WIDESPREAD OF ELECTRIC VEHICLES AND THE PROVISION OF KNOWLEDGE ABOUT FIRE ACCIDENTS FOR EXPRESSWAY MAINTENANCE WORKERS IN JAPAN

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ABSTRACT

In October 2020, the Japanese government declared "carbon neutrality by 2050" and set out a policy to take comprehensive measures to achieve 100% electric vehicle sales in new passenger car sales by 2035. On the other hand, the world situation is changing rapidly, and the spread of electric vehicles is changing due to economic conditions, resource, and energy supply systems, etc., and the impact on Japan must also be predicted. Furthermore, the spread in Japan of electric vehicles is expected to change further due to future technological innovations, electricity demand, and infrastructure development trends. Therefore, it is necessary to prepare to maintain safe and comfortable expressway function without panic even when that stage is reached.

In this paper, we conducted a domestic and international survey on the spread of BEVs, fire accidents and their characteristics, and specific measures to reduce these risks. In addition, by confirming the current awareness of expressway maintenance worker regarding electric vehicle fire accidents, we have summarized the knowledge, issues, countermeasures, equipment, etc. necessary for future tunnel fire safety.

Keywords: expressway maintenance, maintenance worker, knowledge, BEV fire, fire extinguishing.

1. INTRODUCTION

Expressways prioritize user safety and aim to provide a safe and comfortable expressway space 24 hours a day, 365 days a year. To achieve this goal, maintenance work includes inspections of structures and facility equipment, improvement work, reinforcement, and disaster prevention measures to prepare for disasters, recovery, and repair work in the event of accidents, and countermeasures against traffic jams. Checks are constantly made to ensure that expressway functions are maintained and improved.

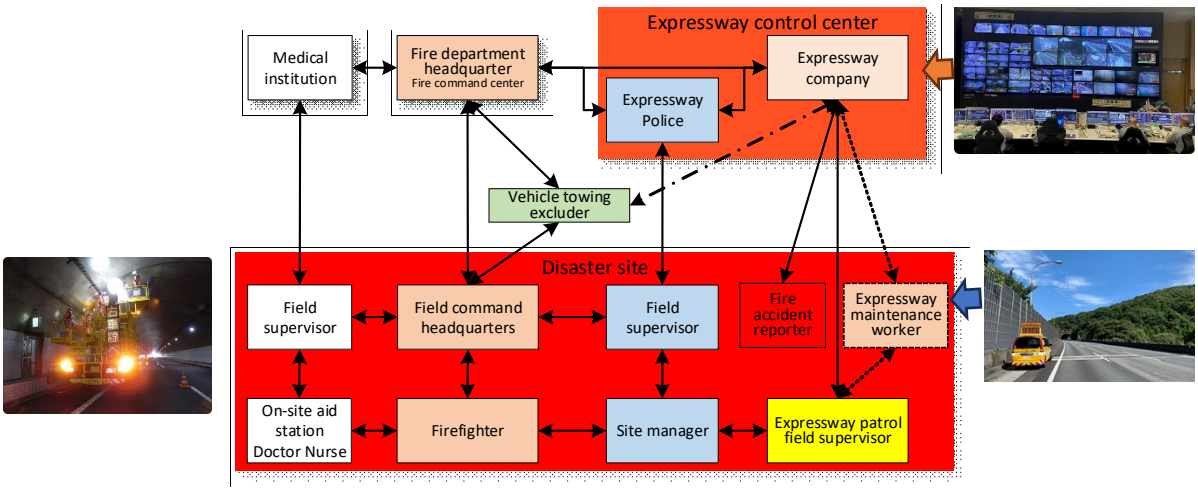

Figure 1: Collaboration with related organizations during expressway accidents and fires

Figure 1 shows the coordination system in case those engaged in maintenance worker an accident or fire while on the move. Currently, maintenance worker needs to minimize the decline in expressway functionality by collecting accurate information quickly and responding promptly and in collaboration with related parties.

Tunnels are special closed spaces that generate smoke, harmful gases, and heat in the event of a fire, so knowledge of emergency response is also required.

2. SPREAD OF ELECTRIC VEHICLES

2.1. Domestic situation

Currently, electric vehicles in Japan are classified into four types: HEV: hybrid vehicle, PHEV: plug-in hybrid vehicle, BEV: electric vehicle, and FCEV: fuel cell vehicle. This section summarizes domestic trends from 2018 to 2022. As shown in Figure 2 and Table 1, the number of electric vehicles in use in Japan is 9.86 million, overwhelmingly HEV, with both BEV and PHEV on the rise, with PHEV at around 200,000 and BEV around 165,000.

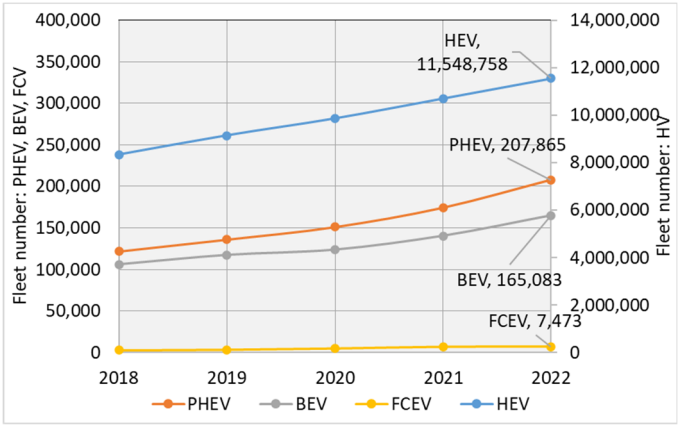

Figure 2: Changes in the number of electric vehicles (passenger cars) owned [1]

Next, as shown in Table 1, the number of registered passenger cars in 2022 will be about 62 million, with HEVs accounting for 19% and BEVs and PHEVs accounting for about 0.3%.

Table 1: Number of registered electric vehicles (passenger cars) and occupancy rate [1]

2022	Passenger cars fleet	61,953,135		
HEV	PHEV	BEV	FCEV	Total
11,548,758	207,865	165,083	7,473	11,929,179
18.6%	0.34%	0.27%	0.01%	19.3%

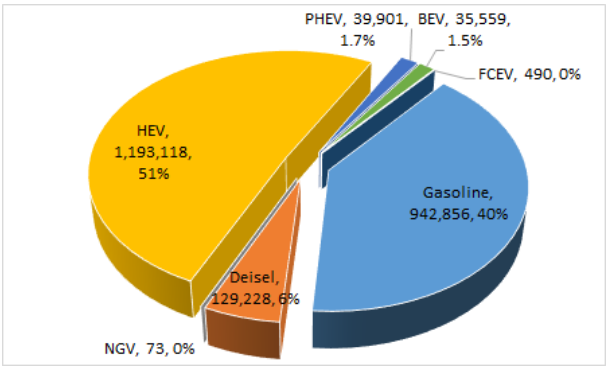

Figure 3: Percentage of passenger car sales by drive type (2022) [2]

Next, Figure 3 shows the percentage of passenger car sales in 2022 [2]. The share of sales is 40% for gasoline cars and 6% for diesel cars, while HEVs account for 51%, BEVs 1.5%, and PHEVs 1.7%. Although the sales volume of BEV and PHEV is on the rise, their market share is still low.

2.2. Comparison with other countries

Figure 4 shows the BEV and PHEV sales volume and the sales ratio of BEV and PHEV from 2018 to 2022 extracted from the literature [3] for data on major countries. The BEV and PHEV sales ratio will be on a slight downward trend from 2021 to 2022.

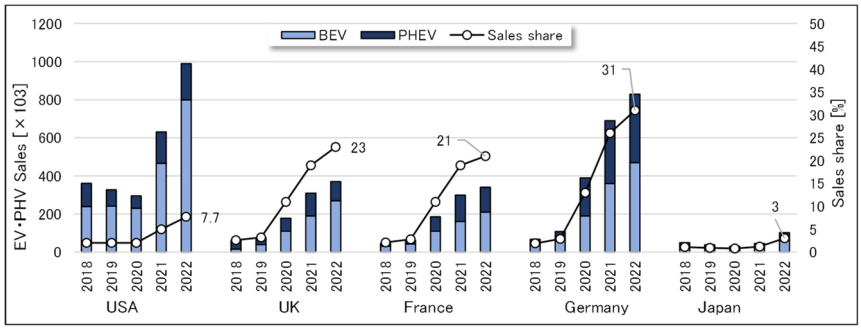

Figure 4: Trends in BEV/PHEV sales volume in each country from 2018 to 2022 [3]

In contrast, the ratio of BEVs and PHEVs in Japan is still low, but the trends are clearly different, with HEV sales in 2022 being about 1.2 million units (Figure 3), and the number of vehicles owned being just over 11.5 million units (Table 1).

2.3. Future trends

According to the electric vehicle spread targets for each country [4] compiled by Japan's Ministry of Economy, Trade and Industry, the target years are slightly different (see Table 2). Additionally, HEVs and PHEVs are handled differently in the EU and in Japan. However, on March 25, 2023, the EU, which had been the first in the world to shift to electric vehicles (EVs) by completely banning internal combustion engines, underwent a major change in

policy. The EU has announced that it will allow vehicles powered by e-fuel, an environmentally friendly synthetic fuel that does not rely on fossil fuels.

Table 2: Electrification targets of each country [4]

Country/Region	Target	Share				
		FCEV	BEV	PHEV	HEV	ICEV
Japan	2030	～3%	20～30%		30～40%	30～50%
	2035	100%				Not applicable
EU	2035	100%		Not applicable		
USA	2030	50%			50%	
China	2025	20%				
	2035	50%				Not applicable
UK	2030		50～70%			Not applicable
	2035	100%		Not applicable		
France	2040	100%		Not applicable		
Germany	2030		15 million			

3. BEV FIRES

3.1. BEV fire characteristics determined through experiments.

In BEV fire experiments conducted in Japan so far [5], differences in vehicle heat generation rate and lithium-ion secondary battery (hereinafter referred to as "LIB") charging rate were ascertained. It was also confirmed that the combustion behavior was like that of a gasoline-powered vehicle, except for the flame eruption caused by LIB thermal runaway.

However, it was suggested that the charge rate affects the characteristics of the erupting fire, that it takes a long time to dispose of residual flames, and to cool the LIB pack, and that continuous cooling is necessary to prevent re-ignition after the fire is extinguished.

3.2. Domestic BEV fire cases

There are very few cases of BEV fires in Japan, so we referred to the past five years of vehicle recall, and defect information published by the Ministry of Land, Infrastructure, Transport and Tourism [6]. This is because this information includes not only recall information, but also accidents, fire events, and their causes. As shown in Table 3, the number of fires occurring is high in HEVs.

Table 3: Status of passenger car fires in the past five years [6]

Fire accidents	2018	2019	2020	2021	2022	Total
BEV	1	0	0	2	1	4
PHEV	1	0	3	1	0	5
HEV	42	33	15	22	26	138
Total	44	33	18	25	27	147

Next, Table 4 shows the causes of fire occurrence. None of the causes of fires in the HEVs, PHEVs, and BEVs we identified were due to accidents, and most HEV fires were caused by modifications (installation of aftermarket lights). Other than that, there are no major differences from conventional vehicles, such as oil leaks and exhaust system issues. Three cases have been reported regarding the causes of BEV fires: a case in which LIB short circuit due to submergence is suspected, a case in which a fire broke out from a cable during charging, and a case in which a fire of unknown cause occurred and completely burned down. Furthermore, on September 21, 2022, a complete fire incident was added, but the cause was said to be an external heat source that caused the fire. As described above, there is very little information on BEV fire accidents and their characteristics in Japan, but fortunately, no events that pose a social problem have occurred.

Table 4: Causes of fires in electric vehicles (passenger cars) over the past 5 years [6]

Cause of fire	engine oil leak	brake fluid leak	exhaust system	tire burst	aftermarket lamps	headlight	aftermarket light	wiring system	charging adapter wiring	suspected battery	fire spread	Cause unknown	Total
BEV									1	2	1		4
PHEV	2		2					1					5
HEV	40		6	1	2	19	55	8		6		1	138
Total	42	0	8	1	2	19	55	9	1	8	1	1	147

3.3. Typical cases of BEV fires

Typical characteristics and points to note are shown below, as determined from BEV accident and fire case studies in other countries [7], [8].

1) Flames and smoke are suddenly emitted from LIB: Do not touch or approach, prepare for emission of harmful gas, prepare a blower, etc.

2) A large amount of water is required to extinguish LIB: Cooling methods such as immersion containers and simple water storage banks, fire blankets, etc.

3) Risk of electric shock due to LIB residual power, repeated ignition: Water spray method, secure water source

4) Prolonged firefighting work: Road closures for long periods of time

5) Prevention of re-ignition when transporting the affected vehicle: Movement and transport methods

6) Isolated space for the storage area of the affected vehicle: Fire spread prevention and monitoring device in the event of a re-ignition

7) The fire incidence rate of BEVs, which are becoming more popular, appears to be lower than that of gasoline and diesel vehicles.

Table 5: Examples of fire cases and fire extinguishing methods

Examples of BEV fire accident cases [7]		
 Fire after collision with garage	 Reignition during loading	 Fired again during storage
Examples of fire extinguishing measures in case of BEV fire [8]		
 Water storage levee	 Lance Water sprinkler Rosenbauer	 Fire blanket
 Fireproof bag		

It is necessary to coordinate among organizations that work together in the event of an expressway fire on the equipment necessary to respond to these incidents. In addition, the knowledge and actions required for maintenance workers in the event of an accident or fire are as follows.

a.) Thoroughly check and ensure your own safety: do not go downwind of the vehicle, do not approach, or touch it, be careful of electric shock

b.) Collect information: location (route direction, kilometer posts, lanes, etc.), traffic conditions, vehicle type (passenger, cargo, electric vehicle, etc.), accident/fire situation (single, multiple, etc.), presence of injuries, etc.

c.) Provide accurate information to the road control center

d.) Prevent secondary disasters: Alert following vehicles, implement simple regulations, etc. (prioritize the safety of disaster victims and yourself)

e.) Wait calmly for the expressway police, emergency fire brigade, and towing service vehicle to arrive.

3.4. Road tunnels and BEV fires

In Japan, experiments have been conducted at the laboratory level to understand the fire characteristics of BEVs, and harmful exhaust gases and heat generation characteristics have been ascertained. However, in tunnels, which are closed spaces, not enough consideration has been given to the necessary equipment, effective fire extinguishing methods and equipment, the impact on the structure, the environmental impact, and methods for removing, transporting, and storing vehicles involved in disasters. These matters need to be addressed before the rapid spread of BEVs is expected in the future. To this end, the information obtained from advanced research examples [9], [10], [11] shown in Table 6 is extremely useful.

Table 6: Examples of technical documents published in recent years.

Alternative Fuel Vehicles in Tunnel [9]	BRAFA [10]	EV Fire Safety in Enclosed Spaces [11]
		
• Tunnel research highlights for traditional fuels • Research Summary in Tunnels; Fire cases, experiments, modeling, etc. related to BEV, NGV, PV, FCEV	• BEV potential hazards, FCEV, risk modeling • Effect of fire on tunnel • LIB/vehicle fire experiments in tunnels, fire extinguishing training, contamination issues, etc.	• Data on the few causes of BEV fires and points to note regarding handling and risks. • Fire in closed spaces, early detection of fire, fire extinguishing equipment, space, and structure, etc.

4. KNOWLEDGE AND EQUIPMENT NECESSARY FOR BEV ACCIDENT/FIRE RESPONSE

4.1. Advancement of fire brigade rescue techniques and prevention of electric shock.

The Fire and Disaster Management Agency has published a document [12] regarding the advancement of technology for responding to accidents and fires for next-generation vehicles, including BEVs. This report shows that, in response to the changing times, technological innovations in next-generation vehicles and mutual cooperative relationships with automobile manufacturers are necessary for firefighters to carry out firefighting and rescue operations safely. It is also shown that training through basic knowledge and practical skills is necessary.

It also introduces the dangers and necessary equipment during the initial response; when expressway maintenance workers encounter an accident or fire, it is difficult to conduct full-scale extinguishing and rescue operations like a fire brigade. However, this knowledge is extremely effective when trying to reduce damage and prevent secondary disasters. For reference, Table 7 shows examples of insulating protective equipment as personal protective equipment to prevent electric shock during rescue operations, as well as examples of main countermeasures against gas, heat, smoke, etc. emitted by accident vehicles.

Table 7: Examples of main insulating protective equipment and equipment [12]

Electric insulation equipment				
 Helmet	 Gloves	 Boots	 Clothing	 Pants
Hydrogen gas detector	Thermal imaging camera	Blower	Explosion proof light	Tools
				

4.2. Current knowledge of maintenance workers

4.2.1. Knowledge survey of maintenance workers

(1) Survey method and target audience

To survey the current state of knowledge, we conducted a simple questionnaire targeting two of our 10 offices that handle expressway maintenance and management work (27 people in total) and the research and design department at our head office (14 people).

(2) Questionnaire items

The questionnaire asked respondents to answer the following questions based on the premise that they encountered an accident or fire while driving a maintenance vehicle for work.

Question 1) Ensuring the safety of disaster victims: "Do you take measures (simple regulations), reporting, rescue, fire extinguishing, evacuation, etc. to ensure the safety of disaster victims?"

Question 2) Vehicle type confirmation: "Do you like to confirm the vehicle type at that time? (Conventional vehicle, BEV, etc.)"

Question 3) Points to note by vehicle type (knowledge): "Do you know that there are points to be noted depending on the type of vehicle (electric shock, harmful gas ejection, explosion, etc.)?"

Question 4) Willingness to acquire knowledge: "Do you want to know how to respond in the event of an accident or fire involving new energy vehicles in order to protect yourself and victims?"

(3) Survey results

Table 8 shows the overall results of the questionnaire. Regarding question 1, "Ensuring the safety of disaster victims," almost all respondents answered that they would do so. However, over 40% of respondents answered that they did not confirm the vehicle type in question 2.

Regarding question 3, "Points to note by vehicle type," just under 30% answered that they did not know. Regarding question 4, "Willingness to acquire knowledge," all participants were willing.

Table 8: Knowledge survey results

Questions and answers		A- operation office	B- operation office	Headquarter	Total
Question 1	Execute	22	4	14	40
	Not execute	1	0	0	1
Question 2	Confirm	10	1	12	23
	Do not confirm	13	3	2	18
Question 3	I know	16	4	10	30
	I don't know	7	0	4	11
Question 4	I want to know	23	4	14	41
	I don't want to know	0	0	0	0

5. CONCLUSION

In this article, we have conducted a survey on the spread of BEVs in Japan and overseas, as well as accidents and fires, and have compiled the necessary information from the perspective of those involved in expressway maintenance work.

On the other hand, the world situation is changing rapidly, and there appears to be a shift to BEVs due to economic conditions, resource, and energy supply systems, etc., and we must also anticipate the impact on Japan.

However, the BEV shift is expected to change further due to future technological innovations, electricity demand, and infrastructure development trends. Therefore, it is necessary to prepare to maintain safe and comfortable expressway functions without panicking each time.

For this reason, it is necessary to continue collecting and maintaining information for a wide range of expressway maintenance workers to acquire knowledge on basic responses and to improve equipment and devices. In addition, our mission is to "maintain safe and secure expressways" by "knowing correctly and fearing correctly" to prevent secondary disasters and protect one's own life, in cooperation with related organizations. And they are just beginning.

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