electric arc, falls or blows as a consequence of electric shock or electric arc, fires, or explosions.

On the other hand, the chemical risk is caused by the presence of highly reactive chemicals inside the high-voltage battery. In the event of a collision or traffic accident, the chemicals in the battery may leak out.

Among the toxic gases created and released, the most dangerous is the lithium hexafluorophosphate in the electrolyte, whose formation increases with temperature and which in contact with water forms the highly toxic and corrosive hydrofluoric acid HF, which can penetrate the skin and cause deep injuries to the body, with even fatal consequences. (Tacheová, 2022)

Figure 6
Injuries caused by hydrofluoric acid.

Source: Centro Zaragoza Technical Magazine. (Tacheová, 2022, pág. 48)

Electric and hybrid vehicles are equipped with several safety systems to prevent batteries from burning and to prevent the risk of electrocution in the event of an accident. If a sensor detects that a collision has occurred or the vehicle's airbag or pretensioners are activated, the high-voltage circuit stops releasing power, thus preventing electrocution and a possible short circuit that could cause a fire. Battery designs must provide for thermal management through a cooling system that absorbs and dissipates heat from the lithium-ion battery packs. (Vervecken, 2021)

Depending on the type of worker who must handle or repair an accident or breakdown of an electric vehicle, they will be exposed to one type or another of the mentioned risks. That is why the appropriate technical, organisational and personal measures to be taken to avoid such risks must be analysed in each case.

Essential aspects like training, information, dissemination, adequacy of facilities, intervention procedures, as well as equipment and tools, require consideration. (AEDIVE y GANVAM, 2020)

Based on a research study into real traffic accidents after which electric vehicles caught fire, the NTSB identified the safety risks to emergency services from high-voltage lithium-ion vehicle batteries: fire, electric shock, thermal runaway and grounding power. (National Transportation Safety Board (NTSB), 2020)

In a study into the training and education of emergency services in the intervention of road accidents with electric propulsion vehicles, the National Fire Protection Association (NFPA) identified the risks, procedures and safe methodologies in this segment of vehicles. It was determined that hybrid and electric vehicle collisions result in potential

fatalities and serious injuries at the scene of the accident for both responders and vehicle occupants, as well as the potential for post-incident injury, death, or damage to crash investigators, towing and rescue personnel.

Potential hazards identified by collisions involving these vehicles are described in the National Highway Traffic Safety Administration's (NHTSA) "Interim Guidance for Electric and Hybrid-Electric Vehicles Equipped With High-Voltage Batteries", and include stalled power, silent movement, toxic and flammable gases emanating from a High Voltage (HV) battery, thermal runaway, battery fires, and the possibility of electric shock from exposed high voltage cables and components. (Klock, 2013)

According to the US Department of Transportation (DOT), this new hybrid-electric technology is, in itself, no more dangerous to emergency services and the public than conventional petrol or diesel internal combustion engine vehicles. It says that the emergency services lack training and experience handling electric vehicle incidents, compared to their more than a hundred years of familiarity with internal combustion vehicles. (Klock, 2013, pág. 7)

When the emergency services have finished their work, particularly if there has been a previous battery fire, there is still a risk of fire, as the batteries may release toxic gases and even re-ignite, posing a risk to the roadside assistance services while towing of the vehicle from the accident site to the repair shop or ELVTC, where the risk will continue during storage, handling and, where appropriate, recycling.

To summarise, during interventions at incidents and road traffic accidents involving electric vehicles with lithium-ion batteries, emergency personnel and second responders, including both vehicle transport, repair, storage and recycling personnel, there are several safety risks related to electric shock, thermal runaway, battery ignition and re-ignition, and stranded power.

Rask et al (2020) reviewed the risks and hazards associated with stranded energy left in HV lithium-ion battery systems, with the aim of developing a tool to allow non-expert personnel, such as tow truck drivers, to assess and deactivate an HV battery system after an accident. The problem was that the tool required a direct connection to the internal battery modules via an HV port and, in all likelihood, the Battery Management System (BMS) and/or HV port would be damaged as a result of an accident or thermal runaway, making access impossible or very problematic. (National Transportation Safety Board (NTSB), 2020, pág. 61)

According to the European Trade Association for the fire safety and protection industry Euralarm (2022), the mere presence of lithium-ion batteries represents a considerable fire risk and "to limit the likelihood and consequences of a lithium-ion battery fire, a comprehensive strategy including risk prevention, early detection, intervention actions, active extinguishing and physical separation should always be adopted".

4. RESPONSE TO THE LINES OF RESEARCH

The question we asked ourselves when undertaking this research is whether the emergency services are adequately trained to intervene in a road accident involving

electric vehicles, and from this starting question we posed three derived questions that we will now analyse.

4.1. Is there any formal training available in interventions in road traffic accidents involving electric vehicles?

The Law on Occupational Risk Prevention (LPRL)[4] requires necessary and sufficient training, specifically focused on the functions performed by the worker. The Royal Decree on electrical risk[5], which is mainly focused on general electrical installations and not on the particularities of electric vehicles, follows the same lines.

As a result of this research we were able to verify the existence of regulatory standards governing specialisation courses and qualifications in hybrid and electric vehicle maintenance, aimed at sectors such as transport, vehicle rental and manufacturing, as well as the necessary qualifications required of ELVTC professionals who are responsible for handling electric vehicles, which, although they may offer curricular content, do not meet the specific needs of the emergency groups responding to a road accident.[6]

We found some training centres with specific approved courses in the handling and intervention of high-voltage vehicles, and in some cases even certifiers such as TÜV SÜD, although the training is oriented towards the needs of technicians to carry out safe repairs and on end-of-life vehicles.

The Vehicle Research Institute Centro Zaragoza and the Savyt Rescue Institute are approved centres in Spain that also offer first level training for emergency service professionals among other groups.

Some companies, such as Irizar e-mobility, offer specific training for drivers of the buses they manufacture.

The above-mentioned regulations aside, there is no formal training in Spain in handling battery electric and hydrogen fuel cell vehicles by the emergency services.

In other EU countries, such as Germany and France, there is regulated training available[7], and although it applies exclusively to those countries it can serve as a guide for the purposes of establishing regulated training in Spain. In fact, the programmes

[4] Articles 18 and 19 of Law 31/1995, of 8 November, on Occupational Risk Prevention (Official State Gazette (BOE) no. 269, of 10 November).

[5] Article 5 of Royal Decree 614/2001, of 8 June, on minimum provisions for the protection of the health and safety of workers against electrical hazards (Official State Gazette (BOE) no. 148, of 21 June).

[6] Royal Decree 265/2021, of 13 April, on end-of-life vehicles and amending Annex VI of the General Vehicle Regulations, approved by Royal Decree 2822/1998, of 23 December (Official State Gazette (BOE) no. 89, of 14 April); Royal Decree 281/2021, of 20 April (Official State Gazette (BOE) no. 111, of 10 May) and Royal Decree 109/2022, of 8 February (Official State Gazette (BOE) no. 34, of 9 February), establishing specialisation courses in maintenance and safety of hybrid and electric vehicle systems.

[7] The German formal training is DGUV 200-006 (2012), which sets training criteria, as well as qualification levels and working methods. Accreditation is obtained by examination at the German Chamber of Commerce.

The French standard is NFC 18-550, developed by the U21 Commission for the Prevention of Electrical Accidents (2015), approved by the French Association for Standardisation *(Association Française de Normalisation, AFNOR*), based on regulatory requirements and procedures to ensure the safety of people from electrical hazards.

offered by the main training centres are classified into three levels of training established by both German and French standards, the first level being applicable to emergency personnel.

In the USA, having identified a gap in fire service training on new propulsion technologies, the NFPA developed a comprehensive training programme along with an on-scene quick reference manual in a variety of formats and media[8], based on research conducted by Dr Jamie L. McAllister and Brian McAllister (2019) who evaluated the current approaches utilised in the fire service for proficiency training and continuing education. The approaches used by parallel professions (emergency medical providers, nurses, law enforcement officers, and teachers) were also assessed, concluding that to ensure they are up to date with changes as they occur and to assess the challenges in implementing uniform training requirements, a model of continuous training for first responders is needed.

In interviews with those responsible for first and second response in road traffic accidents, associations, researchers and experts[9], the Director of the Guardia Civil Traffic School, Colonel José Lope Galiana Fernández-Nespral and the Second Chief of the Aragón Traffic Sector of the Guardia Civil, Commander Raúl Castillo, are of the opinion that the existing regulatory framework for this type of vehicle has focused on approval and safety requirements and on the necessary infrastructure, but neglects the safety aspects of the handling of these vehicles by accident response or rescue personnel, and with regard to training, they acknowledge a lack of training for the group of agents.

With regard to surveys carried out among first responders to road traffic accidents,[10] , although the sample is small, the data is significant, as 60% of the officers surveyed stated that there is a lack of this specific training and the remaining 40% that there is only limited training.

In addition to confirming this lack of training in the emergency services, the Deputy Public Prosecutor for Road Safety in Cordoba, Ms Natalia Izquierdo Siles, warns of the risks that first responders take due to insufficient training in the new propulsion systems.

The Managing Director of the Professional Association of Firefighters Technicians (APTB), Mr Gabriel Muñoz Simal, and the Head of Intervention of the Fire Department of Zaragoza City Council, Mr David Galve Marzal, point to the slow response of training to the new scenarios caused by electric vehicles, which is offset by the experience and general training of firefighters, as well as the lack of a standard that establishes a basic safety design for all manufacturers, an issue that we have seen is also recurrent in other

[8] NFPA educational offerings are available on the NFPA website at *www.EVSafetyTraining.org*

[9] In March and April 2023, 22 personal interviews were carried out by telephone and e-mail with the heads of first response groups (ATGC and Local Police, fire brigades and health services) and second response groups (roadside assistance, road maintenance), as well as other groups that handle these vehicles, such as vehicle repair workshops and ELVTCs, in addition to government officials, associations, researchers and experts related to electric vehicles.

[10] A survey was carried out among 166 professionals from the Guardia Civil, Local Police, Fire Brigade and 112 Health Service in the province of Zaragoza, using a form with six questions with predetermined responses.

countries. In the survey of firefighters from the City Council and the Zaragoza Provincial Council, almost 63% and 90%, respectively, indicated a lack of specific training.

Similarly, local police officers and health personnel say there is a lack of training, a fact corroborated by 73% of the officers surveyed and 100% of the health personnel in the respective surveys. Both the Chief Intendant of Traffic and Road Safety of the Local Police of Zaragoza City Council, Mr Juan M. Maroto Valer, and the head of Security and Civil Protection (112) of the Government of Aragon, M. Miguel A. Cavero, state that there is an absolute lack of specific training in intervention and handling of this type of vehicle. Mr Rafael Benavente, Chief Engineer of the State Roads Conservation and Exploitation Service, shared this opinion with regard to the group of road maintenance workers, whose training is scarce or even non-existent.

The presidents of the Aragonese Roadside Assistance Association (AARAC), Mr José Alonso Doto, and the Zaragoza Vehicle Repair Workshops Association (ATARVEZ), Mr José A. Mora Sotoca, both point to a lack of training as well as a lack of regulation, although the president of the Association of Scrapyards of Aragon (ADESAR), Mr José A. Mora Sotoca, said that there was a lack of training and a lack of regulation of their own. Mrs Mª Antonia Cebollada mentioned the existence of initiatives from different sectors vis-a-vis a specialised training offer, which will become established as the use of this type of vehicle becomes more widespread.

In the interview with Mr José M. Cáncer Abóitiz, General Manager of the CESVIMAP, the Center for Experimentation and Road Safety MAPFRE, and Mr Guillermo Magaz Pilar, General Manager of the Spanish Association of Collaborating Entities of the Administration in the Technical Inspection of Vehicles (AECA-ITV), they point out an absence of regulations and consider that there is a lack of specific training.

In the same vein, the engineer responsible for electric vehicles and mobility at the Zaragoza Centre's Institute for Vehicle Research, Ms Ana Olona, and the Assistant Deputy Director General for Vehicles of the DGT, Ms Susana Gómez Garrido, advocate moving towards Europe-wide legal and regulatory standards, recognising the lack of a unified training standard at national level.

During the research, we also detected a lack of training and information among drivers. We have already mentioned that driving this type of vehicle is more complicated and the potential consequences on the accident rate, with the consequent need for intervention by rescue or roadside assistance services.

When analysing the surveys and interviews carried out with professionals from the world of driver training and DGT officials and professionals and experts in the field of road safety, we observe that not only is there a lack of training for road users, but also a lack of information about this vehicle segment.

While the National Vice-President of the National Confederation of Driving Schools (CNAE), Mr Sergio Olivera, considers it necessary to re-educate drivers in view of the different behaviour of these vehicles when driven, the Director of the ONSV considers that, although the level of training of road users is low, re-education is not a viable solution, and that action should be taken through information and awareness campaigns,

with the participation of car dealers, as well as including training on driving electric vehicles in the scope of Private Driving Schools (EPC).

From the research carried out, we can conclude that, although there is a certain amount of training offered by different associations and organisations in relation to electric vehicles, the existing formal training is aimed more at professionals in vehicle repair workshops and ELVTCs than at first and second responders in emergency services.

As for the emergency services, with the exception of the fire service, whose general training may offset a lack of specific training required for interventions with this type of vehicle, the others involved lack specific training, such as the medical and local police forces, and although the ATGC has just designed a training programme, it has not yet been implemented to cover all its members, a matter which should be addressed as soon as possible.

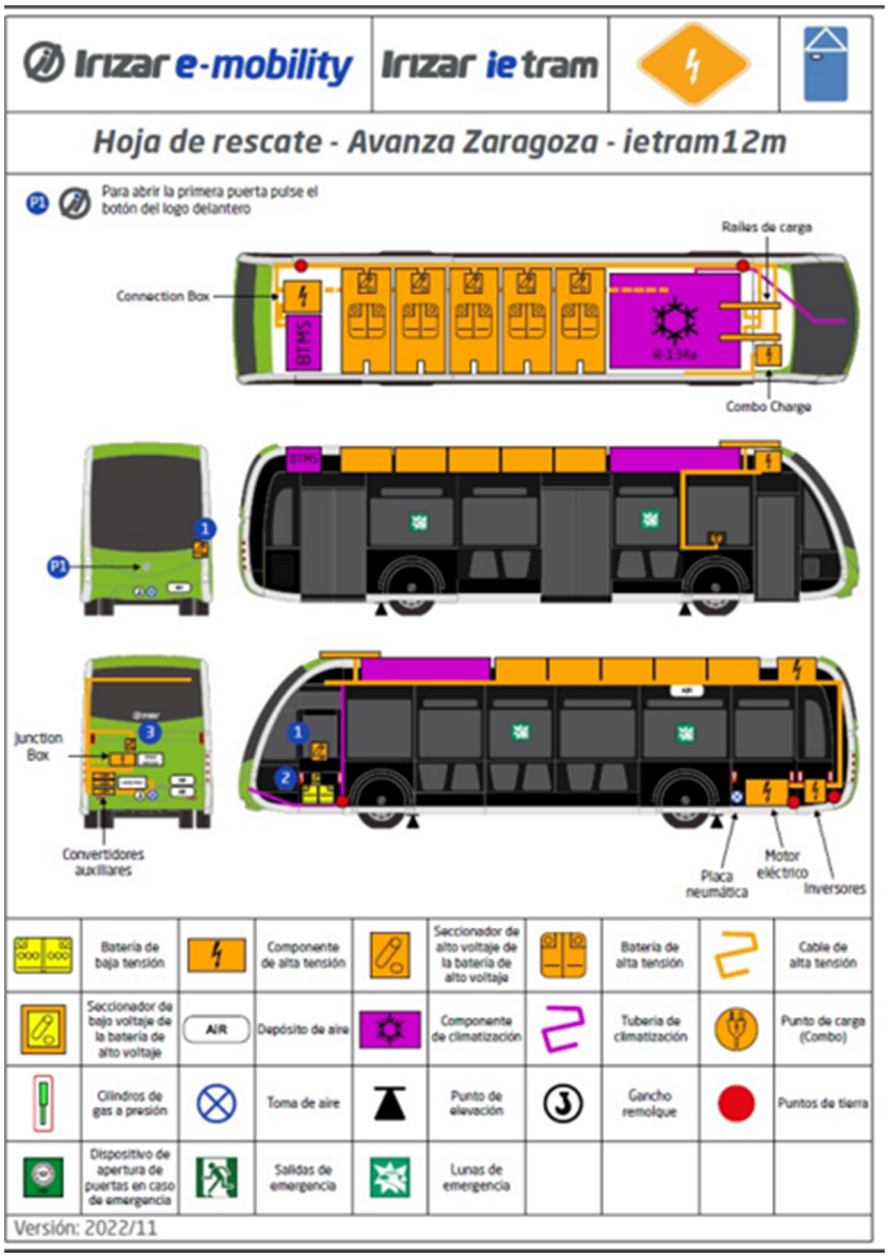
4.2. Is there a specific unified protocol for intervention in road traffic accidents involving this type of vehicle?

The Professional Association of Rescue in Traffic Accidents (APRAT) and the DGT have published a Basic Manual that includes the Unified Rescue Procedure. There are numerous documents of varied content created by different emergency services throughout Spain, which, in different formats and to different extents, cover the different phases of the unified protocol for rescue in traffic accidents, adapted, more or less, to the peculiarities of electric vehicles, but there is no unified protocol for joint action. Some internal procedures of different regional intervention groups have been analysed. (Jimenez Onetti, et al., 2015; Bonilla Blas, et al., 2019; Mateo Fernández, 2021; Agencia de Seguridad y Emergencias Madrid (ASEM), 2019).

In turn, increasingly safer vehicle designs pose new challenges for rescuing accident victims trapped in their vehicles, as does the appearance of new forms of propulsion, such as that used by hybrid and electric vehicles. Finding and disconnecting the batteries in these cars is an additional problem, which may be aggravated by the deformation of the vehicle structure as a result of the road accident.

Rescue sheets, prepared and distributed by vehicle manufacturers for each model, help to identify risks. The Europe-wide use of a standardised rescue sheet is vital in situations where every second counts, avoiding unnecessary delays by providing rescue teams with the information they need.

Figure 7
Rescue sheet 100% electric Irizar ietram city bus.



Source: Avanza Zaragoza.

Euro NCAP, in collaboration with the International Association of Fire and Rescue Services/Comité Technique International de prévention et d´extinction du Feu (CTIF), developed the Euro Rescue application that gives emergency services quick access to the relevant vehicle information.[11]

[11] The "*Euro Rescue*" application is available for both Apple (https://lnkd.in/gZKN_Qd) and Android (https://lnkd.in/gPPhpCY). There is also *Moditech* 's *Crash Recovery System* application for Apple (https://apps.apple.com/app/crash-recovery-system/id1468268628?ls=1) and for Android (https://play.google.com/store/apps/details?id=crs.mobile.moditech.com

Back in 2010, the NFPA co-hosted a National Summit with SAE Internacional (Society of Automotive Engineers, SAE) to address issues related to electric vehicle safety codes and standards, infrastructure, and emergency personnel. The idea was for key individuals, organisations and agencies to develop a common understanding of how to ensure electrical and fire safety standards for electric vehicles. An alternative fuel vehicle safety summit was held again in 2016, in the face of unstoppable growth, concluding that "the most important thing for emergency responders is a clear and rapid understanding of all the hazards they face, especially during an emergency, when accurate real-time information is critical". (Grant, Alternative Fuel Vehicle Safety Summit, 2016)

Based on their research, the American organisations NFPA and NTSB identified the safety risks for emergency services, stating that the main problem is the large amount of vital safety information on a car that a rescuer needs to access when responding to an accident to contain the risk and adopt integrated protection and intervention solutions, developing a quick reference field guide (Electric/Hybrid Vehicle Emergency Fiel Guide, EFG) and a series of best practice recommendations and common procedures for the protection of emergency responders.[12]

The NFPA has carried out research to assess the differences between internal combustion engine vehicle fires and fires associated with electric vehicles. Aimed at strengthening the NFPA Electric Vehicle Emergency Field Guide, the project sought to develop best practices for emergency response procedures for electric vehicle battery incidents. (Long Jr., Blum, Bress, & Cotts, 2013)

The NFPA keeps a collection of Emergency Response Guides (ERGs) from more than 35 alternative fuel vehicle manufacturers, which can be downloaded free of charge. (U.S. Fire Administration (USFA), 2022)[13]

Euralarm (2022) produced a guide to integrated fire protection solutions for lithium-ion batteries for safety, security, fire fighting and fire suppression professionals in relation to the use, storage and transport of lithium-ion batteries and their fire risk.

Based on work carried out by Katharina Wöhrl et al (2021) of the CARISSMA Institute of Electric, Connected and Secure Mobility (CECOS), European countries like Germany produced a document with recommendations for handling electric vehicles in accidents, which, in addition to analysing the risks for rescue services, establish the General Procedures for Traffic Accidents with BEVs and the rescue sequence from the emergency call to the towing and subsequent recycling of the vehicle. France has also developed a series of guides and documents on recommendations and handling of electric vehicles involved in accidents.

Organisations such as the CTIF and SAE International (2019), respectively, developed ISO 17840 and SAE 2990 Recommended Practice, which aim to establish a standard format for emergency response guidelines and a set of best practice recommendations and common procedures for the protection of emergency responders.

[12] The *Electric/Hybrid Vehicle Emergency Field Guide (EFG*) contains only the most important BEV safety information and is available as a printed manual and on smart mobile devices, in a highly indexed and in a consistent format for each manufacturer.
[13] https://www.nfpa.org/education-and-research/emergency-response/emergency-response-guides?l=515

Because the design of electric vehicles is different for different makes and models, and because rescue and firefighting responders need practical emergency guidance specific to the characteristics of each electric vehicle, the NTSB (2020) recommends compliance with ISO 17840 in manufacturers' electric vehicle ERGs.

In addition to identifying the risks faced by emergency responders, a 2020 NTSB investigation into the safety risks faced by emergency services when responding to vehicles with high-voltage lithium-ion batteries[14] identified two safety gaps: inadequacy of vehicle manufacturers' emergency response guidelines to minimise the risks posed by battery fires for first and second responders, and gaps in safety standards and research related to batteries in high-speed collisions. (National Transportation Safety Board (NTSB), 2020)

The survey of the 166 first responders (officers, firefighters and health workers) is virtually unanimous. All those responsible for first and second response emergency teams interviewed highlighted the need for a unified and coordinated action protocol between the different intervening agents.

The Director of the Traffic School considers creating this protocol and training to be essential, especially since on many occasions the Guardia Civil officers are the first to arrive at the scene of an accident when immediate assistance is required, and the Managing Director of APTB recommends the extension of the state-level protocol to the European level.

Ms Susana Garrido of the DGT considers it appropriate to have a unified, coordinated and periodically updated protocol with the innovations of this type of propulsion systems and Mr Jesús Monclús, Director of the area of prevention and road safety of Fundación MAPFRE, sees an opportunity to work on standard protocols and training in the EU and even at a more international level.

The Deputy Public Prosecutor for Road Safety specifies that in addition to the common and basic sections aimed at all first responders to guarantee their safety in the intervention, it should include the corresponding sections that respect the specificities of each group, especially firefighters, as they focus on reducing or eliminating the risks generated by these vehicles.

ATARVEZ and ADESAR consider a unified protocol to be necessary, AECA-itv states that it does not have a specific procedure, accessing information through commercial programmes and platforms, and AARAC considers it absolutely necessary to establish a unified action protocol that coordinates towing services with other agents and provides information that none of the roadside assistance companies surveyed by the association itself has been informed of, knows of or applies a protocol, whether internal or coordinated, between the different first or second responders.

Centro Zaragoza researcher, Ms Ana Olona, believes that the information provided by the manufacturers is adequate, although it is true that as there is no universal and common location for the maintenance connector to disconnect the HV, it is necessary to rely on the Rescue Sheet and stresses the importance that when the damaged electric vehicle

[14] Investigation Report NTSB/SR-20/01

arrives at the workshop, information is provided on the actions that have been carried out on it, allowing the workshop to know what has been done to the vehicle, which will help said personnel to adopt the most suitable protection and/or prevention measures before handling the electric vehicle or its components where appropriate.

Pérez de Lucía, from AEDIVE, considers that there is a lack of sufficient information to inform the different groups about the available documentation and how to access it.

In the US emergency community training project developed by the NFPA, one of the objectives of the project was to establish better communications between vehicle manufacturers and emergency services to improve access to necessary safety information. (Klock, 2013)

We can conclude that information is made available to the different groups through the rescue sheets, but apart from the APRAT/DGT Basic Manual, there is no specific protocol for intervention in road traffic accidents involving electric or hybrid vehicles. There is rather a willingness on the part of some emergency services to regulate these procedures more than the existence of real protocols or guidelines, which in no case are unified, coordinated or generalised.

This is far from the research and studies carried out by American agencies NFPA and NTSB, as well as the summits for the development of common knowledge, safety codes and standards, the approval of a Rapid Emergency Guide, compilation of critical information and manufacturers' guides, continuous training of the emergency services and, ultimately, common procedures for action.

All the agents involved in the intervention were almost unanimous on the need for a unified action protocol, a protocol that should extend second responders, an opinion supported by virtually everyone interviewed, belonging to different fields, some of them including the need for this unified protocol to be even at a European level.

4.3. Do emergency personnel have the necessary protective equipment for these interventions?

All occupational health and safety measures must comply with the general principles of risk prevention set out in the LPRL and other applicable regulations, applying the principle of risk minimisation without forgetting that the lack of qualifications and inadequate instructions to employees is a source of danger.

Depending on which professionals must deal with or repair an electric vehicle damaged in an accident, they will be exposed to one type or another of the risks indicated above. That is why the appropriate technical, organisational and personal measures to be taken to avoid such risks must be analysed in each case.

There is mandatory and recommended Personal Protective Equipment (PPE) the safe handling of an electric or hybrid vehicle. Anyone who must handle or repair an electric or hybrid vehicle that has been involved in an accident must use the following PPE:

dielectric protective gloves and footwear, impact goggles and Self Contained Breathing Apparatus (SCBA) for firefighters.[15]

Surveys of first responders show that, with the exception for firefighters, most officers and health workers believe that they should be provided with the necessary PPE when the intervention involves electric vehicles.

The Road Safety Prosecutor interviewed said that officers should wait for the fire brigade to arrive, proceeding in the meantime to identify the vehicle, immobilise it if necessary and establish a safety zone, considering it feasible to have dielectric gloves for specific occasions.

The general protocol of the Basic Traffic Accident Rescue Manual establishes that if ATGC officers are the first to arrive on the scene of the accident (as is usual on interurban roads) and in the event of imminent risk to the victim, the victim must be rescued and located in a safe area until the arrival of the Fire Brigade or Medical Services. We are faced with the dilemma of a necessary rescue intervention and a lack of protection for the agent due to the lack of even a minimum of protective equipment against electrical risk.

The study shows that dielectric protective gloves that protect against contact, even if accidental, with a conductive element, as well as goggles that prevent possible burns to the face caused by an electric arc, are two items of PPE that officers involved in road accidents involving electric vehicles must have.

The Chief of Fire Brigade Intervention says that if responders are going to act on a risk, they must have the appropriate PPE and makes a very important contribution by pointing out that the use of category III equipment (which protects against risks that can have very serious consequences such as death or irreversible damage) such as dielectric protective gloves or SCBA, must be accompanied by training in their proper use and maintenance. This brings us back to the need for standardised and unified training that covers all aspects.

5. CONCLUSIONS

Based on the analyses, we can confirm that, although information and guidelines are available, we have not found any formal training or unified protocols for action for emergency services intervening in road accidents involving electric vehicles in Spain. We have seen shortcomings in terms of the necessary training of emergency services during intervention in a road accident involving electric vehicles, and even the emergency response guides of vehicle manufacturers are lacking to minimise the risks involved.

[15] Dielectric gloves must comply with the UNE-EN 60903:2005 standard, which specifies the requirements for the manufacture, verification and correct use of electrically insulating gloves and mittens, with and without mechanical protection. Face shields certified according to UNE-EN 166-2002 (individual eye protection) are the only eye protectors valid for this area of the body, and they also include the requirement for protection against short-circuit electric arc.

We will make some recommendations along the lines of the research carried out by the key organisations and agencies referenced, and the opinions of practitioners and experts in the field who have been interviewed for this paper.

The first proposal is to organise a national summit, along the lines of those held in the US in 2010 and 2016 by the NFPA's Fire Protection Research Foundation, to address issues related to training and safety standards affecting electric vehicles and other non-combustion propulsion systems, as well as first and second responders.

Given the complex territorial organisation of the Spanish State, with three territorial and jurisdictional spheres, it will be necessary to determine which national and/or sectoral administrations, bodies, institutions, etc. should participate. The federal organisation of countries such as the USA and Germany, together with the fact that both have conducted research into the subject studied and have formal training and standardised protocols, could be used as a roadmap for an initiative, even at European level, to comprehensively address the current and future safety and environmental challenges brought about by the increasing deployment of new propulsion energy vehicles. Proposal supported by the interviewed officials from DGT, Fundación MAPFRE and the APTB association.

Other institutions, associations, institutes, foundations, university researchers and other fields related to new vehicle motorisation technologies and safety standards should form part of a multidisciplinary team and manufacturers' and dealers' associations, such as ANFAC and FACONAUTO, are essential in that the manufacturers are largely responsible for the necessary information contained in the guides and response sheets to minimise the risks of this vehicle segment.

In line with the American NFPA, a comprehensive training programme should be developed for the emergency services and a quick reference guide should be developed at the scene of a road accident or incident. It would therefore be advisable to add the guidelines of the German standard DGUV 200-06 and the French standard NFC 18-550 to the formal training of Royal Decree 614/2001.

Continuous education and training of health and emergency professionals is essential, and therefore permanent updating should be programmed as new propulsion technologies are developed, which should not be limited to exclusively academic training, but should include activities such as specialisation and refresher courses, conferences or forums for sharing experiences.

Adopting the German proposal to make up for the current impossibility of accessing the relevant battery parameter data, as it is encrypted and accessible only to manufacturers, promoting the development in new vehicle designs of a future Event Data Recorder (EDR) among manufacturers that acts as a black box, containing a minimum of required accident data. This data would be sent to a data centre and would be available immediately after the accident. (Wöhrl, Geisbauer, Nebl, Lott, & Schweiger, 2021, pág. 15)

Information and awareness-raising campaigns, using research results, would be a good practice to implement. Including the transmission of battery and propulsion system data to emergency teams and real-time access to vehicle registration and technical data in the action protocol would be another good practice.

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