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The Role of Aircraft Rescue and Fire Fighters Officers in Handling Electric Vehicle Accidents at Soekarno Hatta International Airport

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ABSTRACT

Electric vehicles are now an environmentally friendly transport solution. Still, the risk of fire due to *thermal runaway* in lithium-ion batteries (LIBs) poses significant safety challenges, especially in airport environments such as Soekarno-Hatta International Airport. This study aims to explore the role and readiness of Aircraft Rescue and Fire Fighting Officers (ARFF) in handling electric vehicle accidents, and identify the challenges faced. A qualitative method with a phenomenological approach was employed, involving five informants selected through purposive sampling, and data collection techniques included a literature review and in-depth interviews. The results revealed three primary roles of ARFF Officers, namely reactive, proactive, and preventive, involving measures such as area sterilization, annual safety audits, and restrictions on the use of electric vehicles in closed areas. However, limited literature, knowledge, training, and specialized equipment are significant obstacles in handling electric vehicle incidents. Thematic analysis shows that although reactive measures have been implemented, these procedures still refer to conventional vehicle handling methods. Proactive and preventive measures, such as the procurement of specialized fire extinguishers and risk management through structural mitigation, proved crucial in minimizing the impact of incidents. The study also found that conventional equipment was less effective for dealing with electric vehicle fires on lithium-ion batteries. At the same time, the use of extinguishing agents such as compressed air foam and water mist provided more efficient results. The research highlights the need for specialized training, the development of electric vehicle-based *Standard Operating Procedures (SOPs)*, and investment in appropriate equipment to improve the response capacity of ARFF officers to the risk of electric vehicle fires in the airport environment. In conclusion, the preparedness of ARFF officers to deal with electric vehicle incidents still requires comprehensive improvement, both in technical and strategic aspects, to optimise public and operational safety in the future.

Recommended Citation:

APA Style

INTRODUCTION

Electric vehicles are vehicles that operate by utilizing electrical energy stored in batteries. (Utami et al., 2022).**.** This vehicle uses a battery to supply energy, an electric motor to drive the wheels, and a controller to regulate the flow of energy to the motor for efficient movement and operation. (Agus Wibowo, 2021). Electric vehicles are now a popular choice as a more environmentally friendly mode of transport. To address climate change, governments and global automotive manufacturers have taken proactive steps in reducing carbon emissions by promoting electric vehicles. (International Energy Agency (IEA), 2022).

Electric vehicles offer benefits like zero emissions, simpler maintenance, higher reliability, lower operating costs, and a more comfortable driving experience with no engine noise or vibration. They are also more efficient, especially with renewable energy, have wider access to low-emission zones, and contribute significantly to reducing environmental impact, promoting sustainability, and fostering cleaner urban environments. (Vanitha et al., 2024).. The increased use of electric vehicles reflects a significant step in environmental conservation. According to RT Cotts, there will be a huge surge in electric vehicle sales with 10.2 million units sold by 2022, bringing the global total to around 25.9 million units. (Zhao et al., 2024)..

In Indonesia, the government's support for electric vehicles is seen through Presidential Regulation No. 55/2019 which aims to accelerate the battery-based electric motor vehicle programmed. Soekarno-Hatta Airport, as the largest airport in Indonesia, has been operating various electric vehicles such as sky train, electric taxi, electric bus, Grab Wheels, Segway, and electric baggage tractor. This step reflects a commitment to adopting environmentally friendly technology and improving the efficiency of airport management. Nevertheless, despite the increasing use of electric vehicles, there are still a number of challenges that need to be overcome (Willstrand & Rosengren, 2019). One such challenge is the thermal runaway phenomenon in lithium-ion batteries (LIBs). The main causes of thermal runaway can be categorized into two groups: failures caused by the internal condition of the battery and misuse or inappropriate use of the battery by the user. (Feng et al., 2018). In particular, overheating of lithium-ion batteries makes electric vehicles more prone to fires than vehicles with internal combustion engines. (Peiyi Sun et al., 2022).. In addition, overcharging and physical damage also contribute to the risk of fire and explosion in electric vehicles (Koch et al., 2018). (Koch et al., 2018).

In the period from 2012 to 2020, several electric vehicle fire incidents recorded significant safety risks. In 2012, 16 Fisker Karma units caught fire due to battery contact with water caused by flooding on the East Coast of the United States. (Łebkowski, 2017). Then, from 2014 to 2020 there were 87 reported electric vehicle accidents, of which 28 occurred while the vehicle was parked (Project, n.d.). (Project, n.d.). Additionally, at Sydney Airport, an explosion of an electric vehicle's lithium-ion battery caused a fire that damaged five cars. These incidents emphasize the need for more attention to electric vehicle safety (Compass, 2023).

The limited research on electric vehicle safety, especially global analyses of crash data, poses a challenge in formulating and implementing effective strategies to address the risk of electric vehicle fires. (Liu et al., 2022). The use of fire extinguishing agents is essential in dealing with electric vehicle fires. Research by (Zhao et al., 2024) found that extinguishing blankets are quite effective in extinguishing the fire and reducing the temperature inside the vehicle, especially when the fire is just starting. However, extinguishing blankets are less effective at stopping *thermal runaway* reactions in batteries. In contrast, water mist spray and compressed air foam are more efficient. Water mist spray can quickly reduce the temperature and extinguish the fire, while compressed air foam can extinguish the fire very quickly.

In handling vehicle accidents at the airport, airport operators are required to Aircraft Rescue and Fire Fighting (ARFF) services in accordance with applicable standards. (Ministry of Transport, 2021). The Aircraft Rescue and Fire Fighting (ARFF) unit has an important role in this task, including providing firefighting services according to operational standards, ensuring emergency response readiness, and managing firefighting and rescue operations in the airport area. (Decree of the Director General of Civil Aviation, 2022).. The Aircraft Rescue and Fire Fighting (ARFF) unit must always be ready and quick to respond to threats at the airport. All emergency handling standards and procedures must be listed in the *Emergency Response Plan (ERP). Response Time* is the time required by the ARFF unit to reach the end of the runway or aircraft movement area under optimal conditions (daytime with good visibility and dry roads). This response time is set at 2 minutes and should not exceed 3 minutes, calculated from the time notification is received or an accident is detected until the ARFF vehicle is ready to extinguish the fire and has expelled at least 50% of the foam capacity of its extinguisher. (Laksono & Suprapti, 2024)..

Recent research on electric vehicle safety and related fire management has shown significant progress in identifying and implementing effective suppression strategies. Research by (Wöhrl et al., 2021) discussed

the initial steps when an electric vehicle accident occurs, from identification, risk assessment, electric vehicle accident handling, rescue actions, to vehicle evacuation. A year later, Palma and colleagues introduced a new technique using pure water and certain chemicals to cool electric vehicle batteries that heat up due to accidents while extinguishing fires that may occur. (Zhao et al., 2024) Palma and his team introduced other advanced methods using extinguishing blankets, water mist sprays and compressed air foam to deal with fires, thereby increasing effectiveness in emergency situations.

The importance of establishing specific standards for handling electric vehicle (EV) accidents in Indonesia, particularly at major airports like Soekarno-Hatta, cannot be underestimated due to the unique characteristics and challenges these vehicles present. Unlike conventional vehicles, EVs require specialized knowledge and tools to address risks such as battery fires, chemical leaks, and electrical hazards. Soekarno-Hatta Airport, as one of the busiest transportation hubs in the region, accommodates millions of passengers annually. This high volume significantly increases the likelihood of incidents involving EVs, which could lead to widespread disruptions, safety risks, and operational challenges if not managed effectively. As described by (Takou, 2024), fire management in electric vehicles requires a specialised approach that differs from conventional vehicles, especially in enclosed environments. In these situations, fires involving electric vehicles can spread rapidly and be difficult to control without adequate preparation and protocols.

Recent research on electric vehicle safety and related fire management has shown advances in risk identification and the implementation of effective suppression strategies. However, there are still gaps in understanding how the knowledge and experience of field officers, particularly CCW officers, play a role in managing such incidents. This research focuses on an in-depth exploration of the knowledge and skills that CCW officers possess, as well as the factors that hinder them in dealing with electric vehicle accidents, a topic that is rarely addressed in the existing literature. The resulting findings are expected to provide new and practical insights in improving the capacity of such officers to face the increasingly complex challenges related to electric vehicle safety at airports.

METHODS

This study uses a qualitative research design with a phenomenological approach**.** The phenomenological approach was chosen because it allows researchers to explore in depth the experiences and perceptions of Aircraft Rescue and Fire Fighting (ARFF) officers in handling electric vehicle accidents at Soekarno-Hatta International Airport. According to (Neubauer et al., 2019)(Neubauer et al., 2019), the phenomenological approach focuses on understanding the meaning of individual experiences in everyday life, which is very relevant to the context of this study.

The population of this study were all Aircraft Rescue and Fire Fighting (ARFF) officers on duty at Soekarno-Hatta International Airport. The sample was selected using *purposive sampling*, which is a sampling technique based on certain criteria. These criteria aim to obtain a sample with characteristics that are in accordance with the research needs. (Agustianti, 2022). Inclusion criteria include officers who are directly responsible for handling electric vehicle accidents and are willing to participate in the study. Exclusion criteria include officers who have communication difficulties or are not willing to provide complete information.

Data was collected through a literature review and in-depth interviews. The review of scientific publications and reports aimed to understand the theoretical context and identify gaps in previous research on electric vehicle accident handling. (Sugiyono, 2021). In addition, in-depth interviews were conducted with Aircraft Rescue and Fire Fighting (ARFF) officers to obtain direct information. These interviews utilised a pre-developed interview framework, focusing on indicators such as general knowledge about electric vehicles, work experience, accident handling procedures, and challenges and obstacles faced in handling electric vehicle accidents. (Abdussamad, 2021).

Data were analyzed using a thematic analysis approach using *Nvivo* software, following the model proposed by Creswell (2014). This approach involved six steps, namely: first, organising and preparing the data for analysis; second, reading through the data in depth for a thorough understanding; third, coding based on themes that emerged from the data; fourth, developing descriptions and linking the themes; fifth, presenting the themes in clear narrative form; and finally, providing interpretations of the themes in the context of the study.

This research is based on emergency response and transport safety theories, focusing on fire management in electric vehicles. It emphasizes preparedness, rapid response, and appropriate technology to minimize risks and infrastructure damage. (Ouyang et al., 2019). The main research question posed was: *"What is the role of ARFF officers in handling electric vehicle accidents at Soekarno-Hatta International Airport,*

and what challenges do they face?". The aim of this study was to identify and evaluate the roles and challenges faced by ARFF officers in dealing with electric vehicle accidents and develop standardized guidelines that can be used in emergency situations.

RESULTS AND DISCUSSION

This research was conducted at Soekarno-Hatta International Airport in Tangerang, Banten. The airport spans 2,555 hectares, with three terminals and a specialized cargo terminal serving both domestic and international shipments. Data in this study were collected using *purposive sampling*, which is a sampling technique based on predetermined inclusion criteria. Based on these criteria, this study successfully involved five participants with the following characteristics:

Table 4.1 Informant Characteristics

Code	Position	Education status
R1	Safety Officer	Bachelor of Management
R2	ARFF Manager	Bachelor of Information Systems
R3	Personnel 1	HIGH SCHOOL
R4	Personnel 2	HIGH SCHOOL
R5	Personnel 3	HIGH SCHOOL

This study aims to determine the role of Aircraft Rescue and Fire Fighting (ARFF) in handling electric vehicle accidents. Research data were obtained through in-depth interviews directly with informants. Thematic analysis conducted with the help of *NVivo 12 Pro software* produced two main themes, namely:

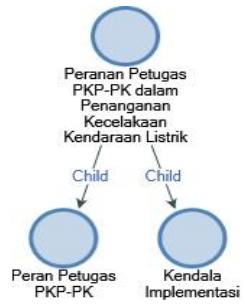

Figure. 1 Theme and sub-theme findings on the role of ARFF officers in Electric Vehicle Accident Handling

Based on the picture above, the first theme is the role of Aircraft Rescue and Fire Fighting (ARFF) officers and the second theme is the obstacles in the implementation of handling electric vehicle accidents. The explanation is as follows:

Role of the ARFF Officer

The research focuses on Aircraft Rescue and Fire Fighting (ARFF) officers' roles: reactive, proactive, and preventive, ensuring a safe, responsive environment.

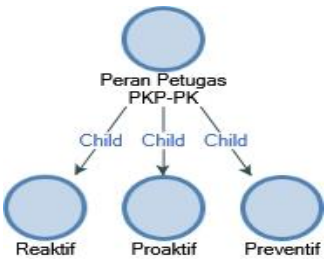

Figure. 2 Sub-theme Findings of the Role of ARFF Officers

a. Reactive

This sub-theme describes reactive measures addressing issues after they occur, often using conventional vehicle accident methods.

"*Secondly, we drivers must know the road conditions, which roads we can access more quickly. During handling, we are more inclined to look for gaps or look for quiet places. Because the vehicle must manoeuvre*"

"*During handling, the first thing we do is sterilisation of the surrounding area*"

"*Then during handling, we give distance, meaning not too close, we can use PPE*"

"*But we make sure it's cooling first, that no fire comes out first. Then there is an opening from the front bumper, we shoot from there, we extinguish as much as possible until the fire decreases in intensity*."

Informant R3 describes reactive actions in handling conventional vehicle fires, including emergency response, mobilization, securing the location, and firefighting. ARFF officers ensure quick, effective responses to minimize losses and protect lives and property.

b. Proactive

This sub-theme describes the proactive steps ARFF personnel take in vehicle handling. Proactive steps include actions taken in advance to anticipate and prepare for potential problems, so that responses can be carried out quickly and effectively. This is reflected in the interview with informant R1:

"*So that we conduct an audit once a year and we enter into the inspection checklist and from ground handling has its own SOP, information about handling is also from ground handling by preparing facilities for extinguishing itself because maybe the vehicle has the tool so that for us it is one of the risk mitigations from the vendor because it already has its own sop and facilities for extinguishing it*".

This statement illustrates ARFF officers' proactive measures, including annual audits integrated into inspection checklists and collaboration with ground handling. Their provision of extinguishing facilities and vehicle-mounted extinguishers ensures quick, effective responses to fire risks, emphasizing preparedness and operational safety.

c. Preventive

This sub-theme describes the preventive measures taken by ARFF officers in vehicle handling. Preventive measures include actions taken in advance to anticipate and prepare for potential problems, so that responses can be made quickly and effectively when problems arise. This is reflected in the interview excerpt with informant R1:

"*So, there are indeed several mitigations that are safety actions that we have taken every time a vendor wants to install a charger parameter. We hope that it is far from other vehicles as an initial mitigation of safety action. Indeed, terminal 3 terminal 2 is far from other vehicles so it is separate*"

"*We have made a proposal for exploitation for extinguishers electric vehicles can also be used such as Blanket*"

"*We are trying to ensure that electric vehicles are not used inside the building but outside the building so that it can also reduce the impact of the possibility of fire spreading to other vehicles*"

This statement illustrates that Aircraft Rescue and Fire Fighting (ARFF) officers' preventive measures are through identification of risks and implementation of comprehensive preventive measures. For example, the placement of electric vehicle chargers away from other vehicles is an early mitigation effort to reduce the risk of fire. In addition, officers proposed the procurement of special extinguishers, such as fire blankets, to deal with electric vehicle fires. These measures also include ensuring that electric vehicles are not used inside the building, but rather outside, to reduce the possibility of fire spreading to other vehicles. These efforts demonstrate officers' commitment to preventing and minimising potential hazards before bigger problems occur.

Implementation Constraints

This theme covers four main aspects: limited literature, limited knowledge, absence of specialised equipment, and lack of training.

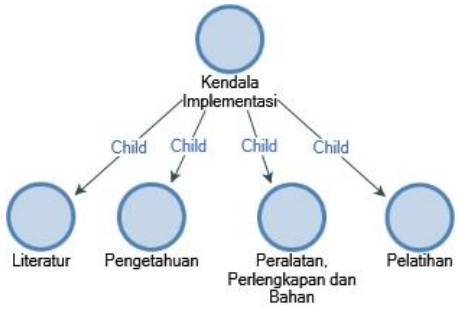

Figure. 3 Sub-theme Findings of Implementation Constraints

Literature; This sub-theme describes how limited literature and adequate sources of information hinder efforts to deepen understanding and knowledge related to handling electric vehicle accidents. This is illustrated in the results of interviews with informants R1, R2. as for the interview excerpts as follows:

"*So we are still looking for an extinguisher that can immediately knock down the fire from the case*"

"*From us, ARFF is still studying and looking for extinguishing materials that are close to effective*"

The above statements indicate the limited literature and resources available in the field of electric vehicle accident management, which impacts the effectiveness of the response from the Aircraft Rescue and Fire Fighting (ARFF) team. Currently, officers are still exploring for extinguishers that can quickly and effectively tackle fires caused by electric vehicle accidents. This confirms that increased access to comprehensive literature and research is necessary to strengthen capabilities and response to electric vehicle accidents.

Knowledge; This sub-theme discusses the limited knowledge that can be a major obstacle for Aircraft Rescue and Fire Fighting (ARFF) officers in carrying out accident handling on electric vehicles. This is illustrated in the results of the interview with informant R2. The following is an excerpt from his interview:

"*So even for now, what we from ARFF have learnt is still something that we have not met*"

"*This is known from the vendor's simulation submission*"

Based on this statement, it illustrates that limited knowledge is one of the main obstacles for ARFF officers in handling accidents in electric vehicles. ARFF officers are still in the learning stage and searching for effective information, and to date they have not found an adequate solution. Information obtained from simulations delivered by vendors has not been sufficient to provide a clear and comprehensive understanding. This emphasises the need for increased knowledge and more intensive training for officers, so that they are better prepared and able to deal with emergency situations involving electric vehicles.

Equipment, Supplies & Materials; This sub-theme discusses the unavailability of specialised equipment, supplies and materials for handling electric vehicle accidents that cause fires. This is illustrated in the results of interviews with informants R1, R2. The interview quotes are as follows:

"*So far, only fire blankets have been used to reduce the impact of fires so that they do not spread to other vehicles and there are no tools that can extinguish them directly*"

"*Based on the information, we can only localise it to prevent it from spreading by using fire blankets*"

"*They want to come up with a new policy, we inevitably have to buy it*"

This statement illustrates that the unavailability of specialised equipment, supplies and materials for handling electric vehicle accidents that cause fires is a significant problem in mitigation efforts. Currently, the use of *fire blankets* can only assist in localising the fire, so that the impact does not spread to other vehicles, but there is no tool that can effectively extinguish the fire directly. This suggests an urgent need for the development and procurement of more suitable extinguishers, as well as clear policies to support investment in the necessary equipment. This situation reflects the importance of collaboration between authorities and manufacturers to create more effective solutions for dealing with electric vehicle fires.

Training; This sub-theme describes the limitations of special training for officers regarding emergency handling procedures for electric vehicles which results in less than optimal readiness. This is illustrated in the results of the interview with informant R5, following the interview excerpt:

"*Yes, I have never participated in training on handling electric vehicles*"

Based on the interview excerpt above, it is identified that ARFF officers experience limitations in the knowledge and skills required for handling emergency situations involving electric vehicles. One of the reasons is because ARFF officers have never attended specialised training related to electricity handling procedures. This has the potential to result in less-than-optimal readiness in responding to incidents involving electric vehicles, where appropriate and rapid handling is crucial to prevent further risks.

DISCUSSION

This study found no electric vehicle accidents at Soekarno-Hatta Airport, but ARFF officers' reactive measures only apply to conventional vehicles. Increased electric vehicle usage requires special preparedness and capabilities to handle potential electric vehicle accidents. This is in line with research (Jhu et al., 2011) which states that lithium-ion batteries have a unique chemical composition, store electrical energy, and have a different design. Reactive measures include the use of appropriate fire extinguishers and evacuation of the area around the burning vehicle. (Christensen et al., 2021)..

(Geisbauer et al., 2021) identified three main hazards in electric vehicles: Electrical risks from high voltage, Thermal risks from *thermal runaway* in lithium-ion batteries, which can trigger fires or explosions

and Chemical risks from battery chemicals that can leak or catch fire, thus complicating the handling of electric vehicle accidents. *Thermal runaway* is a condition in which the temperature and pressure in the battery increase drastically and uncontrollably. This condition is usually triggered by battery damage due to misuse, such as *overcharging*, *excessive discharging*, physical damage such as pressing or puncturing, short circuiting, or overheating. The result of these conditions can be gas leaks, fires, or even large explosions. (Tran et al., 2022).. This poses a serious threat to user safety (Koch et al., 2018). The readiness of emergency personnel to deal with electric vehicle fires is still at the development and adjustment stage. Many officers do not yet have specialised training, and the availability of necessary equipment, such as specialised extinguishing agents and proper personal protective equipment, is still a challenge at present (J. Liu et al., 2023).

In response to such threats, a number of studies have tested various fire extinguishing agents to assess their effectiveness in overcoming *thermal runaway* in lithium-ion batteries: (Zhao et al., 2024) found that compressed air foam provided the highest cooling rate in extinguishing electric vehicle fires. (Zhang et al., 2020) concluded that the combination of C6F12O and water mist was more effective than the use of a single agent, providing the best extinguishing and cooling effects. The use of large amounts of water or other extinguishing agents can be used to cool the battery and prevent further spread of the fire. (Sun et al., 2020). (Lim et al., 2021) showed that there was no significant difference in temperature reduction effectiveness between water-based extinguishing agents, but direct cooling was more effective in lowering the temperature of the damaged battery. (Huang et al., 2021) identified that liquid nitrogen is effective in delaying and cooling *thermal runaway*. (Li et al., 2023) found that water mist is effective in suppressing the onset of *thermal runaway* with a rapid decrease in temperature. (Palma et al., 2023) stated that pure water is the most efficient extinguishing agent for lithium-ion battery fires, followed by a mixture of water with F500. Lastly, (Barelli et al., 2021) developed a *Vanadium-water* flow battery-based system that also serves as fire protection by reducing oxygen levels within the protected volume. Each of the extinguishing agents tested had advantages under certain conditions, which highlights the importance of selecting the appropriate agent based on the situation.

The results of this study confirm the superiority of each firefighting agent under certain conditions, while emphasising the importance of selecting the right agent according to the situation at hand. As illustrated by (Hassan et al., 2023) through an incident in Australia, the effectiveness of a reactive approach in dealing with electric vehicle fires depends largely on the preparedness and capacity of the firefighting team. The use of adequate amounts of water or other extinguishing agents is highly recommended to cool the battery and prevent further fire spread. Therefore, the selection and application of appropriate extinguishing agents is key in dealing with the challenges posed by electric vehicle fires.

In this study, researchers found that proactive measures taken by Aircraft Rescue and Fire Fighting (ARFF), such as annual audits, collaboration with *ground handling* teams, and efforts to procure firefighting equipment such as fire blankets, demonstrate readiness and anticipation to reduce fire risks and ensure operational safety at the airport. According to (Ouyang et al., 2019), proactive measures can be taken by improving the intrinsic safety of batteries, for example by using safety devices in batteries, adding fire-resistant additives, and improving battery management systems. This is in line with research showing that the installation of early detection systems and fire alarms in electric vehicles can be used to warn drivers of potential fires. (Sun et al., 2020). Another proactive measure can be implemented through the development and implementation of *Standard Operating Procedures (SOPs)* to mitigate the risk of electric vehicle fires. These SOPs include systematically identifying, assessing and managing the risk of electric vehicle fires to reduce the negative impacts that may occur. (Hassan et al., 2023)..

In this study, researchers found that preventive measures taken by Aircraft Rescue and Fire Fighting (ARFF) include placing electric vehicle chargers in safe locations and limiting the use of electric vehicles in certain areas to prevent and minimise the risk of fire. According to (Ouyang et al., 2019), specialised training for firefighters in dealing with fires caused by lithium-ion batteries needs to be conducted as a preventive measure. Other preventive measures include standardised testing of electric vehicle batteries, including performance and safety tests, which can provide insights into battery failure responses due to internal and external causes. It is also important to design better fire protection systems for buildings and parking areas with many electric vehicles and charging stations, to improve overall safety. (Sun et al., 2020).

One example of a preventive measure is the use of flame-retardant materials in battery components to reduce the risk of fire (Christensen et al., 2021).. In addition, a thorough revision of certain technical aspects

is required to ensure that load-bearing parts of the building, such as columns and beams, are able to withstand fire conditions. This is particularly important in areas such as multi-storey car parks, basements and tunnels. In addition, existing fire-fighting methods and techniques should be utilised effectively to ensure maximum safety. (Kang et al., 2023).

Researchers identified challenges in responding to electric vehicle fires at airports, including limited literature, knowledge, equipment, supplies, and training. This lack of resources hinders effective Aircraft Rescue and Fire Fighting (ARFF) response, emphasizing the need for better access to research and knowledge. This is in line with research (Hassan et al., 2023)which emphasised the urgent need for an improved fire risk mitigation framework and continued research to understand and address fire risks in electric vehicles.

In addition, lack of knowledge is a major challenge for Aircraft Rescue and Fire Fighting (ARFF), so more in-depth training and information is essential to improve readiness to handle electric vehicle accidents. This is in line with the findings of (J. Liu et al., 2023), showing that more than 40 per cent of firefighters had not received any training related to electric vehicle safety, so their knowledge in dealing with related situations was limited. In addition, there are shortcomings in the emergency response guidelines provided by vehicle manufacturers, further complicating officers' preparedness for electric vehicle incidents.

The research found that the lack of specialized equipment for electric vehicle fires is a major barrier. Extinguishing blankets only localize fires, highlighting the need for better firefighting equipment and policies to support investment in specialized tools for effective fire mitigation (Sun et al., 2020). This is in line with the findings of (Takou, 2024) who mentioned that the lack of specialised equipment to extinguish lithium-ion battery fires is a major challenge in effectively dealing with electric vehicle fires.

The study also found that lack of specialised training Aircraft Rescue and Fire Fighting (ARFF) are poorly prepared to handle emergencies involving electric vehicles. Without adequate training, their knowledge and skills are not optimised, increasing the risk of mishandling and potential further harm. According to (Sun et al., 2020), specialised training is needed for firefighters to handle lithium-ion battery fires in electric vehicles, as well as to implement effective fire prevention strategies. This is in line with the findings of (J. Liu et al., 2023) who emphasised the importance of specialised training for firefighters so that they understand how to handle fires caused by electric vehicles. In addition, comprehensive emergency response guidelines are essential to ensure the safety of both officers and the public. Without proper training and guidelines, the risk of electric vehicle fires can become more dangerous and difficult to control.

CONCLUSIONS

This research highlights challenges in handling electric vehicle accidents at Soekarno-Hatta International Airport, particularly regarding Aircraft Rescue and Fire Fighting (ARFF) Officers. Despite proactive and preventive measures, gaps in knowledge, training, and specialized equipment remain, especially for lithium-ion battery fires. Proactive measures, such as annual audits, collaboration with ground handling, and procurement of specialized extinguishers, reflect efforts to improve preparedness, though not yet optimal. Preventive actions, such as placing electric vehicle chargers in safe locations and restricting usage in specific areas, have reduced fire risks. Challenges include limited literature, a lack of specialized training, and inadequate equipment for electric vehicle fires. This study highlights the urgent need for tailored training, advanced extinguishers, updated guidelines, and public awareness to enhance airport safety and address the rising risks linked to electric vehicle incidents in Indonesia.

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