Eur. Transp. Res. Rev. (2017) 9: 25
DOI 10.1007/s12544-017-0240-1

ORIGINAL PAPER

# A case study exploring firefighters' and municipal officials' preparedness for electrical vehicles

**Christina Stave**[1] · **Annelie Carlson**[1,2]

Received: 1 August 2016 / Accepted: 11 April 2017 / Published online: 3 May 2017
© The Author(s) 2017. This article is an open access publication

**Abstract**
*Purpose* This study presents a social perspective on new vehicle technology. It explores the self-reported preparedness of the fire departments (i.e., rescue services) in Sweden's three largest cities regarding rescue operations involving electrical vehicles (EVs).
*Methods* In this multi-method study, in-depth interviews were performed with emergency service officers and municipal officers in each city.
*Results* The results indicate that firefighters have little experience of accidents with EVs and they are learning reactively. The risks were not clearly identified. More knowledge is needed of identifying and disconnecting electricity in EVs. A more efficient way to find information about new vehicles is vital concerning the safety aspect in rescue operations**.** The level of knowledge about new vehicle technology varied between departments. For the municipal officers, environmental aspects are of most interest, whereas safety and rescue operations involving EVs are rarely addressed. The responsibility for disseminating information about the safe handling of EVs was unclear.
*Conclusion* The fire departments need more resources for education and training to keep up with technical developments and to be proactive. Another desired development is a solution for easy access to vehicle information**.** Since the environmental issues are setting the agenda, not the safety issues, lesser environment risks could become greater safety risks. We stress the need for various occupational decision making at all levels of society to cooperate in order to take responsibility for the safe introduction for new more environmentally friendly transport vehicle technique and disseminating safety information in a collected and systematic way.

**Keywords** Firefighter · Electric vehicles · Safety training · Traffic accident

This article is part of Topical Collection on Smart cities and transport infrastructures

✉ Christina Stave
Christina.stave@vti.se

[1] VTI, Swedish National Transport Research Institute, Box 8072, SE-402 78 Göteborg, Sweden

[2] VTI, Swedish National Transport Research Institute, S-481 95 Linköping, Sweden

## 1 Introduction

One consequence of measures taken to reduce greenhouse gas emissions is that more electric vehicles (EVs) are appearing on the roads. Oslo, Norway, for example, has encountered a huge increase in such vehicles in recent years [1]. This increase will bring accidents differing from those involving conventional combustion engines, and news coverage has reported on fires in EVs. There is a need for information about how to handle such new technology in case of accidents. This involves the community more than the individual vehicle users [2]. In today's complex technical society, Rasmussen [3] describes the difficulty of handling risks when many stakeholders are involved in socio-technical systems. There is a need for different occupational groups and decision makers in all levels in society to cooperate. Important questions for society include facilitating adaption and taking responsibility for risk evaluation and information dissemination about the safe handling of EVs. Some car companies have produced specific information for rescue services, e.g., [4, 5]. In the USA, where manufacturers bear considerable responsibility, some EV producers have cooperated with national and international organizations

to compile an Emergency Response Guide [6]. The National Alternative Fuels Training Consortium also provides information about EV training programs for rescue services [7].

Much existing knowledge is national in focus and ignores the local level. Visvikis et al. [8] observes a gap in the type-approval legislation relating to safety and rechargeable energy storage systems (RESSs). Standards would improve safety [9] because few local rescue services have the capacity to learn about all the different EV models. Few studies have examined safety behaviour and knowledge among emergency responders [10]. In sum, the literature on EV risks primarily has a technical focus, and one specific research gap concerns rescue service self-reported preparedness and the local authority views of EV risks and safety. Here, preparedness means the ability to effectively handle accidents with new types of vehicle technology and the possession of sufficient resources, such as technical devices, vehicles, and competence [11].

Accordingly, this study explores stakeholders' experiences of rescue operations involving EVs and how stakeholders reason about their preparedness regarding EV risk and safety issues. It is their own estimation of their capacity and abilities to handle EV risk and safety issues. This was done using a multi-method approach addressing two stakeholder groups in Sweden. To operationalize the aim, it was divided into two sub-questions: (a) How do stakeholders reason about their preparedness regarding EV risk and safety? (b) What are the perceived barriers to and facilitators of the future handling of EV accidents?

## 2 Background: The Swedish rescue service context

In Sweden, municipalities are responsible for emergency assistance within their geographical areas, evaluating their needs for staff and staff education. Each municipality in Sweden must have a fire chief who is responsible for keeping emergency services dispatchable and for allocating resources to rescue operations as needed. The Swedish Civil Contingencies Agency (MSB) is a national governmental authority responsible for developing and supporting societal preparedness for accidents and crises. It coordinates various sectors of society and ensures that education and training are performed.

A full-time firefighter must undertake two years of education arranged by MSB [12], which also educates emergency operation leaders. More than half of all firefighters in Sweden work part time and have another employer in addition to the municipal emergency service. They are on standby duty (usually every fourth week) and are obliged to participate in education and regular training, but can join the force after only a two-week preparatory course.

Accidents with EVs are described in MSB information material treating rescue operations involving both people and vehicles [13]. The MSB website [12] also provides information and an instructional film for rescue personnel dealing with traffic accidents involving EV cars [12]. One example of such information is a report on the "state of the art" from the Räddningskedjan research project [14]. Education with a special focus on EVs has been given to some firefighters, based on international research and full-scale tests of burning batteries in electrical cars [15].

## 3 Methods

This case study examines three rescue services and municipalities in Sweden's three largest regions, namely, Stockholm, Göteborg, and Malmö. It is an exploratory study of society's use of resources and the safety aspects in relation to new types of vehicles.

A case study provides information very close to actual perceptions and behaviours in daily performance. Multiple information sources are applicable in case studies [16] accordingly, a multi-method approach was applied in three steps:

1. An overview of documented accidents and potential risks of EVs was compiled: First, accident statistics were analysed. A search of accidents involving EVs was conducted in the Swedish Traffic Accident Data Acquisition (STRADA), a database of injuries and accidents occurring throughout the Swedish road transport system. Another search was conducted in the MSB accident database [17]. We then reviewed the literature on investigations of accidents involving EVs.
2. Data from step one were analysed and four potential accident scenarios were constructed as a basis for in-depth interviews with emergency responders at the rescue services. The purpose is to explore their experience in their situation, not to evaluate their knowledge or stated behaviour in relation to any appropriate response.
3. During in-depth interviews with firefighters and rescue leaders, the four potential accident scenarios were orally presented and discussed. Local and regional authority street-level bureaucrats were also interviewed regarding their roles and responsibilities. For all stakeholders, the questions addressed knowledge, preparedness, and experience of EV safety and risks.

The personal interviews were performed using a semi-structured interview guide [18] and lasted about two hours each. The interviews were conducted at the interviewees' offices in October and November 2013. They were recorded, transcribed, and analysed using a simple form of content analysis [19]. In this analysis, themes were sought within the frame of the interview guide, and key quotations were used to reflect the interviewees' knowledge, attitudes, and practices. All interviewees were anonymized.

From the analysed interviews an image was created to synthesis the conclusions. This representation of the results is presented as the inverse of reported deficiencies, showing the potentials to increase firefighter's preparedness and safety in handling accidents where EVs are involved.

### 3.1 Participants

The three regions were chosen because the EV fleet is expected to increase first there and thus the experience is expected to be the greatest in these areas. We interviewed one rescue leader in Stockholm, one rescue leader and two firefighters in Göteborg, and one rescue leader, one training leader, and two firefighters in Malmö. All interviewees except for the training leader were men. One municipal official specializing in traffic and/or the environment was interviewed in each region; all three of these officials were women.

## 4 Results

### 4.1 Overview of documented accidents involving EVs and of potential risks

#### *4.1.1 Statistics of accidents with electrical cars*

Over seven years (2006–2012), there were 477 accidents involving various sorts of EVs registered in STRADA. Only one (2012) of these accidents involved a battery electric vehicle (BEV). Four of the accidents were fatal and 103 caused serious injuries. Many of the EVs involved in these accidents were small vehicles for example, postal service cars, golf carts, and moped-cars, driven at a maximum of 45 km/h. This means that the accidents often happened on cycle paths. In STRADA, the only way to register how the involved vehicle is powered is to record it as a comment, which is rarely done. The accident descriptions we found made no reference to electrical systems or batteries. The MSB accident database (2002–2012) included only four registered accidents involving EVs. Also in this database, electrical cars can only be identified if the rescue services specifically recorded that the accident involved an EV. In neither database were the causes of the recorded accidents linked to electricity.

#### *4.1.2 Literature review of investigations after accidents involving EVs*

A report from Räddningskedjan, [14] note that the battery systems in EVs are made of various flammable materials, leading to uncertainty and danger among rescue teams as well as people involved in the accidents. Results of fire tests of EVs battery cells and packs has also been published [20]. Hoffman [21] examines how a 400-V traction battery reacts to contact with fresh and salt water. Nothing drastic happened during the tests, but a battery that has been drenched with water and not discharged could still retain a dangerous voltage level several months later, which rescue services, car mechanics, and car recyclers should be informed of.

Sturk and Hoffman's report [14] on the potential risks of EVs in traffic accidents presents an overview of various accidents involving EVs, focusing on batteries and fire. The following summarize several accidents covered in the report:

- After a crash test of an EV there were no serious problems with the car. Three weeks later, the car caught fire due to the electrical energy left in the battery. The combination of the particular damage and the weather conditions led to a short circuit, which caused the car to ignite.
- A petrol-fuelled car crashed into an electrical taxi at 180 km/h in China. The taxi flipped over, hit a tree, and caught fire, resulting in the death of all three passengers. The tree penetrated the battery, causing arcing and a short in the high-voltage electrical circuit, which ignited flammable material in the car, including the battery. The battery did not explode and no faults were found in the design of the safety system.
- A fire occurred in an EV on a ferry between Oslo and Copenhagen; the EV was a rebuilt SUV (sport utility vehicle), converted from petrol to electricity. The charging was performed using a homemade charger and the car was not approved. No signs indicated that the fire started in the battery.
- Three fires occurred within six weeks in the USA. An EV caught fire on the motorway after hitting a hard object that penetrated the front part of the battery and damaged some electrical components. The second fire occurred in an EV driven at high speed into a roundabout, where it crashed into a concrete slab, hit a tree, and caught fire. The third fire was caused by a hard object penetrating the front part of the battery from beneath, which damaged the electrical system and started the fire.
- An accident involving a car that was converted from petrol to electrical operation was investigated in Sweden [22]. The fire started when the car had likely been charging for more than 24 h. The car probably lost coolant and the heat became so intense that aluminum in the vehicle heater melted (660 °C) and started a fire inside the car. The traction battery probably did not start the fire, but could have arced when the cabling was damaged, possibly contributing to the fire.

A section of the MSB instruction book [13] focuses on the safe handling of EVs, including how to handle and shut down their electrical circuits, the risks of lithium-ion batteries, and chemical risks associated with handling batteries and fires in battery packs. The book also notes a problem in identifying

EVs, as there is no standard or industry agreement for how to mark electric and hybrid cars. A software system, the Crash Recovery System (CRS), that can help identify EVs and indicate how to handle them in order to disconnect the battery power has been introduced in Sweden. Data stored in a CRS can provide a diagram of where the batteries are located, where various pressure containers are found, at what points the vehicle is reinforced, and what safety equipment the vehicle contains. The software is installed in a laptop or tablet PC controlled by a touch screen. Emergency Call (eCall), another tool under development to assist the rescue services, causes EVs to automatically dial 112 in case of an accident.

#### *4.1.3 Five risk areas*

The above overview identified the following problem areas:

1) difficulty identifying whether or not a vehicle is an EV
2) knowledge of how to turn off the electricity in all car models, to be able to cut open an EV safely
3) the kinds of fluids that can leak from batteries and how to handle them
4) how to put out fires in electrical cars and what gases can develop in these fires
5) risks associated with electricity if an EV comes into contact with salt water, and whether this risk would remain after a rescue operation

From the five problem areas identified above, four scenarios were created as a base for discussion with firefighters about their preparedness and actions with electrical vehicles in accidents, see section 4.2.2.

### 4.2 Interviews with stakeholders

Presented here are the results of the interviews with rescue leaders in Stockholm and Göteborg regions, Rescue Services South/Malmö as well as firefighters in Göteborg and Malmö. First the different rescue services are presented in addition with their attitudes towards and experience with electrical vehicles. This is followed by their responses of how they would act in the four scenarios according to their perceived experience and knowledge.

#### *4.2.1 Interviews at the rescue services*

*Storstockholms brandförsvar* (SSBF), the largest rescue services organization in Sweden, involves cooperation among ten municipalities; it employs approximately 750 firefighters at 15 fire stations and provides rescue services for 1.1 million people. All SSBF firefighters have undergone specialized education, including training in operations involving car accidents, and some of them have specialized knowledge of particular areas. The nearest fire station responds to the accident alarm, and special competence is called from other stations as needed. The rescue services lead the operations at car accidents.

According to the interviewee, SSBF has little experience with EVs, and there are probably firefighters who have never attended an accident involving a BEV. They have received information about EVs from personal contacts, MSB, and contacts with the Swedish car manufacturers Volvo and Saab. SSBF has no technical help systems today, but the SSBF interviewee thinks that eCall would help reduce the time between call and response and that it would be a good system to link to the Crash Recovery System (CRS), which SSBF plans to buy for five new vehicles. “Electricity is something that many are worried about. We get questions about EVs during training and the guidelines say to be careful with orange cables when cutting through vital supporting parts of the car. I have heard that there is no danger to your life or of electricity running through your body, but if you feel your nose starting to itch, you should back off. The high risk today is our lack of knowledge – I see that as the worst problem. The recommendation is that we should keep on working and using the same routines as we have used before”.

*Räddningstjänsten Storgöteborg* (RSG) is a rescue service organization serving six municipalities and 794,000 inhabitants. A total of approximately 500 firefighters work for RSG, and there are four specialized fire stations, each with 30 personnel who are specifically educated to handle traffic accidents. These specialized firefighters can help during first calls in severe accidents if there are problems, for example, with electrical vehicles. These specialists have better tools, more knowledge, and more training than the rank-and-file firefighters. There is a contact person at every station who is also a specialist responsible for training, seeking information, and maintaining international contacts. During the interviews, it became apparent that knowledge of electrical vehicles varies among firefighters. In most cases, members of the public arrive first at the accident scene, followed by the rescue services, the ambulance, and finally the police. There is little cooperation between RSG and the ambulance service or police due to a lack of time and resources. MSB has a web-based training programme that the interviewees from RSG find useful, though they are hesitant about the quality of the training outcome. RSG is positive about eCall and, because they have CRS and can get information about EV risks from MSB, they find themselves able to handle most EV models. “It is not so easy to see whether a car is a hybrid, but we have a system to help us determine this. We would like to see a standard for how to deal with accidents involving EVs. We are kind of left in the dark, but have some vehicle models we know how to handle”.

RSG has some experience of accidents with various EV models. The firefighters learned early on to disconnect the

electricity while wearing insulating gloves and they got information from EV manufacturers. RSG is close to Volvo Cars laboratory, and the interviewed firefighters think that RSG gets good information from Volvo, but that there are several other EV models that they know little about. According to tests from the USA, smoke from battery fires is very toxic, so RSG is hesitant to expose anyone to it. The standard is to extinguish car fires with water, and this applies to EVs as well. They do not think that there is a great risk of arcing or short circuits/electric shocks." We do not regard EVs as exceptionally dangerous unless we have to cut them up or we see damage to the battery". "We cannot be afraid of doing something, because we have to take care of the crash victims".

*Räddningstjänsten Syd* is a rescue services organization working for five municipalities (including Malmö) with 513,000 inhabitants. It has approximately 350 employees, 25% of whom work part time. All its units can respond to traffic accidents, but two of the fire stations have special skills for dealing with heavy vehicles and complicated operations. When a severe accident occurs, one of these two stations gets the call. The interviewees think that Räddningstjänsten Syd is not very experienced at handling accidents involving EVs, but is learning from accident investigations and training. Accidents with EVs have happened, but not everyone gets information about these cases because the operation reports, which are sent to MSB, are not followed up. The information often stays with the people involved in the operation. The Räddningstjänsten Syd interviewees think that the particular risks with EVs are short circuits along with risk of fire, electrical shocks, and leakage from the battery/high-voltage system. They think that it is difficult to identify how a car is powered, and that it is impossible to know every vehicle model in Europe. To identify cars, Räddningstjänsten Syd is now evaluating CSR, but the interviewees point out that education is required to handle CSR, understand the risks identified, and handle them properly. Stockholm, Göteborg, and Syd/Malmö regions have more time for these matters than do small, part-time units. "We always work following a standard, not special routines or instructions depending on different types of vehicles or car models". "The rescue services need a system, a way to operate that functions everywhere, regardless of car model. We have to work in a general way, we cannot know every detail – that is too much to keep track of".

Räddningstjänsten Syd uses water to put out fires in EVs and has not tried other types of fire extinguishers. Regardless of whether they are responding to a traffic accident or a fire in a car, the responders all use protective equipment, such as protective respirators, and must be prepared for explosions. "If you ask the manufacturers, they say that it is almost impossible for anything to happen to them (i.e., the batteries). But something could happen, and then you could get leakage of all sorts of fluids, toxic gases, and also hydrogen. Then you have to work with a lot of ventilation, know the risks, and be able to handle them".

#### *4.2.2 The rescue services' handling of the four accident scenarios*

Below are the results of the interviews with firefighters from the three Swedish regions, written from their perspectives and in their voices. First, each scenario is presented. This is followed by a summary of the responses from the firefighters in the three Swedish regions.

Identification of the vehicle at the accident scene is done based on experience and by looking for a label on the car or a power outlet. If vehicles are severely damaged, the identification is difficult.

Scenario 1 – Risk of electric shocks

A single-car accident involving a BEV car on a 90 km/h road: The car drives off the road onto the shoulder and spins around. The vehicle is partially deformed in the front and rear, though there are no clear signs of battery leakage. The car may still be in the driving setting/in gear, although the wheels are still. The ignition key/circuit breaker cannot be reached. People remain in the car, partly trapped and needing help to get out. The first at the scene is the ambulance crew, who can communicate with the BEV driver. There are standard routines that set out every task for every firefighter arriving at an accident scene. One firefighter is responsible for protecting the others from fire. If people are trapped in a car, the firefighters take out the fire extinguishers. Sometimes there is a problem turning off the ignition, because often the car doesn't have a key, or the ignition switch cannot be reached. If the firefighters cannot turn off the ignition, they have to work very carefully so that the airbags do not inflate, which poses a risk to both the rescuers and those being rescued.

Response:

The firefighters do not consider it dangerous to walk up to the vehicle, but there is some concern about electric shocks when cutting open a car that has been deformed in a crash. At first, they try to locate any orange cables, often placed in the supporting frame and in the middle of the car. The routine is to disconnect the 12-volt battery. "We know that we cannot cut orange cables". "If I had my Ipad (with CRS), I would have searched for information". There are various approaches, for example: "When it is an electrical vehicle, everyone thinks more and does not cut as much, but works with tools instead.", "We are not good at all and get worried when we see these vehicles". "Just because it is an EV, we don't see increased danger – there are other risks, like airbags".

The electricity in most EVs can be switched off in one handgrip, but it is done in different ways in different models – "We would like it if all cars had one switch of the same colour in the same place". But it could also be different ways to switch off the electricity and sometimes the switch is difficult to reach. "Even though an EV is out of power, one should still not cut the cables". "All firefighters should know that the cables are often placed in the centre of the floor of the car – this is a matter of education". The interviewees think that there is generally little experience of EVs in Sweden.

The firefighters do not believe that electric shocks from the car's body are a risk with EVs. They think that shock risks arise only when they have to use force to get the crash victim out of the car or if there is leakage from the battery. They know that if high-voltage cables get damaged and come into contact with the chassis there will be a short circuit and arcing can occur. If there is a short circuit, however, the fuses will take care of the problem. "I have no evidence of how dangerous it is or of how great the electric shock risk is for EVs, but it is worrying. We have not had this type of accident yet, though". At one station, the interviewees say that firefighters wear rubber gloves when working, and that some fire trucks are equipped to be able to disconnect the electricity in EVs. At another station, firefighters say that certain car manufacturers advise them to wear the special gloves that electricians wear, but that they don't have such gloves. "We don't expose ourselves to any deadly risks".

Scenario 2 – Battery leakage

Two passenger cars collide. One car is a BEV car and the other is a biogas-powered car. There are large frontal deformations of both vehicles, and both drivers are severely injured and trapped in the cars, unconscious. At first sight, the drivers seem to be very injured, as they have a hard time breathing and their blood circulation is impaired. Immediate action is required: getting them out of the cars, first aid treatment, and transportation to hospital. The battery pack in the BEV is out in the open and damaged, the batteries are leaking unknown fluids, and both vehicles and probably both drivers are also contaminated.

Response:

The interviewees assume that it requires great violence for battery leakage to occur, because the high-voltage batteries are placed in the safest position in the car, i.e., in the centre, near the back, and encapsulated in a box for protection. A critical, very dangerous situation is when they must get the occupants out of a car as fast as possible. How they act depends on how much leakage there is from the battery and whether or not the fluid is toxic. If someone has come into contact with toxic fluid, the foremen must increase the safety level and implement decontamination. As long as there is no steam, the battery fluid can be washed away and personnel must avoid coming into contact with the fluid. If there is gas leakage, a fan can be used to blow the gas away, and if it leaks a little, they spray foam around it to prevent fire: "Cutting someone loose in this situation is not fun." "You recognize the smell of gas and some people know what the old batteries smell like, but the new ones…?" "We will cut and take out the victims, and then we have the security firefighter spray water if something might happen to the battery. It is crucial to get the injured people out". The interviewees find that they have little knowledge of situations involving chemicals, and seeking information from car manufacturers about the fluids in batteries is difficult. It is the effect of the chemicals that is the big worry: "The absorbent takes care of the chemicals, but you wonder what is leaking. You want to know afterwards what you have been dealing with – was it very toxic?"

Scenario 3 – Fire in garage

Smoke is seen coming from a parked electrical vehicle charging in the underground parking garage of a large shopping centre, at 2:00 pm on a Saturday. The cause of the fire is unclear, and the way to the smoking car passes within at least 50 m of other vehicles filled with diesel, petrol, or ethanol.

Response:

A fire in a parking garage requires a big operation and poses great risks to the firefighters. One cannot simply let it burn: the fire has to be limited in some way, as otherwise it could cause structural weakness in the building. "It is an adventure even to reach the burning car – it is very difficult in these underground parking garages. One must ventilate and evacuate them to get in safely". Protection for all the firefighters must be ensured, and it can take a long time to get inside if there is a lot of smoke. The centre of the fire can be located using a heat camera, but if it is only smoking, there is nothing to help the firefighters find the burning car. When they get to the car they have to identify it as an EV; it could be difficult to see small lettering in the smoke, but hopefully they can see the cord leading to the charger. They can put out the fire with foam, but the foam disappears quickly. "Fires in garages are a big problem for us, but electrical vehicles are not so dangerous. I would say that we have a car fire in an underground parking garage almost every week, so this is not an unusual scenario for us. The fact that it is in a shopping centre with a lot of people is not so

common". There are fires in vehicles every day, and the interviewees think that they might have put out fires in many EVs without realizing it. They say that the approach to safety is completely different compared with ten years ago, because it is more dangerous when cars burn now, both because of what you get on your body and because of the fumes you breathe in. The interviewees think that the more expensive a car, the more dangerous it is, and if it is built out of carbon fibre, the risk is similar to that of asbestos.

Scenario 4 – Electrical vehicle under water

During a storm with flooding, a petrol-electric hybrid becomes stuck in the water underneath a bridge. The driver calls emergency services to say that the car's occupants cannot get out of the car and will drown if they do not receive immediate help.

Response:

The firefighters are unsure whether or not a submerged car will be conductive: "Yes, water conducts electricity. I have also posed that question and not got an answer". If nothing has damaged the car, they believe that there is no danger. They remember one situation in which some people were trapped in a car submerged in water and couldn't get the doors to open. In that case, they lifted the car out of the water. "I don't think that we should be scared of getting an electric shock. We should just go in and take them out. The car is only stuck because of the water; it has not crashed. We only have to get the door open and get the person out – I don't think we should consider this dangerous". Some have got information from manufacturers that their EVs react to water exposure by automatically turning off the high-voltage system. They assume that they should therefore have treated this electrical vehicle in the same way as an ordinary car.

### 4.3 Interviews with municipal officials

The following are the results of interviews with officials from the environmental or traffic offices in Stockholm, Göteborg and Malmö.

*In Stockholm*, we interviewed the person responsible for the national electrical vehicle procurement contract. This makes the Stockholm case special in that this person has more knowledge of EVs than do the other officials interviewed. The electrical vehicle procurement contract summarizes safety issues connected with electrical vehicles [23] state: "There is knowledge of how to deal with electrical cars in many different places. In some areas, however, for example, when charging indoors, there is a lack of knowledge, routines, and rules. The knowledge is not widely disseminated". The interviewed official knew about the problem but did not have a clear strategy for how to disseminate the information and did not know who should be responsible for doing so. "We feel responsible because we are promoting electrical vehicles and installing charging stations in the city, so of course we think about this". "We have also been thinking about what will happen if a charging station gets hit by a car or vandalized, but we have equipment that will switch off the electricity". "We have not been in contact with MSB regarding EVs; we have mainly had contact with Swedish Energy and the car manufacturers directly". "Now there is a growing number of electrical vehicles, and when we meet the car manufacturers they say that the cars are approved and that the electricity will be switched off if the car crashes". The official informed us that you do not need a building permit to install charging stations, but that there are rules and recommendations and a checklist to follow. Car repair shops servicing EVs must have knowledge of high voltage and a three-day course is required for the mechanics. The official says that her office has not been in contact with the Swedish vehicle inspection company, as the inspectors will not work on EVs in any case. When it comes to scrapping EVs, it is the manufacturers' responsibility, and they must take back both the batteries and cars. In Norway, all number plates of EVs start with "EL", so it is very obvious what cars are EVs.

*In Göteborg,* we interviewed a green vehicle project leader in the Traffic Department. She claimed that the development of new environmentally friendly cars is technology driven. The engineers talk about what kinds of cables to use for charging different cars, but that is nothing the City of Göteborg should care about. The project leader was also hesitant to say whether EVs should be treated differently from other green solutions. When it comes to charging at home, the energy company in Göteborg is responsible. Regarding public charging stations, it is not clear who is responsible if something happens and, if so, who will take care of whatever then needs to be done. The project leader sees EVs as safe vehicles in accidents, problems only arising if the car is not charging properly or if there are knowledge gaps about charging. She has heard worries because of fires in EVs in the USA when the cars have become too hot, but the project leader does not think this will be a problem in Sweden's cold climate. If there are problems, she is convinced that the vehicle industry and the electricians will solve them." We have no cooperation with the rescue services, but they have not come to me either. I wonder if they have been contacted regarding the new electrical bus, in case something should happen, I mean". The possibility of accidents involving EVs has not been raised. The project leader thinks that the question of how, for example, towing

service, vehicle inspectors, and vehicle recycling will handle EVs would be an interesting subject for a workshop.

*In Malmö*, we interviewed an official at the Environmental Office working on the city's overarching environmental goals in cooperation with Gatukontoret, which is responsible for Malmö's green vehicle strategy. It is the energy company in Malmö and the city parking company that own the charging stations. She says that it is the energy company's responsibility to inform the public of any associated risks; it is not the rescue services or the municipality that is responsible. She thinks that people are afraid just because new, unknown technology is involved. She says that energy companies are supposed to inform the public of any associated risks; this is not the role of the rescue services or the municipality." We do not think about safety when it comes to EVs or the environment. I don't think that anyone in Malmö thinks about these issues. I fully trust that EVs are safe – we have to trust that the car manufacturers produce safe products. But you never know, it's like with everything else, like, for example, mobile phones and radiation. It is not something that I ever think about".

In addition, a telephone interview was conducted with the emergency coordinator at the County Administration Board of Västra Götalands Regionen, the Safety and Security Unit. The County Administration Board is responsible for monitoring to ensure that the municipalities uphold their contracts. The coordinator informed us that "the municipality does not conduct impact assessments when setting goals, to be able to adjust, for example, electricity, safety at charging stations, or public information. The environmental issues are setting the agenda, not the safety issues. The rescue services take the initiative when they have experience of accidents or get information from car manufacturers".

## 5 Conclusions

This study focus on safety in the society and how technical questions regarding safety needs to be addressed when strategic choices are made that are supposed to lead to a better environment and/or better economy. It is of importance to explore the working situation and context for the rescue service in relation to their stated preparedness to see what is actually executed, and not only how it should be. However, it would be of interest to further investigate EV manufacturers response to the proper actions for their EVs regarding the four scenarios and what information the manufacturers are actively providing the rescue service with on an international as well as national level. The technical development for cars seem to run past the community service and there is a risk that safety is not maintained.

In response to the research question about how stakeholders reason about their preparedness for EV risks and safety issues, the interviewees from the emergency services state that their preparedness needs to improve. The appropriate knowledge should be disseminated to both full- and part-time firefighters. EVs are not yet very common, but as they increase in number, more knowledge will be needed. One critical issue is the ability to identify the type of car involved in an accident, because this has a bearing on how to disconnect the electric power, how to get into a crashed car without risk of encountering high voltage, what toxic gases may be released, and the likelihood of explosion. The emergency officers claim that there is an immediate need to solve these problems. One of the problems identified is that each single emergency service has to search for this information for every new car model. It is not possible for every single emergency service to have an all updated data base with all information needed. And one of the needs identified in this study is the need for a different system to gather and provide necessary information in an efficient way. Information should come to them automatically and be presented simply and understandably. With new services such as eCall, the emergency services may be able to get needed information when on their way to the accident. However, this requires that the "SOS Alarm" service have the appropriate resources to handle and communicate the information. It bears repeating that the interviewees do not regards EVs as riskier than any conventional vehicle.

In response to the research question about the perceived barriers to and facilitators of the future handling of EV accidents, there were comments on the need for more resources in the form of knowledge, tools, and training. Another barrier concerns how firefighters internally gather their knowledge. The analyses showed that there is a partly reactive safety culture within the emergency services – that is, learning by doing when real accidents happen. This could be a problem one day if a battery breaks and toxic fluids or gases injure firefighters or the people that they need to rescue. According to the interviewees, this is considered the most severe problem, leading to knowledge gaps when it comes to EV risks and how to address them. Although the firefighters are trained to put out fires in EVs, their success is also dependent on how many firefighters they can send to the accident. Another obstacle to greater preparedness for EV risks and safety issues was the lack of horizontal consultation between diverse stakeholder organizations, such as the emergency services, municipalities, police, ambulance services, vehicle scrapping enterprises, and car recyclers.

As facilitators, the interviewed emergency services call for standards to ensure that high voltage is switched off in crashed EVs because they cannot learn all the technical details of various vehicle types. The responding firefighters also need tools for measuring toxic gases. Furthermore, they believe that the Crash Recovery System (CRS) could be a helpful tool; at the same time, they also raise questions concerning what organization should be responsible for updating the vehicle data in the CRS and for training firefighters in its use.

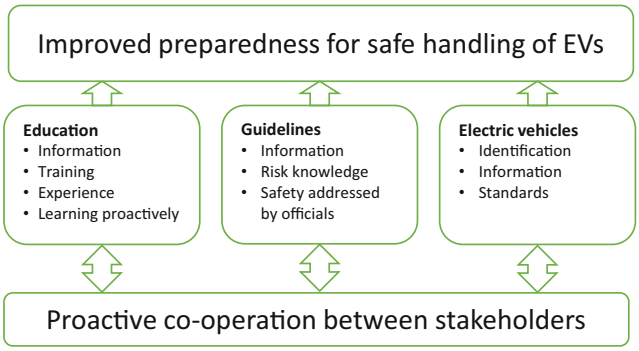


**Fig. 1** Possible facilitators for firefighters' preparedness

A figure synthesizing the needs to reach improved preparedness and safer handling of EVs in accidents is presented in Fig. 1. Three main areas has been identified in the interviews. These are Education, Guidelines and Electric vehicles, each containing tasks that are of importance for the rescue services. For efficient implementation, there is a need for proactive co-operation between different stakeholders.

Finally, this study shows that impact assessments are not conducted when setting environmental goals, and we conclude that when planning for more environmentally friendly vehicles, beside public policies and economic incentives, the costs of rescue and safety information should be included in the calculations. There is a need for a systems perspective and to break down goals and resources from the strategic to the operational levels. That the emergency services are involved earlier in planning in order to give feedback. This study demonstrated that within the municipalities the responsibility for and communication of preparedness for EVs and their charging stations are unclear. Risks arise when environmental goals do not take account of safety and when safety issues are noticed only after an accident happens instead of beforehand. In line with Rasmussen [3], we stress the need for various occupational groups and decision makers at all levels of society to cooperate in order to facilitate safe adaption of new transport technology and to take responsibility for evaluating risk and disseminating information, see Fig. 1 above. A clear definition of responsibilities is required. It is especially important to have a party who has the task to gather available knowledge and information, to present it in a uniform way and to ensure it is updated. This could be a knowledge-hub for both users (rescue services) and providers of the information (car industries and researchers). Furthermore, to facilitate for the first responders of an accident site, the vehicles should have a clear mark that identify the type of driveline. In this, there may be a need of standardization that can easily be adapted to technological advances. If the different stakeholders do not cooperate proactively, a development with lesser environment risks could become greater risks for the people handling new types of vehicles emerging from the rapid technical development of the car industry.

**Acknowledgements** We would like to thank all the interviewees. We also wish to thank Jan Wenäll, research engineer at VTI, and Hans Antonson, researcher at VTI, who worked on the project and shared their great experience with us.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

## References

1. Figenbaum E, Fearnley N, Pfaffenbichler P, Hjorthol R, Kolbenstvedt M, Jellinek R, Emmerling B, Bonnema GM, Ramjerdi F, Vågane L, Iversen LM (2015) Increasing the competitiveness of e-vehicles in Europe. Eur Transp Res Rev 7(3):28. doi:10.1007/s12544-015-0177-1
2. Leurent F, Windisch E (2011) Triggering the development of electric mobility; a review of public policies. Eur Transp Res Rev 3:221–235. doi:10.1007/s12544-011-0064-3
3. Rasmussen J (1997) Risk management in a dynamic society: a modelling problem. Saf Sci 27:183–213. doi:10.1016/S0925-7535(97)00052-0
4. i-MiEV (2011) Information till räddningspersonal för Mitsubishis elbil från Mitsubishi Motor https://www.msb.se/Upload/Insats_och_beredskap/Brand_raddning/Trafikolycka/Information%20till%20r%C3%A4ddningspersonal_i-MiEV%20elbilpdf/. Accessed 18 Nov 2015
5. Teslamotors (2015) http://www.teslamotors.com/firstresponders/. Accessed 17 Nov 2015
6. Green Car Congress (2015) www.greencarcongress.com/2010/08/gmfr-20100827html/. Accessed 18 Nov 2015
7. NAFTC (2015) http://www.aedve.info/training/first-responder-safety-training-2/. Accessed 18 Nov 2015
8. Visvikis C, Morgan P, Boulter P, Hardy B, Robinson B, Edwards M, Dodd M, Pitcher M (2010) Electric vehicles: review of type-approval legislation and potential risks. TRL report CPR810 ENTR/05/17.01
9. Brown S, Pyke D, Steenhof P (2010) Electric vehicles: the role and importance of standards in an emerging market. Energ Policy 38:3797–3806. doi:10.1016/j.enpol.2010.02.059
10. Prati G, Pietrantoni L (2012) Predictors of safety behavior among emergency responders on the highway. J Risk Res 15:405–415. doi:10.1080/13669877.2011.634519
11. Andersson Granberg T, Granlund R, Lundberg J, Ulander (2014) Dynamisk planering av räddningstjänst. Publikationsnummer MSB 797–714
12. MSB (2015) https://www.msb.se/sv/Utbildning–ovning/Utbildning/Skydd-mot-olyckor/alt/Insats–beredskap/Brand–raddning/Trafikolycka/Raddning-e-fordon/Kunskapsoversikt-/alt http://e-fordonblogspotse/. Accessed 18 Nov 2015
13. MSB (2011) Wargclou D (ed) Extrication from Cars during Road Traffic Accidents https://www.msb.se/RibData/Filer/pdf/26070.pdf
14. Sturk D, Hoffman L (2013) E-fordons Potentiella Riskfaktorer vid Trafikskadehändelse. Report in the FFI-project Räddningskedjan SP 2013:58
15. Long R T Jr, Blum A F, Bress T J, Cotts B RT (2013) Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale

Testing Results http://energy.gov/sites/prod/files/2014/02/f8/final_report_nfpa.pdf
16. Yin RK (2009) Case study research: design and methods, 4th edn. Sage, Thousand Oaks
17. Asp M (2013) Telephone and mail-conversation with the MSB statistics department, 2013-09-09.
18. Kvale S (1996) InterViews: an introduction to qualitative research interviewing. Sage, Thousand Oaks
19. Ryan GW, Bernard HR (2003) Techniques to identify themes. Field Method 15:85–109. doi:10.1177/1525822X02239569
20. Sturk D, Hoffman L, Ahlberg Tidblad A (2015) Fire Tests on E-vehicle Battery Cells and Packs. Traffic Injury Prevention 16(sup1): S159–S164. doi:10.1080/15389588.2015.1015117
21. Hoffman L (2013) Vattenbegjutning av 400 Volt traktionsbatteri i färskvatten och saltvatten. Rapport 2014:9
22. Hoffman L (SP), Söderholm T (MSB) (2013) Elbilsbranden i Ösmo lördagen den 11:e augusti 2012. RAPPORT SP Sveriges Tekniska Forskningsinstitut 2013–01-08 14429 2013:01 6 (20)
23. Eriksson L, Yagci K (2009) Säkerhetsfrågor kring eldrivna fordon. Miljöbilar i Stockholm