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THESIS

WHAT STRATEGIC ADAPTATION TO TECHNOLOGY WOULD BENEFIT FIREFIGHTERS RESPONDING TO AND PREPARING FOR ELECTRIC VEHICLE EMERGENCIES?

by

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March 2023

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The number of electric vehicles in use in the United States is rapidly increasing. Without proper preemptive education, this new technology places first and second responders in potentially fatal situations every day. First responders are placed in dangerous situations when they are not equipped with the essential knowledge about the threats they face when responding to electric vehicle–related emergencies. This thesis investigates how first responders can develop and sustain a functional knowledge of electric vehicles, including technological changes, to handle emergencies safely for responders and citizens. The best way to provide a timely solution to the current knowledge gap for firefighters about electric vehicles is to offer rescue sheets to first responders through a web-based mobile application. The rescue documents are open-source, readily available information that manufacturers provide for use by first and second responders. The application will aid in usable documents and sharable current available information. Action research methodology tested if and how a mobile catalog could (1) be created and (2) be used by first responders.

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WHAT STRATEGIC ADAPTATION TO TECHNOLOGY WOULD BENEFIT FIREFIGHTERS RESPONDING TO AND PREPARING FOR ELECTRIC VEHICLE EMERGENCIES?

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ABSTRACT

The number of electric vehicles in use in the United States is rapidly increasing. Without proper preemptive education, this new technology places first and second responders in potentially fatal situations every day. First responders are placed in dangerous situations when they are not equipped with the essential knowledge about the threats they face when responding to electric vehicle–related emergencies. This thesis investigates how first responders can develop and sustain a functional knowledge of electric vehicles, including technological changes, to handle emergencies safely for responders and citizens. The best way to provide a timely solution to the current knowledge gap for firefighters about electric vehicles is to offer rescue sheets to first responders through a web-based mobile application. The rescue documents are open-source, readily available information that manufacturers provide for use by first and second responders. The application will aid in usable documents and sharable current available information. Action research methodology tested if and how a mobile catalog could (1) be created and (2) be used by first responders.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADAC	General German Automobile Association
ANCAP	Australasian New Car Assessment Program
DOT	Department of Transportation
ERG	Emergency Response Guide
ECWTVA	European Community Whole Vehicle Type Approval
EuroNCAP	European New Car Assessment Programme
EV	Electric Vehicle
EVS25	Electrical Vehicle Safety Committee meeting #25
FDNY	Fire Department of New York City
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LSS	Life Safety Systems
MOU	Memorandum of Understanding
MVP	Minimum Viable Product
NFPA	National Fire Protection Association
NTSB	National Transportation Safety Board
NHTSA	National Highway Traffic Safety Administration
PIO	Public Information Officer
PPP	Public-Private Partnerships
PWA	Progressive Web Application
QR	Quick Response
QRG	Quick Response Guide

RDS	Rescue Data Sheet
ROI	Return on Investment
SAE	Society of Automotive Engineers
SME	Subject Matter Expert
UNGTR	United Nations Global Technical Regulation
VIN	Vehicle Identification Number

EXECUTIVE SUMMARY

Firefighters operate on and around electric vehicles (EVs) every day; these vehicles pose a lethal threat if responders do not know the hazards within the vehicle. EVs are very different from classic internal combustion engine (ICE) vehicles that firefighters have grown accustomed to over the past 100-plus years. To mitigate this hazard, functional knowledge of evolving technologies for current electric vehicles needs to be consistently supplied and available to firefighters. Rapid evolution of technology around electric vehicles results in fire departments' inability to keep standard operating procedures (SOPs) up to date.

Due to this rapid shift, first responders and occupants of EVs are placed in unsafe situations during emergency incidents. In 2021, an estimated 42,915 people died in motor vehicle traffic accidents in the U.S.[1] Globally, an estimated "23 to 34 million people are injured in road traffic accidents annually."[2] In 2012, police reported 5,615,000 motor vehicle accidents in the United States.[3] Because first responders respond to millions of vehicle accidents annually, their experience makes them experts in this field. Over the last 100-plus years, fire departments have formulated best practices involving motor vehicles with ICEs. The transportation industry is undergoing a paradigm shift, the size of which has not been seen since the conversion from horse and buggy to ICEs. The transition is now from ICEs to EVs.

Although EVs are statistically safer, the danger from the knowledge gap has the potential to grow as the automobile market changes over to all-electric and the majority of incidents involve EVs. EV manufacturers, including Ford and General Motors, aim to

[1] National Highway Traffic Safety Administration, "Early Estimate of Motor Vehicle Traffic Fatalities in 2021" (Washington, DC: National Highway Traffic Safety Administration, April 2022), 1, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813283.

[2] Charles G. Manyara, "Combating Road Traffic Accidents in Kenya: A Challenge for an Emerging Economy," in *Kenya After 50*, ed. Mickie Mwanzia Koster, Michael Mwenda Kithinji, and Jerono P. Rotich (New York: Palgrave Macmillan U.S., 2016), 101, https://doi.org/10.1057/9781137574633_7.

[3] National Highway Traffic Safety Administration, "Traffic Safety Facts 2012" (Washington, DC, May 2014), 1, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812016.

transition to 100% EV production by 2035. EV sales are increasing at an extreme rate.[4] First responders are already experiencing difficulties extinguishing EV fires and navigating power removal in EV incidents. This knowledge gap is a compounding problem. Failure to address this knowledge gap now risks the negative impact of first responders' ability to quickly, safely, and proficiently execute their duties.

This thesis explores how first responders can benefit from the creation of a rescue document-sharing application in the United States and evaluates how the findings can benefit EV safety and regulation. Through an iterative lean process, this thesis documents the creation of a document-sharing application that provides first- and second responders with the needed information to operate safely during EV incidents. This thesis used simple interactions and basic testing to identify the best solution available that can be implemented to bridge the first responders' knowledge gap. Furthermore, this thesis reports on the findings from interactions with subject matter experts during four testing phases.

The two pictures in Figure 1 demonstrate the dangers that are only inches under the outside covering of the vehicle. The orange cables denote high-voltage wiring that carries potentially fatal amounts of electrical current.

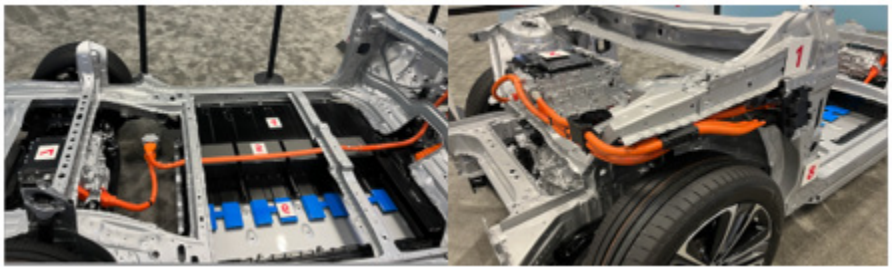

Figure 1. Break-out view of Electric Vehicle

This report started with evaluating the ability of individual departments to stay informed on the evolving technology of EVs. It is apparent one thesis cannot entirely bridge the knowledge gap. First responders must ensure a safe operation for those involved in incidents and responders themselves across many different types of responses. The first-

[4] See Figure 14 in the appendix.

responder community requires a basic level of comprehension to render emergency services in emergencies. Departments globally cannot link the current knowledge gap between continuous evolution in battery and vehicular technology. This report focuses on sharing rescue documents as a first step to solving this crucial and complex puzzle.

Rescue documents, including emergency response guides (ERGs), rescue data sheets (RDSs), and quick response guides (QRGs), are a way for manufacturers to communicate critical information to first responders in preparation for and at operations involving EVs. The research indicates that mandated standardized rescue documents provided by manufacturers are the answer to this current knowledge gap. Current barriers to consistent rescue document use include the following:

- lack of standardization in rescue documents from manufacturers
- lack of document awareness
- lack of a functional delivery system for documents

A functioning practical delivery system would create a path toward solving the current barriers in the problem space. I hypothesize that a web-based central rescue document catalog available with and without cellular data is the first step in connecting manufacturers and first responders with the ability to create new solutions for all parties involved.

After communicating my concerns over these dangers to first responders and sharing feedback from the first hypothesis testing, the Fire Department of New York City (FDNY) has committed to creating an online database. The life safety systems unit (LSS), which develops and maintains web-based applications for the FDNY, has adopted the project. Currently, the application is on the priority list of future projects. Due to staffing shortages, it is unclear when the application will be finished. As of January 14, 2023, there was a functioning model for testing. The thesis concludes with a summary of the FDNY document-sharing applications progression.

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I hope my efforts here do justice to the incredible men and women who have worked so hard to maintain such a high standard at NPS and the FDNY.

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I. INTRODUCTION

A. WHO, WHERE, WHAT?

From 2011 to 2021, annual electric vehicle (EV) sales increased by 399%.[1] This dramatic increase in the new technology without proper preventative education places millions of first and second responders in potentially fatal situations every day.[2] First responders face additional risk in dangerous situations when they lack the proper knowledge about the threats involving EV emergencies. This problem has several components, but this report focuses on one solution to a piece of a more significant problem and, in turn, will create avenues for solving other deficiencies in this problem space. This research intends to mitigate the hazards presented when uniformed first responders operate at EV emergencies by supplying first responders with greatly needed information through a mobile application delivery system.

EVs are presented as a safer alternative to Internal Combustion Engines (ICE) and are ten times less likely to catch on fire per mile driven than conventional vehicles.[3] But the increase in EV usage with proper training and information for first and second responders is causing deadly situations during emergency responses.

The first responder community is slowly adjusting to the new technology presented by EVs. A recent article on the Vox website summed up the problem best:

> Although they're relatively rare, electric car fires present a new technical and safety challenge for fire departments. These fires burn at much higher temperatures and require a lot more water to fight than conventional car fires. There also isn't an established consensus on the best firefighting strategies for EVs, experts told Vox. Instead, there's a hodgepodge of

[1] Bureau of Transportation Statistics, "Hybrid-Electric, Plug-in Hybrid-Electric and Electric Vehicle Sales," National Transportation Statistics, 2019, https://www.bts.gov/content/gasoline-hybrid-and-electric-vehicle-sales.

[2] Rita Fahy, Ben Evarts, and Gary P. Stein, U.S. *Fire Department Profile 2020* (Quincy, MA: National Fire Protection Agency, 2022), https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osfdprofile.pdf.- The NFPA claims the U.S. has over 1 million paid and volunteer firefighters in 2020.

[3] Brian Engle and Kurt Vollmacher, "Li-Ion Cell Venting Risks, Detection, and Countermeasures" (presentation, SAE First and Second Responders Task Force, June 16, 2022), 3.

> guidance shared among fire departments, associations that advise firefighters, and automakers. As many as half of the 1.2 million firefighters in the U.S. might not be currently trained to combat EV fires, according to the NFPA.[4]

The slow adjustment by first responders will not bode well for occupants of crashed EVs with only seconds to escape. A lawsuit resulting from a 2019 crash of a Tesla Model S alleged a police officer was unable to open the door of a vehicle after a crash resulted in a vehicle fire with an occupant trapped inside, ending with the fatality of the occupant.[5] Required training to address the differences in new EV operations likely could have addressed this knowledge gap.

The introduction is organized as follows. After the brief introduction to the problem space before this paragraph, the next section will inform readers of the research question. Following the question is a short review of the information available to first responders on EV dangers and applications that show potential for solving similar problems. I then state the hypothesis that was formulated from the review of the problem space and literature. From there, I briefly describe why action research was the right choice for this effort and what it entails. The chapter ends with a quick summary of the research design or formula.

B. RESEARCH QUESTION

How can first responders develop and sustain a functional knowledge of EVs, including technological changes, to handle emergencies safely for responders and citizens?

[4] Rebecca Heilweil, "Why Teslas Keep Catching on Fire," Vox, January 27, 2023, https://www.vox.com/the-highlight/2023/1/17/23470878/tesla-fires-evs-florida-hurricane-batteries-lithium-ion.

[5] Willard Shepard, "Lawsuit: Tesla's Door Handles Blamed for Broward Doctor's Death," NBC 6 South Florida, May 25, 2022, https://www.nbcmiami.com/news/local/lawsuit-teslas-door-handles-blamed-for-broward-doctors-death/2770024/.

C. LITERATURE REVIEW

1. Information Available to First Responders

The National Fire Protection Association (NFPA) estimates that half of the 1,200,000 firefighters in the U.S. are not adequately trained to respond to EV fires.[6] This problem is a derivative of the lack of knowledge combined with the little information being supplied adequately to first responders or the lack of a central location for the information without charge. With Tesla as the premier EV manufacturer in the U.S., a significant amount of information is focuses on the manufacturer and placed on sites like YouTube, but these sources come with inherent problems. Studies and reports suggest that one of the best tools to use to evolve and educate is emergency response guides (ERGs) supplied by manufacturers.[7] Other countries use web-based applications to bridge the knowledge gap. Action research will be used to test the possibility of a web-based application filling the knowledge gap, and the effort will be analyzed.

This literature review will cover three sections applicable to this study 1. Training material on the subject, 2. studies identifying the problem space, and 3. current applications worldwide. The literature review will be followed by a hypothesis formulated from this literature and then a brief review of Action Research literature. Firefighters and police officers do not have the proper information to address the growing use of EVs. Subsequently, emergency responses and action research is the best way to address this problem.

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[6] Heilweil, "Why Teslas Keep Catching on Fire."

[7] National Transportation Safety Board, *Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles*, NTSB/SR-20/01 (Washington, DC: National Transportation Safety Board, 2021), 64, https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf; Marcus Wisch et al., "Recommendations for Safe Handling of Electric Vehicles after Severe Road Traffic Accidents," in *24th International Technical Conference on the Enhanced Safety of Vehicles (ESV)* (24th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Gothenburg, Sweden: National Highway Transportation Safety Administration, 2015), https://www-esv.nhtsa.dot.gov/proceedings/24/files/24ESV-000361.PDF.

2. Informational Content on EVs and EV Emergencies

As the largest EV producer in America, Tesla sponsors and stars in most instructional videos. Advanced Extrication produced several videos, giving quality information and insight into the hazards of Tesla model EVs.[8] Due to the Tesla sponsorship, one must question the products reviewed. These public videos appear to be the most comprehensive open-source information for pre-emergency response training, even when factoring apprehensions over inherent bias. An Advanced Extrication video demonstrates a dashboard displacement maneuver using a Tesla Model 3.[9] With the support of the Tesla and Hurst tool, this same production company produces video instruction guides for operating on most Tesla models. Just as Tesla funds specific training on a Tesla vehicle, so does Lucid with a training video on the Lucid Air, again, with similar drawbacks with model specific examples and a lack of directives for all vehicles.[10] The gap in the deliverable product is the lack of comparison from vehicle-to-vehicle with the Tesla line and the larger EV market. The inherent bias that comes with production sponsorships undermines integrity in the scope of the evaluation.

Countless other sources, including Hurst tools, the National Transportation Safety Board (NTSB), and local news sources across the country also produce videos. In conjunction with Tesla, Hurst makes an informational video with similar drawbacks to the other Tesla-sponsored videos.[11] On the opposite side of the spectrum, the NTSB presents research in a 2021 video that outlines hazards from these fires but fails to give an actionable recommendation to fire departments.[12] Content on the internet does not become a helpful

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[8] "Tesla Model X First Responder Training – Advanced Extrication," May 24, 2016, Brock Archer, video, 0:30, https://www.youtube.com/watch?v=D4peF1EYke8.

[9] "Emergency Response to the Tesla Model 3," January 18, 2019, Brock Archer, video, 25:48, https://www.youtube.com/watch?v=2X_WorH4pUw.

[10] "Emergency Response to Lucid Air," January 8, 2023, video, Energy Security Agency Production, 1:11:06, https://www.youtube.com/watch?v=os6UbuTv0NI.

[11] "HURST Jaws of Life Demo on 2018 Tesla Model 3," April 16, 2019, Hurst Jaws of Life, video, 14:32, https://www.youtube.com/watch?v=_gLVBcY2rXc.

[12] "Lithium-Ion Battery Fires in Electric Vehicles: Safety Risks to Emergency Responders," January 13, 2021, National Transportation Safety Board, video, 5:26, https://www.youtube.com/watch?v=J6eS6JzBn0k.

resource until departments evaluate and verify it. For-profit companies create these videos, which carries the risk of bias, further complicating whether departments can rely on the information. When reviewing videos online outside of a paywall, no single source covers all dangers present in EVs. An accredited impartial body must verify and vet available information or produce different instructional media that shows safe operating procedures for departments.

The NFPA has a paid training program that gives a summation of basic operating procedures for EVs. The content has information for a first responder but does not include necessary specialist-level details to construct strategies or create standard operating procedures (SOPs) for one-off situations. Manufacturer-funded training programs give some of the best information available for general practices but differ in recommendations to manufacturers and models within a manufacturer. Additionally, most manufacturers advise first responders to reference ERGs as guides to work from in emergencies, referencing the NFPA-believed complete catalog available online. Paid subject matter expert giving lectures I attend do not provide enough information to create a thorough understanding of the detailed workings of the subject and only provide general direction and an acknowledgment of the knowledge gap. Of the six EV training I am familiar with, all acknowledged that a downloadable application might help to solve this problem.

3. Studies

As EVs comprise a small fraction of the cars on the road and account for minimal accidents, little information on past crashes and hazards is available. The two best examples of current concerns are the German Federal Highway Safety Institute Report from 2015 reviewing the EVERSAFE Project and the 2021 study from the NTSB.[13] From the studies available, responders identify safety threats as chemical hazards, fire, electrocution, and explosion.[14] Each manufacturer's current NFPA Emergency Response Guides address some of these concerns. Still, neither of the cited reports gives directives on how to mitigate

[13] Wisch et al., "Recommendations for Safe Handling," 14; National Transportation Safety Board, *Safety Risks to Emergency Responders*.

[14] Wisch et al., "Recommendations for Safe Handling."

all hazards.[15] Every ERG document tailors the guide created by the individual manufacturer and covers different aspects of the automobile's construction. ERGs demonstrate the battery pack's location and high-voltage cables, accounting for the first responder's electrocution concern. Some ERGs describe the battery packs' content and other dangerous chemical compounds within the vehicle construction. The ERGs fail to address the other concerns of fire, explosion, and operational direction for vehicles involved in a crash. The NTSB 2021 evaluation notes the lack of uniformity across these guides as a liability and identifies four other areas of information the ERGs lack.[16] Although the German Highway Research institute believes the danger of explosion from a lithium-ion battery is minimal, its report recommends implementing preventive measures.[17] The report (GHR 2015) also criticizes the infrequency of manufacturers' recommendations for first responders to use electrical safety gloves to prevent shock; this highlights the conflicting messages. Both documents verify the dangers faced by first responders today and confirm there is no current source of information available to first and second responders that address all concerns presented.

In 2013, NFPA documented its efforts to inform emergency responders of EV-related hazards in the "Emergency Responder Training for Advanced Electric Drive Vehicles" report.[18] This report details NFPA's process in acquiring and enacting a plan for the $4.4 million three-year grant: funded to understand the hazards of EV and Hybrid vehicles and present the findings to the public. The report covered the efforts from 2009 to 2013 when this report was released as *Best Practices for Emergency Response to Incidents*

15 "Emergency Response Guides," Alternative Fuel Vehicles Safety Training, accessed March 23, 2022, https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides.

16 National Transportation Safety Board, *Safety Risks to Emergency Responders*, 59–60.

17 Wisch et al., "Recommendations for Safe Handling," 10.

18 Andrew Klock, *Emergency Responder Training for Advanced Electric Drive Vehicles* (Quincy, MA: Fire Protection Research Foundation, 2013), 6, https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EVTrainingEmergencyResponders.ashx.

Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results.[19] The main goal was to educate all first responders through a train-the-trainer program. The grant-funded effort established the available knowledge base of tests and educational efforts before 2013. Since this time, the efforts waned. Many websites cited in the two documents are no longer accessible, and actionable task-based information dwindled to manufacturers' ERGs where applicable. This gap shows the lack of practical information on EVs for emergency responders.

4. Apps

The latest resources for firefighters worldwide are mobile device-based applications and rescue software. In the last 15 years, numerous applications fluctuated in their availabity and reliability. Currently, companies only advertise a handful of rescue tech applications. In reviewing the available options, no free application is viable in the United States.

The company Moditech Rescue Solutions, based in the Netherlands, developed an app-based informational tool for first and second responders. Their rescue platform advertisement shows a diagram for every type of vehicle, indicating battery, high voltage wiring, fuel tank, and other possible hazards and locations, much like an ERG.[20] The theory behind the product is reasonable, and it provides the most suitable type of usable data. However, a paywall blocks the application's access, making it difficult to judge the practicality and usefulness of the product.

The Australasian New Car Assessment Program (ANCAP) Rescue and Euro Rescue are currently the best free applications worldwide.[21] The application is white-

[19] R. Thomas Long, Jr. et al., *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results* (Quincy, MA: Fire Protection Research Foundation, 2013), https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EV-BatteriesPart-1.ashx.

[20] "Crash Recovery System Standard Full Edition," Rescue – Vehicle Extrications, 2022, https://www.moditech.com/crash-recovery-system/rescue-vehicle-extrication/standard-full-edition/.

[21] "ANCAP Rescue Apps," ANCAP Safety, accessed July 18, 2022, https://www.ancap.com.au/apps.

labeled and presented with applicable models in each jurisdiction.[22] The Australian New Car Assessment Program, more commonly referred to as ANCAP safety, resembles the 5-star National Highway Traffic Safety Administration (NHTSA) rating program in the United States. ANCAP and the European New Car Assessment Program (EuroNCAP) developed an application that separately shares available rescue data sheets for all model vehicles in Australia and Europe. The product, ANCAP Rescue App, and Euro Rescue App, have a downloadable format for use in areas with poor cellular service. The apps function well but lack full coverage of vehicles; some makes and models appear unavailable. This privately funded effort enables ANCAP and EuroNCAP to develop a helpful and informational app. However, this app only includes rescue data sheets or ERGs, not operational guidance outside of these documents. The ERG is a basic SOP and lacks more detailed direction from the manufacturer, primarily due to a lack of understanding from the manufacturer. This app will be an excellent example of a potential starting point for a platform in the U.S. market.

D. HYPOTHESIS: HOW TO MAKE THE TRANSITION

While a better ERG delivery method and platform is in numerous reports and implemented in other countries, it must come to fruition here in the U.S. First responders nationally need an available actionable solution.

Hypothesis: The best way to provide a timely solution to the current knowledge gap that exists for firefighters about EVs is to offer rescue sheets to first responders through a web-based mobile application. The rescue documents are open-source, readily available information manufacturers provide for use by first and second responders. The application will aid in the usability of documents and sharing currently available information.

Action research is the best method to test the hypothesis. Action research allowed for low-cost agile testing methods and was integral to this thesis. This next section describes the tenets of action research used to create this paper's methodology.

[22] White-Labeling is the process of creating a web page skeleton. The skeleton can be filled in or used as each contracting party find necessary.

1. Action Research and Agile Testing of Business Ideas

The struggles from the knowledge gap when dealing with EVs is not unique to FDNY. Fire and Police Departments nationally and globally currently have similar difficulties, and there is no simple answer. The problem may manifest in one way for firefighters in California and another for police officers in Michigan. All three major stakeholders (first responders, government regulators, and EV manufacturers) experience different pain points. As the problem presents itself differently to each stakeholder, it must be considered from other viewpoints. As the *SAGE Handbook of Action Research* states, "Action researchers bring together action and reflection, as well as theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern."[23] For these reasons, Action Research is the most prudent solution available.

Action research allows this thesis to make a difference in the first responder world. The supporting documents defined the process and guided the methodology of the work. Formal action research literature allowed the work to follow the scientific approach, while informal works like *Pretotype It* by Alberto Savio helped inform a scientific approach to experimentation. Action research provided a commitment to use the findings of every interaction to define project direction and prevent a dedication to unique ideas and biased beliefs, allowing the work to find the best solution with minimal effort and almost no financial responsibility.

Action research originated with Kurt Lewin in 1947 at the Research Center for Group Dynamics (University of Michigan).[24] The process was developed to understand social ills after World War II, where scientists intervened in each experiment and became participants in their own research.

Action research proves beneficial, as documented in the *Journal of Applied Behavioral Science* in 2006. Action research identified causes and solutions of burnout in

[23] Hilary Bradbury, ed., *The SAGE Handbook of Action Research*, 3rd ed. (Los Angeles: SAGE Publications, 2015), 1.

[24] Richard Baskerville and Michael D. Myers, "Special Issue on Action Research in Information Systems: Making IS Research Relevant to Practice: Foreword," *MIS Quarterly* 28, no. 3 (2004): 330, https://doi.org/10.2307/25148642.

the federal fire service. The method used the holistic approach that found solutions tailored to the organization's needs. Action research was effective as it was able to interpret and respond to multiple contributing factors at the same time. Much like the study on fire service burnout, I chose action research because it addressed significant organizational issues while concurrently improving knowledge on the subject.[25]

The Sage Handbook on Action Research and work by Hilary Bradbury guided the approach and model used to implement the research. The work by Hillary Bradbury gives excellent insight into the action research method and how it is ideal for the challenge found here involving multiple stakeholders and an evolving problem. The advantage of action research is finding participants' familiarity without knowing they have exclusive knowledge. Our research findings were a sum of the whole as intended by action research as "Its modality is primarily participative and democratic, working with and toward knowledge in action."[26] A large amount of learning gleaned from the interactions within the efforts is defined as second-person practice. Our research efforts aimed to interact with SMEs, take their information, and use their feedback to guide the effort; as Bradbury says, we were "looking, listening, and taking action with others."[27] With my background in the field for numerous years, action research will allow me to impact testing positively. Action research allows the researchers to participate in the studies, not just conduct them. The beliefs brought along with our inquiry remained flexible and able to adapt to the agreed understanding discovered in the process.

Agile testing is integral for one person to undertake a study covering this vast scope. It is imperative to hypothesize and test. I came into this undertaking with biases and preconceived ideas but used the agile testing method to test my assumptions before committing an entire study to these self-created facts. Some of my first ideas could have

[25] Jonathon R. B. Halbesleben, Holly K. Osburn, and Michael D. Mumford, "Action Research as a Burnout Intervention: Reducing Burnout in the Federal Fire Service," *The Journal of Applied Behavioral Science* 42, no. 2 (June 2006): 247, https://doi.org/10.1177/0021886305285031.

[26] Bradbury, Hilary, "Action Research, Concept Of," in *SAGE Research Methods Foundations* (1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2020), 13, https://doi.org/10.4135/9781526421036805697.

[27] Bradbury, Hilary, 15.

been more realistic and were quickly corrected. The books *Testing Business Ideas* by Bland and Osterwalder, *The Lean Startup* by Eric Ries, and *Pretotype It* by Alberto Savoia guided the practical testing of the application hypothesis.[28]

The literature follows and guides research on similar principles. The more effort and resources committed to a test a hypothesis, the longer it will take to complete the test and the larger the commitment becomes to have the test validate the results in favor of the hypothesis. *Pretotype It* helps us understand multiple methods of validating an idea before the resources are committed to creating the prototype, hence the name Pretotype.[29] *Testing Business Ideas* was an informative guide for a novice to use to develop and guide experiments. At the same time, many scenarios were more complex to relate to government-funded projects than a profit-based model. The book is a solid playbook for reference and used for direction in testing. *The Lean Startup* has an interesting take on the OODA loop process that this thesis followed.[30] This process was the build, measure, learn cycle with the pivot or preservers juncture after learning was the methodology followed for every test undertaken.[31]

2. Research Design

This thesis follows the tenets of action research combined with an agile and lean methodology guided by the principles laid out in the literature review of Agile testing.[32] Every test started with a hypothesis, and from here, I created a way to test this hypothesis using as little capital as possible. With the results from each test, data or simple feedback was interpreted, and learning informed a new hypothesis. A similar cyclical formation of

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[28] Savoia, Alberto, *Pretotype It: Make Sure You Are Building the Right It before You Build It Right*, 2nd ed. (Mountain View, CA: Albert Savoia, 2011), https://www.pretotyping.org/uploads/1/4/0/9/14099067/pretotype_it_2nd_pretotype_edition-2.pdf; David J. Bland and Alexander Osterwalder, *Testing Business Ideas* (Hoboken, NJ: John Wiley & Sons, Inc, 2020); Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses* (New York: Crown Business, 2011).

[29] Savoia, *Pretotype It*.

[30] OODA loop stands for: Observe Orient Decide Act repeated in a looping process

[31] Ries, *The Lean Startup*, 75, 164.

[32] Savoia, *Pretotype It*; Bland and Osterwalder, *Testing Business Ideas*; Ries, *The Lean Startup*.

testing followed each test. The main detractor of this method is that testing on this system or idea will never be completed. The written thesis here documents the first four or five actions undertaken to validate ideas and explore the problem space. At a certain date, the record of this effort will stop, but the work toward creating a safer environment for firefighters will continue. The culmination of this study will hopefully be produced and shared nationally with first and second responders. The production of a viable application may create a new set of hypothesis testing and ideas to provide better information and feedback to and from first responders.

This application will be useful for secondary responders with the eventual sharing of information, but this is not the focus of this thesis. EV manufacturers also do not have standard recommendations for handling emergencies in these vehicles, with directives varying between models and brands.

Through action research, this thesis answers the question: Can rescue documents be better delivered to first responders? This work documents the attempt to construct a mobile application to deliver EV schematics. Making these rescue documents available to first responders for use in training and on-scene emergency responses will decrease the dangers to first responders by alerting them of fatal hazards within the vehicles and informing first responders of manufacturer-recommended mitigation techniques. This thesis used an action research method to develop a prototype and use interactions with SMEs from the FDNY, the Naval Postgraduate School (NPS), private enterprises, and numerous other professional hazard mitigation organizations globally. The process iteratively tested and revised a prototype for an application that will communicate necessary rescue documentation to first responders on the scene at emergencies. The report documents the considerations taken to provide first and secondary responders with essential information for EV safety. The thesis will use action research to iteratively test different hypotheses progressively.

The subsequent chapters give the reader a better understanding of the problem. Chapter II is a background of the problem space and a background on why apps may be the answer. Chapter III details the methodology on which the testing was constructed and the ideals followed in testing. Chapter IV documents our agile and progressive testing that

iteratively built successively on the results of previous tests. Chapter V is about the implementation considerations. Chapter VI presents the conclusion of lessons learned and the next steps to follow this endeavor to fruition.

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II. BACKGROUND: EV TRENDS AND NEW DANGERS

"A whole new world."[33]

An adaptation has not matched the change in automotive technology from ICE to EVs in the hazard mitigation community. In 2020, the NTSB recognized the lack of available information to first and second responders and recommended adopting and using a standardized rescue document, in this case, ERGs.[34] The adoption of ERG use can inform firefighters, police officers, and tow truck drivers of the location of potentially fatal hazards within EVs. There are current models for ERG delivery, but inherent design flaws limit their practical usability. Market regulation looms and will force the further proliferation of EV usage within the U.S.; this problem will only grow, which makes it worth solving. In addition, technology will continue evolving and presenting new dangers. If the first responder community does not get a handle on the current hazards while we have the opportunity, it will become an uphill battle.

The recent advancements in automotive technology have changed the concept of automobiles. EVs and partially electrically operated or dual-fueled vehicles (further separated into plug-in hybrid and hybrid) replace ICEs. The market is committing to the change so much that U.S. automakers are no longer investing in research and development for ICE vehicles. EVs contain dangerously high voltage within battery packs, wiring, and some drive components. While the technology continues to advance, first responders, including the FDNY, NYPD, and others around the country, are unable to keep operational guides current or applicable to all models. Many departments, including the FDNY, do not and have not had any valuable guides on the subject for years.

Locations of high-voltage components and energy storage systems change from model to model, as does associate manufacturer guidance. In 2012, the U.S. Department of Transportation (DOT), in conjunction with the NHTSA, recommended that fire officers

[33] As Aladdin predicted as he sang to Jasmine in the "A Whole New World" soundtrack of the 1992 Disney classic. *Aladdin.* Lyrics by*:* Tim Rice (Burbank, CA: Walt Disney Records, 1992).

[34] National Transportation Safety Board, *Safety Risks to Emergency Responders*, 58.

operating at scenes involving EVs refer to the emergency field guide or other appropriate guides, which have now evolved into today's ERGs.[35] The ERG and other similar documents, such as a Rescue Data Sheet (RDS) or Quick Response Guide (QRG) and supporting documents, are produced by manufacturers to enable firefighters to minimize dangers while mitigating emergencies involving EVs. ERG, QRG, and RDS are all rescue documents and can be used interchangeably depending on the place or time the document was manufactured. These documents are still not readily available for emergency responders operating at emergencies due to a lack of a forum, guidebook, or available catalog.

As technology changes continuously, it is impractical for fire and police to have policies in an eternal state of change and updates. Instead, responders need a broader approach to all EV incidents. A flexible policy is based on a few constants but references the associated emergency documentation from manufacturers for specific procedure variations from model to model. In a report in 2020, the NTSB advised firefighters to reference the NFPA's bank of ERGs hosted online at operations.[36] On October 6, 2022, the NFPA's site was no longer current; the online database excluded many new model EV ERGs, and the online catalog did not add new EV manufacturers with available ERGs.[37] The report by the NTSB also acknowledged that lack of standardization is problematic for first responders when using ERGs.[38] With over 40 manufacturers and an incomplete national library, finding an appropriate Rescue Document for a potentially fatal accident is more complex than it should and could be.

Federal regulations are prominent as the federal and local governments have started to pass restrictions and incentives on green technology at an increasing pace. The U.S. Federal Government has implemented an executive order to make all federal fleet vehicles

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[35] Long, Jr. et al., *Best Practices for Emergency Response*, 22.

[36] National Transportation Safety Board, *Safety Risks to Emergency Responders*, 43.

[37] National Fire Protection Association, "Emergency Response Guides."; Polestar U.S., "Polestar 2: 5dr Hatchback (2020)," Polestar Emergency Response Guide (Gothenburg, Sweden), accessed November 17, 2022, https://euroncaprescuesheets.blob.core.windows.net/rescuesheets/Polestar/Polestar_2__Hatchback_2020_4d_Electric_EN.pdf.

[38] National Transportation Safety Board, *Safety Risks to Emergency Responders*, ix,64.

zero emissions by 2035.[39] California is trying to reduce pollution by limiting the sale of internal combustion engines. Governor Gavin Newsom implemented an executive order restricting sales of all new light-duty internal combustion engine vehicles sold in the state after 2035, with New York close behind.[40] Forcing such a ubiquitous change without having the knowledge in emergency workers' hands will amplify the problem.

A. WHAT IS YOUR MAJOR MALFUNCTION—INFORMATION PROBLEM

There is a major malfunction in the communication between the manufacturers and first responders. The mechanisms in place to ensure safety recommendations are disseminated to the emergency services field are not working. In 2009, the General German Automobile Association (ADAC) appealed for manufacturers to make rescue sheets available at accident scenes.[41] For years, the International Organization for Standardization (ISO) has been working on creating a standardized document to deliver information to first responders at an accident scene (ISO 17840). With the ability to share data between auto manufacturers and first responders and national directives from a central authority, it is possible to minimize the problem.

With the enormity of the challenge for a first responder to understand an emergency scene involving an EV, far more supporting material is needed. The FDNY (the largest fire department in the United States) only has a 1-page pass-along document that does not constitute an SOP.[42] The current national catalog for ERGs hosted on the NFPA website shows an incomplete roster of makes and models; this database is also unavailable to

[39] Catina B. Latham, *Federal Vehicle Fleets: Observations on the Transition to Electric Vehicles*, GAO-23-105635 (Washington, DC: Government Accountability Office, 2022), https://www.gao.gov/products/gao-23-105635.

[40] David Shepardson, "New York State to Adopt California 2035 EV Rules," Reuters, September 29, 2022, 1, https://www.reuters.com/business/autos-transportation/new-york-state-adopt-california-2035-ev-rules-2022-09-29/.

[41] Wisch et al., "Recommendations for Safe Handling," 5.

[42] Fire Department of New York City, "Tips from Training: Tesla First Responder Loop" (New York: FDNY Fire Academy, March 22, 2021), 1.

responders in locations without cellular service. At the time of this research, no mobile applications are available in the U.S. that is not behind a paywall.

On November 23, 2019, at 22:19 hours, Fort Washington Fire Company 1 responded to a Tesla EV fire. This car was charging at the time, and first responders did not know the extent of the dangers present at this scene. Since the incident, firefighter executives did not thoroughly communicate the lessons learned from this operation to other departments. In a separate incident in 2013, when a Tesla Model S caught fire after a piece of metal punctured the battery's protective cover, firefighters pierced the battery to extinguish the fire with water. Tesla C.E.O. Elon Musk commented on the incident later that week, remarking, "it was correct to apply water (vs. dry chemical extinguisher), but not to puncture the metal firewall."[43] These two examples out of thousands of incidents demonstrate the needless endangerment of first responders. The information from these incidents was not shared with the first responder community on a general forum page. The lessons learned could be delivered to departments through a similar application.

B. APPLICATIONS AS A POTENTIAL SOLUTION

Just as vehicle technology changes, so have the information-sharing methods available. Web and mobile-based applications can be used in this problem space. Applications in recent years are used as study guides, 3D image scanners, fitness trackers, and crime or incident reporting systems. ShotSpotter facilitates additional efficient responses to gunfire by police departments.[44] Citizen app allows police departments to utilize citizens as force multipliers in reporting incidents, producing faster responses by integrating this information into dispatch centers. Research indicates motorists report vehicle collisions four minutes earlier on the navigation application Waze than by 911 calls.[45] These examples show the potential that a mobile application can have and how a

[43] Elon Musk, "Model S Fire," *Tesla* (blog), October 4, 2013, https://www.tesla.com/blog/model-s-fire.

[44] "ShotSpotter Mobile App," ShotSpotter, accessed January 25, 2023, https://www.shotspotter.com/shotspotter-mobile-app/.

[45] Michelle R. Potts, "When 9-1-1 Is Not Enough: Transitioning the 9-1-1 Center into a Multi-Channel Emergency Communications Center" (master's thesis, Naval Postgraduate School, 2019), 50.

low-cost solution can have a significant impact on a problem. Applications are already used for this problem space in other countries, giving a viable model to use as a proof of concept.

Web and mobile applications are valuable tools and can be a possible solution for the information gap between EV dangers and first responder knowledge base. Unlike printed guides or books, applications are fluid and agile; they can pivot or change quickly by discovering new information. Applications have relatively low maintenance costs and can be revamped when necessary. For this reason, this research focuses on an internet-based application for rescue documents for first and second responders.

Most developed countries deal with a similar problem. Australia and Europe alike in 2020 launched a mobile application that centrally located and hosted manufacturer's rescue sheets for use by first responders free of charge.[46] The two applications are hosted by Euro NCAP and ANCAP similar to the 5-star crash test rating agency in the U.S., NHTSA. As noted in the 2020 DOT report, ANCAP and EuroNCAP recognized the need to distribute standardized documents for Rescue workers to use at an emergency scene. ISO 17840 is an international standard developed by a worldwide federation of national standards.[47] It created a uniform template for manufacturers to present information consistently for rescue workers. EuroNCAP and ANCAP centrally collected and distributed all rescue sheets and have been able to leverage their influence on manufacturers to have all manufacturers submit ISO 17840 compatible rescue sheets.

ANCAP and EuroNCAP connected the submission of ISO format rescue sheets to the 5-star crash rating system, in effect influencing vehicles' sales. If the vehicle sheet is not submitted by the time of the crash test, the car could only score four of five stars. The rating system can be influential during the consideration of purchasing a vehicle. The rescue data sheets' connection with scores on the ANCAP and EuroNCAP grading assessments incentivizes the standardization of rescue documents and helps the

[46] National Transportation Safety Board, *Safety Risks to Emergency Responders*, 43.

[47] International Organization for Standardization, "ISO 17840-3:2019(En), Road Vehicles — Information for First and Second Responders — Part 3: Emergency Response Guide Template," International Organization for Standardization, accessed October 8, 2022, https://www.iso.org/obp/ui/#iso:std:iso:17840:-3:ed-1:v1:en.

application's success. The central hosting of ERGs by ANCAP and EuroNCAP leverages the position of these entities in the marketplace.

Making rescue sheets mandatory over a 3-year process and creating a robust database of rescue documents for reference was made functional by creating a rescue application in Europe and Australia. The functioning use of the rescue application and the incentivization has created a proof of concept of this model in Australia and Europe. This model is exceptional because it found a way to work around the incredibly slow pace of regulation. An obstacle in the U.S. is that one of the entities that produce 5-star crash test ratings is a government body (NHTSA) that is not interested in enacting this type of incentivization at this time. NHTSA does not create regulation but enforces regulation. The conversations with NHTSA lead me to believe NHTSA must wait for the government to develop mandates allowing them to implement these ideas.

ANCAP and EuroNCAP created brilliant rescue applications that bridge the knowledge gap and deliver quality and actionable information to first responders; why does it not work in the U.S.? ANCAP and EuroNCAP created this product and shared the cost burden while the U.S. did not. The white-labeled application allows users to input vehicle make and models relevant or available in those localities. The lack of U.S. investment in the initial product created a barrier to entry, and neither application has all applicable vehicles for the U.S. ANCAP rescue has some models available in the U.S. Still, as of 2022, models are depicted with right-hand drive, which is not valuable for the U.S. In addition, the ANCAP Rescue application has many irrelevant models in the U.S., i.e., the Citroën C4.[48] These rescue applications do not have the entire catalog of vehicles in the U.S., such as larger electric cars that are likely to do well in the U.S. market. Models including the GMC Hummer and the Ford F-150 are unavailable on Euro Rescue or ANCAP Rescue. The Ford F 150 Lightning is the top-selling electric truck in America and will have hundreds of thousands of models on the road in coming years.[49] Speculation is

[48] "ANCAP Rescue Apps."

[49] Peter Johnson, "2022's Top 10 Best-Selling Electric Vehicles in the US: Find out Why They Made the Cut," Electrek, January 10, 2023, https://electrek.co/2023/01/09/the-top-10-best-selling-electric-vehicles-in-the-us-of-2022/.

that the application hosting contract will end in late 2023, and EuroNCAP and ANCAP will be looking for a new design and web hosting service. For these reasons, neither of these applications would fit the U.S. market's needs for first responders.

With the Euro Rescue app and ANCAP rescue app functioning well in their respective countries, it is a valid question why the U.S. still needs to use these applications. Once created, the applications acted as a joint venture between the two new car assessment enterprises. The initial investment was split by the two private enterprises, not the Insurance Institute for Highway Safety (IIHS) or NHTSA (the two new car assessment programs in the U.S.) The application was designed as a wireframe and "white labeled" the design so each entity could plug in relevant manufacturers and vehicles. The models presented on the applications represent multiple manufacturers not here in the U.S., and conversely, many U.S. model vehicles do not show up on the applications. The applications include all models, not just dual-fueled vehicles like the NFPA catalog. Without a complete catalog of vehicles in the U.S., it is not a viable answer to the problem space. It is unclear if the entities in the U.S. had the chance to invest in the application design, but it is apparent that the opportunity is not currently available.

Creating a mobile application here in the U.S. will help bridge the gap in information needed and available to first responders. Mobile applications create a downloadable catalog negating the need for continuous cellular service. Additionally, any downloaded ERG or Rescue Sheets will be available instantly when needed. As demonstrated by ANCAP and EuroNCAP, using a mobile application built for delivering ERGs in a downloadable format is a functional method for information exchange between the producer (auto manufacturers) and end users (first and second responders). One of the many benefits of this format is the ability to update as frequently as needed when the mobile device has data or cellular service. This design of the downloaded setup allows the information being delivered to evolve as quickly as the technology it supports, presenting a dynamic solution for a dynamic problem. The application can prove the use of ERGs by responders, encouraging manufacturers to produce better ERGs and RDs and consider emergency documents more.

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III. METHODOLOGY

A. ACTION RESEARCH

Action research uses first-person information, second-person feedback on that learned knowledge, and third-person validation of the findings, with all interactions having equal weight and ability to alter and inform the direction of the process. According to Bradbury, "Action research allows iterative and emergent approaches because action researchers do not believe that a fully fleshed out plan could actually match complex reality. Planning is, at best, a way to align stakeholders."[50]

As stated earlier, the research question that informed the effort at the start of the endeavor was: How can first responders develop and sustain a functional knowledge of EVs, including technological changes, to handle emergencies safely for responders and citizens? Informed by the stakeholder evaluation and marketplace analysis, one of the areas that connected the three main categories of stakeholders (the many auto manufacturers, government bodies, and first responders) was the rescue documents, including ERGs and QRGs. The iterative testing model was built on the premise that the ERG was the answer to the problem faced by first responders, and ERG delivery was the leverage point within reach of this thesis. My research method allowed each test and subsequent results to inform further testing.

Guided by the principals from *Testing Business Ideas* book by David J. Bland and Alex Osterwalder, I used the tools and resources available that required the smallest investment of capital, giving me the ability to pivot based on the findings. ERGs were quickly identified as the best (not perfect) information readily available to first responders. Test one was designed as the first interaction to examine if the resource could and would be used by subject matter experts on calls, also known as emergency responses. The goal was to validate the experiments' foundation of initial beliefs and the value proposition.[51] Test one, indicative of action research, would also provide an instant value to participants

[50] Bradbury, "Action Research, Concept Of," 13.

[51] Bland and Osterwalder, *Testing Business Ideas*, 30.

if the value proposition was correct (the knowledge of using ERGs). The design was constructed to use feedback to inform future planning of tests and have an immediate impact on the safety of the first responders using the added tool.

Unlike traditional research that follows a more rigid approach, action research allows for tests to iteratively build upon one another. The second test used the lessons learned: ERGs would be used in the field without an extensive effort for adoption. The test now focused on the subject matter experts' input to confirm if the ERG displayed the correct information that firefighters would need in the field. The test also considered the practical application of the process as opposed to the theoretical design; the underlying concern this test examined is the weight of this additional information when competing against the mental demands an officer (first-line supervising firefighter) faces when overseeing the high-stress, high-stakes operation of extrication. The construct of this test aimed at getting answers to the two questions posed here and eliciting unexpected feedback. The experiment subjects examined the information, and one-on-one casual conversations helped extrapolate from the experience, recorded answers, and aggregated information to show feedback.

The third interaction was a trip to Vance, Alabama, sponsored by Hurst extrication tools, where members were invited to perform extrication techniques on new Mercedes vehicles. This interaction was a meeting of over 45 SMEs focused on evolving extrication techniques involving newer vehicles, including EVs. This trip was the first interaction with another stakeholder segment; an auto manufacturer. Mercedes Benz also recognized the problem and constructed a solution for their vehicle brands. The information learned at this juncture included an alternate path to deliver the ERGs, including progressive web applications (PWAs) combined with quick response (QR) codes. The trip influenced our learning progress but was under the direction of the two co-sponsors and, in effect, limited the available interactions with SMEs for other departments. One of the most significant realizations made during the entire effort was at Mercedes Benz when it became apparent that manufacturers did not have the answers and were looking for feedback from first responders. Likewise, they wanted input from the field from those who responded to EV

incidents. Manufacturers are unaware of all the challenges firefighters face when dealing with EVs and do not know the best solution for a lithium-ion battery fire in a vehicle.

The fourth test used all findings to that point and communicated them in a single function-minimum viable product (MVP). With help from Sukh Singh at the Berekley Disaster Lab, a functioning model was created through Figma. The model has 17 working pages users could test and give feedback. The model application displayed the corresponding EV ERG for an extrication demo. The Cadillac Lyric was the first EV cut using a prototype ERG display application we had control over in our testing. The feedback was used to inform the FDNY prototype and further support from decision-makers in the FDNY.

The final test to be completed is an A-B test with unlimited iterations. The basis of the last process is constructed to create an application built around user feedback. The purpose is to test the application's functionality and find shortcuts to life-saving information with user feedback. The direction of the A-B test will inform decisions in building a PWA to deliver ERGs. A-B testing with subject matter experts will create a design that is a solution to the pain points found in the market. The continuous experiences with subject matter experts should build a product that avoids the pitfalls of classic waterfall designs engineered for perceived problems, not actual market needs.

B. EFFORTS ON MANY FRONTS

To better understand all sides of the marketplace for vehicles, it was necessary to evaluate the creation of standards and codes. One of the predominant standards for auto manufacturers globally is the UNGTR 1998 and UNGTR 1958 agreements.[52] As the United States is a contracting party to the 1998 agreement, the evolving code of the UNGTR can positively affect the safety of first responders in the United States.[53] I recently joined the United Nations General Technical Regulations committee at the 25th Electrical

[52] UNGTR 1998- Global Technical Regulations Under the United Nations/Economic Commission for Europe 1998 Global Agreement

[53] Costandinos Visvikis, "Safety Considerations for Electric Vehicles and Regulatory Activities," in *26th Electric Vehicle Symposium 2012, EVS 2012* (26th Electric Vehicle Symposium 2012, EVS 2012, Los Angeles, CA, 2012), 3.

Vehicle Safety Committee meeting (EVS25). The committee meets to address standards for EV technology and passenger safety. The committee is forward-thinking and makes significant efforts to address missing gaps in protection for occupants and post-incident emergency personnel. The committee requested first responder input on ISO 17840 and future EVS meetings. Attending this meeting showed that regulation will be essential to creating and sustaining a first responder-based catalog application for EV safety documents.

The regulatory process meeting included representatives from countless different organizations. Two of the three main stakeholders in this problem attended, with auto manufacturers represented by numerous parties and many national departments of transportation represented. Still, no representative besides myself was at the meeting to give the first responder's perspective. The group acknowledged this gap, welcomed me, and asked for feedback from the first responder segment. Given regulation will take far longer to show results, this will be an ongoing effort and may take years to see change.

Many of the participants of the EV25 support an ERG sharing app and want to contribute to the product but need a proper mechanism to do so. The potential for PPP is tremendous; this will be an area where all three stakeholders can collaborate to influence a positive outcome. Members of the UNGTR recommend global safety through influence on manufacturers and governments. Future involvement in the UNGTR and EV meetings may prove immensely beneficial to first responders.

After attending the EV25, I was invited to join the SAE Hybrid and Electric Vehicle First and Second Responder Task Force. The SAE Hybrid and Electric Vehicle First and Second Responder Task Force work to establish recommended practices and provide safety information to first and second responders regarding incidents involving vehicles that contain high-voltage electrical systems. The task force reviews the fire, crash, and electrical system performance of high-voltage vehicles involved in real-world incidents, monitors safety regulations and other standards, and discusses new technology that may benefit the public safety community. It is a massive bonus in this action research to have input on the future safety of responders.

IV. ITERATIVE TESTING: RESCUE DATA SHEETS AND DELIVERY METHODS

The design of this action research was based on the belief that agile, low-cost testing was needed to pivot rapidly and find the solution that best fits this problem quickly to remain relevant to the market.

To test the underlying assumption of this academic work, I challenged the hypothesis: Rescue Data Sheets available to first responders from a mobile application will aid them in operating safely. Tests were designed to elicit information from the user and avoid bias design by the researcher. Test designs built upon knowledge unearthed during previous tests and successively honed in to gather actionable data.

A. TEST 1: TESTING NYC FD RESPONSE - PRETOTYPE

- Setting: FDNY; citywide
- Question: Is it practical for fire duty companies to use a mobile device at the scene of an accident?
- Process: Add to department iPads, followed by training and evaluation

Using the pretotype "fake it before you make it" testing method, feedback confirmed the parts of the hypothesis.[54] A web browser hyperlink icon was added to all FDNY iPads on May 24h 2022, linking directly to the NFPA catalog of ERGs; the training to introduce the addition projected to follow shortly after.

Before the department published training or official directives, members of Ladder companies found and used the provided dataset. Emails and informal feedback demonstrated usefulness in the tool. Feedback from Ladder Company 108 included an interim SOP they had produced to use the information in a timely manner that did not detract from their operations at the scene. The company reported using the available documents during emergency response to locate high-voltage disconnects, battery

[54] Savoia, *Pretotype It*, 21.

locations, and high-voltage wiring and components, including battery trays. These emails in Figures 1 and 2 illustrate the desire for content.

From: Ladder 108 (FDNY) <[redacted]>
Sent: Thursday, September 29, 2022 12:51 PM
To: Training Tips (FDNY) <[redacted]>; Remote Tactical Training Unit (FDNY) <[redacted]>
Subject: EV Vehicle Extrication / NFPA APP on IPAD

Good morning,

Thought we'd pass along our SOP re: car accidents involving EV/hybrid cars. At accidents, once the vehicle involved is identified as EV or hybrid, Year Make and Model type is relayed to the LCC. The LCC then accesses the NFPA APP on the FD IPAD. Here a link to an extensive list of Emergency Response Guides of various vehicles by Year, Make , and Model are listed. These guides are consulted to determine the various hazards associated with the vehicle. Details provided in the guides vary, however most give info re:

1. Cut Loop Location
2. High voltage disconnect procedure
3. Low voltage battery location
4. High Voltage wiring location
5. High strength steel zones
6. Lifting points
7. Airbag locations etc.

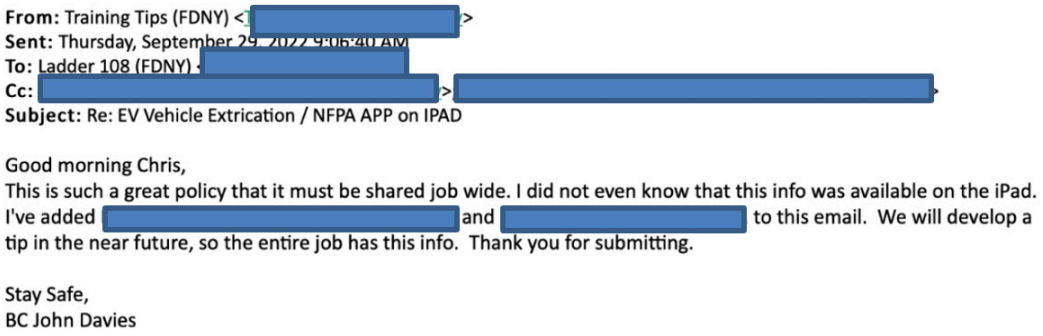
Although the list is not completely comprehensive, we find it is worth look in an effort to avoid some of the associated hazards when operating at incidents involving these vehicles. The guides are in color with diagrams using uniform symbology. Attached is an example of an ERG. Hope this helps. Apologies if this is redundant information.

Respectfully,

Lt. Chris Walter
Hundred N Eight Truck

Figure 1. An email from Lt. Chris Walter with SOPs using the NFPA icon[55]

[55] Email message to Training Tips, FDNY, 29 Sep. 2022



From: Training Tips (FDNY) <[redacted]>
Sent: Thursday, September 29, 2022 9:05:40 AM
To: Ladder 108 (FDNY) <[redacted]>
Cc: [redacted]
Subject: Re: EV Vehicle Extrication / NFPA APP on IPAD

Good morning Chris,
This is such a great policy that it must be shared job wide. I did not even know that this info was available on the iPad. I've added [redacted] and [redacted] to this email. We will develop a tip in the near future, so the entire job has this info. Thank you for submitting.

Stay Safe,
BC John Davies

Figure 2. Training Tips' response to SOP[56]

The NFPA's website hosts an incomplete database of all dual-fueled and EVs in the U.S. First responders nationwide utilize this website for rescue sheets, but the lack of upkeep is worrisome. The database has incomplete sets of data due to a lack of updating popular brands, including Acura, BMW, Dodge, Buick, Polestar, and Toyota with their incomplete data sets. Tesla accounted for 79% of EV sales in 2020 and 70% in 2021; the majority of EVs in New York and the U.S. are Tesla models. The NFPA has kept the Tesla dataset somewhat current over the past four years.[57]

The link on the department iPads functioned as a pretest as it did not fulfill all mission objectives. It served as a substantial victory in solidifying the assumptions of need and practicality. FDNY technical staff received feedback from field units and supporting documentation, and work on an in-house app was formally started on September 21, 2022. The proposed EV application was adopted and put into the planning stages by the Life Safety Systems team of the FDNY.

[56] Email message from Training Tips, FDNY, 29 Sep. 2022

[57] Can Emir, "Tesla Proves Dominance in the EV Market with a 75 Percent Market Share," *Interesting Engineering*, April 29, 2022, https://interestingengineering.com/transportation/tesla-ev-market-75-percent-market-share.

1. Findings

- The primary assumption tested by the pretotype was: first responders will take time to use an application before, during, and after emergency responses. The concern was that the time taken to use the application at an emergency scene might be thought too critical to reference technical documents. The pretotype dispelled this concern.
- Members are looking for information on EVs.
- Some members of the departments are keen on technology.
- SOPs will be required to accompany the application.

2. Concerns

The link was lacking in two areas: it required connectivity to operate, and the catalog within the database lacked multiple models altogether. Other areas found to be a problem were the navigation tools for the site, and there are no quick response guides for some models.

B. TEST 2: TESTING AT RANDALL'S ISLAND NYC, RELABELING

- Setting: FDNY extrication training unit, Randall's Island
- Question: Does the ERG/ QRG satisfy the needs of firefighters for extrication?
- Process: Evaluate potential ERG/QRG delivery methods through interactions with subject matter experts

The initial hypothesis went through tests for practical use for the FDNY, and first responders within the FDNY consulted as industry experts. The value proposition expanded to show the need for information on all vehicle models, not just EVs. The interaction was designed to produce user feedback and avoid constructing a test on my own biased beliefs. Findings from these subject matter expert interactions would dictate the design of future experiments.

The first in-person fact-finding scenario was tested using the Re-label technique by Alberto Savoia, author of *Pretotype It*.[58] Nine FDNY officers in the rank of Lt and Captain were shown the ERG of a Tesla Model S from 2016 on a mobile tablet device (iPad) and a mobile phone (iPhone 11) before an auto extrication exercise at Randall's Island Training Academy. The iPad was pre-loaded with a Tesla QRG schematic (as seen in Figure 3) from the Tesla first responders web page https://www.tesla.com/firstresponders. The fire officers then gave feedback before and after engaging in an auto extrication training exercise on an older internal combustion engine vehicle, different from the car pictured in the rescue document. The test used the previous knowledge from test one and built on the theory; if users would use the information on an ERG or QRG, what information would they want to get from the document, and in what order? A review of the documents before and after an extrication exercise was used to create a setting that would elicit real-world concerns while performing extrication on a vehicle.

Subjects were asked not to focus on the QRG but possibly the delivery method and changes that could be made post-production of the QRG. Figure 3 shows the first page of the QRG used in testing. The QRG displayed is based on the ISO 17840 standard and displays information that has been suggested by the standard. While future changes may alter standard ISO 17840 our intent was to evaluate if the current document provides enough information to help solve the knowledge gap.

[58] Savoia, *Pretotype It*, 40.

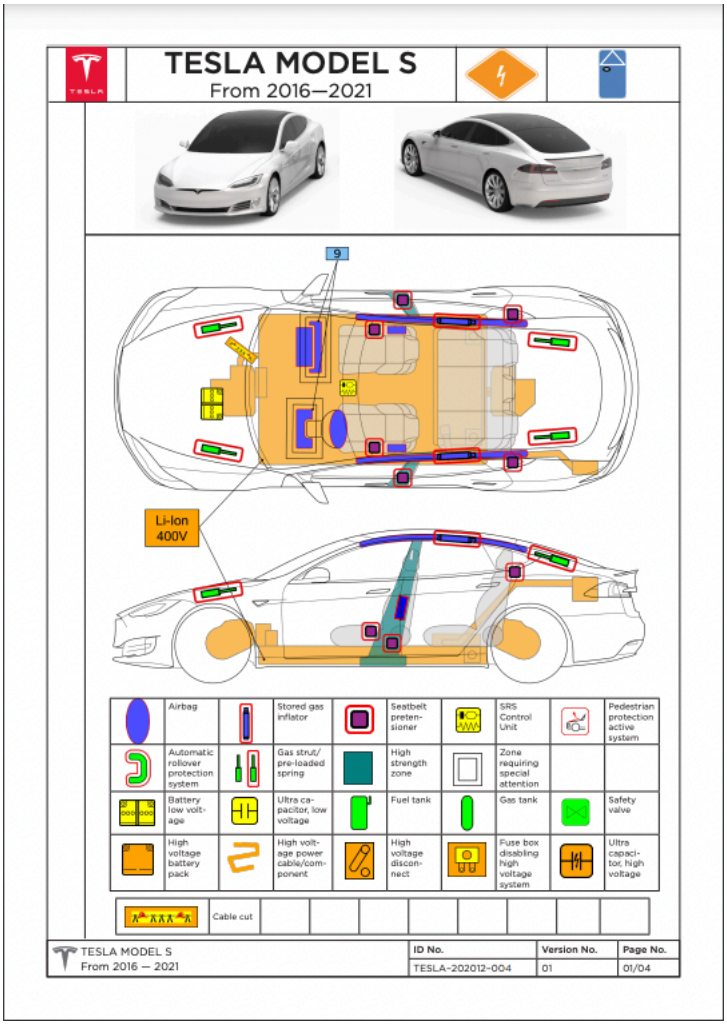


Figure 3. Tesla Model S QRG used during testing

1. Findings

This experiment validated assumptions of application benefits with unintended consequences but gave further feedback from users. See Table 1 for a summary of lessons learned.

- The potential implications created by the added knowledge caused firefighters to hesitate to use a metal automotive jack to lift the vehicle due to the proximity of the battery tray. This insight highlights the need for departments to supplement the information with training.

- The size of the delivery method was a concern.

- All segments could benefit from response guides, including ICE responses.
- Color coding on 17840 compliant QRG raised questions.
- Users desired direct navigation to information (i.e., power shut off).
- Users requested the availability of a training section of the application.
- Additional uses besides on-scene reference:
- Application use training with SOPs for use at the incident scene
- Post incident, EV incident training
- Reference material for EV knowledge training
- Fire case studies with pictures for best practices
- Reservation on technology adoption
- Key takeaway-deficient knowledge or use of this tool

Table 1. Pivot based on lessons learned from Test 2

Questions	Findings
Did you know about these guides?	1 of 9 had previous knowledge of the guides
Have you seen one of these before?	NO 9–9
Could this be a beneficial tool?	100% positive feedback
What do you think?	Overarching theme-Like the simplicity
What do you want to see first/ what is the most important information you think you would use?	Most said the schematic
What do you want this to tell you?	Safety information, shutoffs, high voltage, airbags
How could this be delivered?	App tablet or phone, printed in the car, computer in the firehouse
What training would you want before using this?	Demo with user-guided experience, not under pressure Scenario training- Online training
Is there anything you would want to add?	Mostly No, the simplicity is important

Questions	Findings
If an interactive feature was possible, what would you want to know?	Battery information, state of charge, activated safety devices, hi-voltage power isolated, BMS info, temperature.

The potential users showed interest in and for EV training using supporting documentation before, during, and after incidents with EVs. Internal combustion engine models share hidden dangers and difficult-to-find low-voltage batteries, and the application identifies information for all vehicles on the road. The experiment demonstrated the value of the application across many vehicles, makes, and models beyond EVs, as unknown factors on other models produce similar risks. In addition, this test questioned and validated the benefit of having advanced operational directives at a crash scene. Finally, the Rescue Documents delivered with the application were a positive input and helped show ways to avoid danger and improve the safety of responders and occupants.

2. Concerns

Size and speed were revealed to be primary factors of importance. Pictures and icons need to be large enough to use and vision of users may be less than perfect. The pictures must load quickly. The lack of knowledge surrounding the existence of rescue documents was alarming.

C. TEST 3: FDNY TRIP TO MERCEDES BENZ FACILITY, VANCE, ALABAMA

- Setting: Vance, Alabama, training facility. Hurst demo.
- Question: How does MB delivery differ from other manufacturers
- Process: Subject Matter Expert interaction- Action Research

Testing at the Mercedes plant in Vance, Alabama, showed the benefits of viewing ERG schematics before engaging in auto-extrication exercises on new model vehicles. Members from the FDNY participated in an auto extrication series at the Mercedes Benz training facility. Members from the trip communicated takeaways routinely during the trip and shared feedback after returning. The event allowed members to consider ERGs before

performing extrication maneuvers. The ERGs proved beneficial on many levels, including non-electrified vehicles.

The training series by Mercedes-Benz focused on auto extrication led by a trainer from the manufacturer. The manufacturer-led training concentrated on the physical advancements of the engineering department, mostly the vehicles' boron or high-strength steel components. Technology developed by Mercedes Benz links a QR code placed in two locations on the vehicle that directs users to the manufacturer's hosted web-based ERGs. The potential integration of this technology into the application showed a tremendous benefit of timesaving at an operation.

The QR code proved to be a helpful tool to assist in finding the model quickly on the platform. For example, in our prototype applications tested on Randall's Island Training Academy, users navigated through three to four selection pages before arriving at the desired rescue document. The QR code feature provided by Mercedes routes members directly to the Emergency documents page hosted by the manufacturer. The feature saves time by circumventing three to four selection pages and eliminates the potential for incorrect selection of the wrong emergency response guide. The QR code also has significant potential to reduce the time required to identify the vehicle brand and model. Model identification is a primary concern; with over 400 models of cars available for sale this year alone, the variations on the road are in the thousands.[59] In the emergency response scenario, every second saved is an advantage to the occupants in the vehicle.

The document storage format is a downloadable catalog as a PWA.[60] The PWA downloaded database linked with the QR code created an instant link quickly, providing access to the correct documents. The construction of the available ERG catalog as a PWA acknowledges the need for first responders to have information available without connectivity to cellular or wifi service at the scene of an incident.

[59] James Riswick, "Vehicle Types, Car Body Styles Explained," *Car and Driver*, August 1, 2019, https://www.caranddriver.com/shopping-advice/g26100588/car-types.

[60] Mercedes-Benz, "Mercedes-Benz Rescue Sheets," The Digital Rescue Assistant as a PWA, accessed October 7, 2022, https://rk.mb-qr.com/en/pwa/.

1. Findings

The four members of the FDNY testing team found the ERGs helpful on all models. Unanticipated uses for the ERGs became evident in gas models as well as electric models. The ERGs drastically reduced the time to find airbag initiators. Airbag initiators or inflators are pressurized cylinders hidden in countless places throughout vehicles: from under the headliner in the roof or door pillars to the sides of each seat in the vehicle.

Our group did not consider the concept of a PWA until the Mercedes-Benz trip. While the PWA was not our original plan, the change allowed us to use a larger pool of developers and possibly reduce costs. Mercedes-Benz has a proven concept to work across all platforms (IOS, MAC, desktop, and mobile platforms). The ERG for gas models proved beneficial. The QR code technology is an excellent integration for an application. A camera-based reader for QR codes, vehicle identification numbers (VIN), or license plate numbers showed benefits in locating the ERG promptly and minimizing the possibility of an error.

2. Concerns

Given the lack of damaged EVs available, it is very hard to procure vehicles for training at the FDNY. The majority of EV training comes from third parties with set agendas that do not allow for thorough testing of our application in simulated settings. 09843qzd

It is a concern that we will not have example vehicles to test the application on.

D. TEST 4: GENERAL MOTORS MILFORD, MICHIGAN-SINGLE FUNCTION MVP

- Setting: General Motors Testing Facility; Cadillac ERG demo
- Question: Will using the ERG give appropriate information for extrication on an EV
- Process: Use the Single Function MVP to elicit feedback surrounding the extrication exercise based on the Cadillac Lyriq

General Motors hosted the National Urban Security Technology Laboratory (NUSTL) and Dager enterprises for a System Assessment and Validation for Emergency Responders (SAVER) evaluation of lithium-ion battery-powered extrication tools from various manufacturers. After three days of testing extrication tools, the 11 first responder/ industry experts were invited to participate in extrication training on four General Motors vehicles. The training included extrication on two EVs and two autonomous driving EVs. Schematics of the vehicles were shared before rescuers were used to cutting the cars. Then, before the physical test of cutting the car with extrication tools, participants observed the schematics of the car to familiarize themselves with possible danger areas. Participants reported the application's usefulness and ease of use by design simplicity. The single-function MVP application was created using FIGMA, a collaborative interface design tool.[61] Sukh Singh of the Berkley Disaster Lab produced the design through a pro bono effort to aid in first responder safety when responding to EVs. The QRGs on the Figma application appeared on the iPhone 11.

Past lessons were built into the user interface design when constructing the Figma application. The application also added the option of a directory of users on the first page. This directory brought users directly to opportunities that would be considered high priority. The separation of long pages allowed users to navigate through the four-page document to find the possible ideas quickly. The optional QR code scanner we learned of in Vance, Alabama, gave insight into entering a VIN or QR search. Vehicle identifiers can link through likely search engines, like Carfax, currently used by law enforcement and do not share privately protected data like the owners' personal information.

Testing the single-function MVP allowed test subjects to navigate through the Rescue Data Sheet in a new way not previously explored. This MVP's design lets users navigate directly to specific parts of the MVP through an added selection page. The use of the information was the same, but the delivery method allowed for slightly more control in direction through the 4-page rescue sheet. Exercises were conducted on autonomous self-

61 "Figma: The Collaborative Interface Design Tool.," Figma, accessed December 5, 2022, https://www.figma.com/.

driving vehicles after, and feedback indicated the need for directives on the platform for addressing emergencies involving autonomous self-driving vehicles.

Figures 4–12 show the Figma application in order as users would see it as they navigated through to find the Make and Model to get to the associated ERG/ QRG with the vehicle schematic.

Figure 4. Log in selection

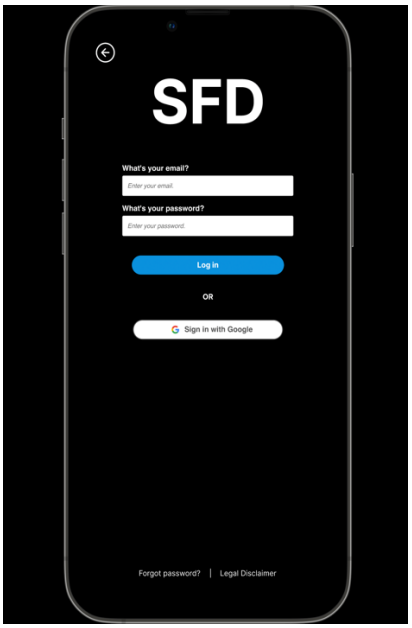


Figure 5. Log in

Figure 6. Make selection

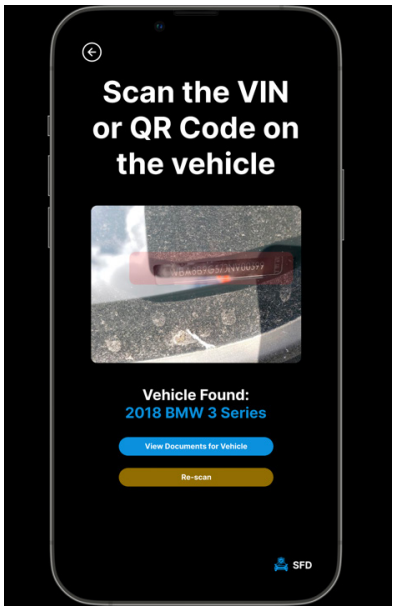


Figure 7. Vin tool

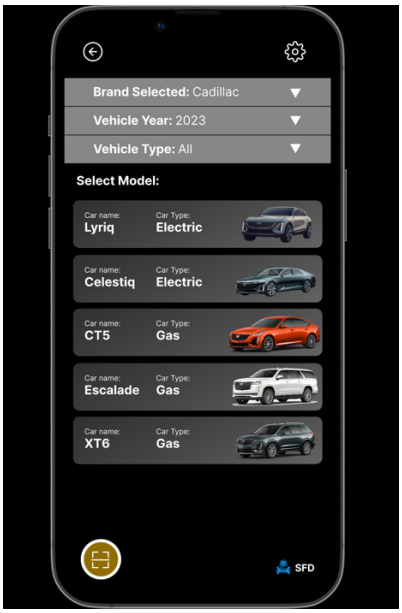


Figure 8. Model selection

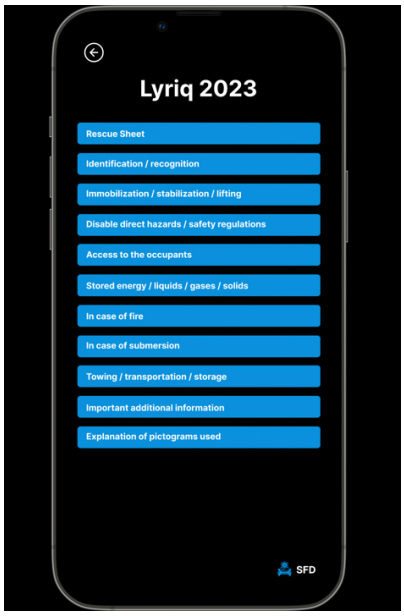


Figure 9. Index

Figure 10. Schematic

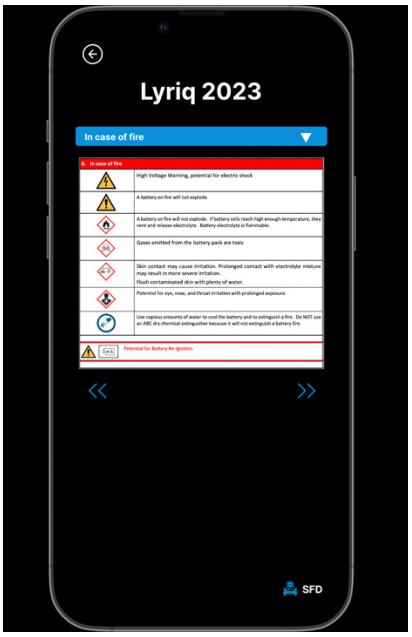


Figure 11. Directives for fire

Figure 12. Directives for disabling vehicle

1. Findings

The confirmation of the application's usefulness on actual EVs during the testing validates two prior assumptions:

- Delivering directions to first responders for EV responses via an application is possible.
- The information on the QRG would aid in hazard mitigation at an accident scene for firefighters.
- A VIN scanner option is immediately available.
- The size was a concern; all users trialing the reported it would be more practical in a larger format, iPad, not iPhone.
- Reviews of the application were 100% positive, besides the size of the display
- The current PDF format causes technical difficulties in adding selection or navigation options.

2. Concerns

Only two users reviewing the data on the Cadillac Lyric model in the Figma application could perform the extrication exercise on the vehicle but were guided by experts from Hurst Extrication Tools. User feedback was provided, yet critical decisions were not based on information provided by the application. All members that reviewed the Figma application created by Sukh Singh from the Berkley Disaster Lab were extrication experts with no prior experience or knowledge of EV hazards.

E. TEST 5: A-B TESTING OF FD MOBILE APPLICATION

- Setting: FDNY extrication training unit, Randall's Island
- Question: Using alternative options to guide application use tests will measure functionality quantitively and qualitatively
- Process: Timed functional testing measuring: intuitiveness, the overall time to achieve desired information, and ability of responders to use on scene followed by a questionnaire

The iterative testing of the FDNY application is incomplete and ongoing. The finding has again indicated that the pdf format used by the majority of manufacturers is not the best choice for building an application that can be easily formatted to quickly communicate data.

Changing the look and user interface is complicated because the data sets' delivery format is essentially an image. A standardized jpeg or other digital formats could potentially benefit the Rescue data sheets in the future development of an application and should be considered further.

F. WHAT THE TESTS DID NOT COVER

The tests did not act as A-B comparative testing. The goal was not to see the fastest method of information delivery. The experiments helped validate the following:

- the need for information sharing
- mobile/ web application ability to deliver needed info
- the functionality of use in the field setting
- potential for members to accept/ adopt the technology

The experiments were not designed to perfect or enhance the application's efficiency. The goal was to evaluate the benefit before an application's costly and time-consuming production.

G. SUMMARY

During the FDNY pretotype test, both presumptions were tested and validated with minimal financial commitment or effort. Within weeks of adding a hyperlink icon on FDNY iPads with no associated rollout notifications to units, an assigned Lieutenant responded with an email to the training unit. This email demonstrates that our target end users are searching for this specific information and that our application was a match for their needs. The icon would have been the simplest solution, but the link to the application presented flaws. The NYC FD pretotype test solution lacked usability in areas without

wireless internet access and reliability (NFPA does not keep a current and complete catalog of vehicles). The NFPA catalog was incomplete and outdated since 2019 due to many factors, including budget and lack of regulation forcing manufacturers to produce and submit documents. As a result, future dependence on the product was uncertain; even though the NFPA's catalog is cited widely as the catalog for EV documents, it is hosted by a private corporation and does not receive funding for the effort.

We further tested these ideas and realized the possibility and practicality for firefighters to use this technology at the scene of an accident.

The application showed potential further benefits when dealing with autonomous self-driving vehicles, with the potential to provide directives to first and second responders. First responders may be approaching a vehicle with no driver or human representative for the vehicles, and it may not be intuitive how to open the vehicle or mitigate an emergency. Potential hazards or SOP will not be known by police and fire departments, and a step-by-step process available in ERG or QRG format will aid in interactions. Numerous subject matter experts involved in the General Motors training session expressed concern about the need for available directives before encounters in the field.

The most significant concern for the FDNY working group entering the project was the possibility of electrocution by a first responder or civilian at the scene of an accident. The research showed that there had been zero reported cases of a first responder fatality by electrocution with an EV at an emergency scene. On the other hand, dozens of reported cases included injuries of civilians and first responders caused by the unexpected movement of an EV, including the noteworthy incident of an FDNY firefighter in Manhattan on July 17, 2022. The vehicle in Figure 13, courtesy of the *NY Post*, is a BMW x5 e45.[62] The "e" signifies an electric drive motor that, when in standby mode, is silent; possibly giving the responders the idea that the vehicle is not on. With high torque, a vehicle can go from a complete silent stop to moving in fractions of a second. The learned knowledge from the research will influence the application development. It would be

[62] Joe Marino, Kyle Schnitzer, and David Meyer, "NYC Firefighter's Leg Crushed When SUV Tips over after Crash," *New York Post*, July 17, 2022, https://nypost.com/2022/07/17/nyc-firefighters-leg-crushed-when-suv-tips-over-after-crash/.

prudent to include a disclaimer or warning that even though high voltage is potentially deadly, responders must still be aware and prepare for unexpected vehicle movement. While we are all worried about the low probability of high-risk events, preparing for the high possibility of potentially high-risk events is prudent.

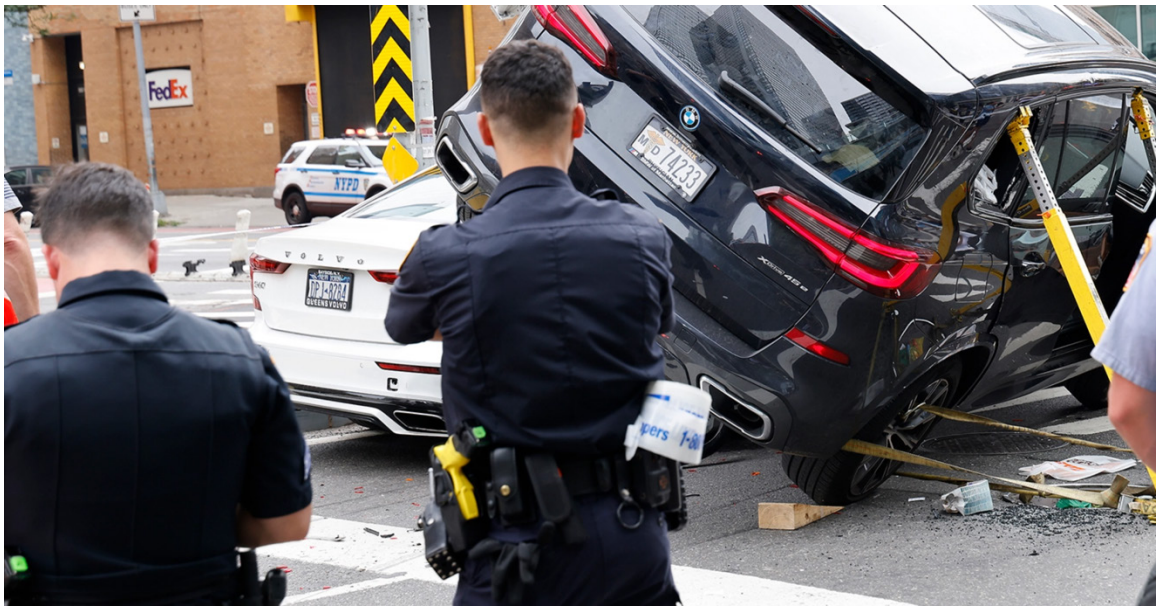


Figure 13. Accident involving an EV[63]

Through conversations with other departments worldwide and country, it is evident that an application with the capability to share directives is highly desired. Still, other potential tools could be added to the interface.

Our testing revealed key findings and confirmed our hypotheses. The testing proved there is a knowledge gap, and members currently look for a solution. The testing showed that a technological solution can fit the needs. The absolute lack of knowledge and use of ERGs is a concern; steps will be taken to address this oversight immediately. The application may have a much greater impact than expected and can be used on more than just EVs. The potential for the application to include technology outside the ability of the departments may be necessary and should be researched. Many manufacturers are working

63 Marino, Schnitzer, and Meyer.

on solutions individually. Testing indicated users will have a further need for supplemental application functions, and this must be evaluated further. Further evaluation of formatting for the rescue documents must be considered as other file types, such as jpeg, may be better suited to be the medium to communicate the content rather than PDF.

The testing confirmed the potential for application success and brought insight that will impact application creation. A lean methodology proved greatly beneficial and will continue to be used in the development of the application. Feedback on the effort to address the knowledge gap validated the need for more attention to this medium.

Continued efforts in regulatory reform and input must be pursued. The application must be developed and tested to produce a product that will provide life-saving benefits. The connections developed through the research must be fostered to find benefits.

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V. IMPLEMENTATION PLAN

A. STAKEHOLDER ANALYSIS

The creation of the mobile application started with an evaluation of stakeholders. The primary stakeholders are the auto manufacturers, the governing bodies, the end users of the EVs, the media, and first responders across the U.S. Considerations for these groups produce three value propositions. First, the application would benefit manufacturers by limiting liability. Secondly, the application would benefit the government and the public by improving safety for the occupant. Third, the application will make interactions between first responders and EVs safer. Considering EV safety and potential hazards within the vehicle, a functional web-based application has a value proposition for each group. The values found to be inherent to manufacturers were the benefit of limiting liability and improved communication channels. The added benefit to the first responder and end-user or occupant was enhanced safety. Another potential value for government and regulators is that this app could add a mechanism for reporting irregularities found in the field during emergency responses. If the production of the application is successful, the stakeholders will benefit from the developments but in different ways. The cost of not having the application available to first responders could be immense. Every vehicle incident involving EVs is under tremendous scrutiny. Every extra second a fire burns inside a vehicle battery adds risk. A potential fatality through electrocution of an occupant or first responder would be highly detrimental; having proper procedures known by occupants and responders will be crucial until all manufacturers use a standardized format.

The application would help auto manufacturers impart specific instructions for operations on the different technology; this will minimize damage to vehicles during the response from first and second responders, potentially improving customer experience. The proper technique applied to emergency response can mitigate danger to responders limiting liability from manufacturers.

Governing bodies can benefit from a central storage application for first responders because an application can be flexible and keep pace with changes in the industry. This

flexibility will allow emergency procedures to adapt to new challenges while regulation catches up. As the advancement of automotive technology continues, it is difficult for regulatory bodies to produce prudent regulation. The causes for this gap can be attributed to a lack of technical insight or knowledge of emerging products. The struggle of code to stay current with emerging fields is known as a pacing problem; it is present in all areas and is unavoidable.[64] It is not unusual for technology to outpace regulation, and if fields are over-regulated, then " regulations may inhibit socially beneficial innovations."[65] With time and the continuation of evolution, regulation may standardize the placement of high-hazard components or mitigate potentially dangerous situations; until then, first responders will rely on the application produced by this endeavor.

Rescue documents are one of the most practical ways to handle the challenge of the growing knowledge gap. Battery technology evolves quickly, usually quicker than first responders update operating procedures. The solution of informing occupants and responders of hazards and protocols must be agile, as the problem space will change quickly for the next few decades.[66] Departments must transition to a flexible strategy using ERGs, QRGs, and new rescue documents for specific tactics. Referencing rescue documents in emergencies can inform first responders of unknown dangers from new technology. These documents need to be available before rescue products come to market. The progression of batteries will continue to evolve; voltages will get higher, and demand for quicker charging will move energy into batteries faster. The hazards are going to increase.

A mechanism should be put in place that prevents new dangers from entering the marketplace without providing insight for first responders. Regulating mandatory rescue sheets before products come to market and making them readily available can help

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64 Gary Elvin Marchant, Braden R. Allenby, and Joseph R. Herkert, *Growing Gap between Emerging Technologies and Legal-Ethical Oversight: The Pacing Problem*, International Library of Ethics, Law and Technology, v. 7 (New York: Springer, 2011), 3.

65 Mark Fenwick, Wulf A. Kaal, and Erik P. M. Vermeulen, "Regulation Tomorrow: What Happens When Technology Is Faster Than the Law?," *SSRN Electronic Journal*, 2016, 569, https://doi.org/10.2139/ssrn.2834531.

66 Sangwook
Electric Vehicles," *Energy Technology* 10, no. 8 (August 2022): ii, https://doi.org/10.1002/ente.202200303.

responders operate on a vehicle safely and proficiently. I recommend regulation to solve this problem.

B. SOLUTIONS

Web-based applications from Europe and Australia provide example solutions that offer insight to first responders, allowing them to operate at emergency scenes safely. A mobile database with downloadable schematics enables first responders to operate on a basic set of SOPs and use the insight of the design of each vehicle to assist and protect first responders. The question is not what is needed but how this database can be implemented. The three possible methods of implementation that have been identified as viable solutions are private enterprise solution, government action, and public-private partnerships. Each model's advantages and disadvantages are as follows.

1. Private Enterprise Solutions

Private enterprise solutions for the endeavor are usually among the first considered as they allow for maximum control and the quickest time for results. The downside is the solution needs to be profit based, as the NFPA showed in 2013 when they partnered with Moditech to make an application for first responders to view ERGs and Rescue Sheets for a subscription fee. The effort failed, and the NFPA abandoned the application solution as the application came with a high cost, and updating the rescue documents was too labor-intensive. The reasons for the failure are obvious with hindsight, but they should be considered with market's landscape changes.

While most first responders did not know about ERGs and Rescue Sheets in 2013, many now look for the documents as electric and alternative-fueled vehicles' presence on our roadways show increase in the past decade. In 2013, the rescue documents did not provide the same level of information they did in 2022. For instance, each manufacturer produced documents ranging from four to one hundred pages containing whatever information felt essential to that individual manufacturer and put it in whatever order each found useful. The variations in the documents made them extremely hard to use at the scene of an emergency.

The international organization for standards (ISO) produced ISO 17840 to streamline the use of safety documents for vehicles. ISO 17840 is referenced in numerous safety reports on EVs, including the 2020 report by NTSB citing the need for uniformity in rescue documents.[67] ISO 17840-compliant documents are now becoming the norm.[68] Rescue documents now carry much more utility, and their value is more widely known, possibly changing the value proposition for private enterprises. With 20 manufacturers making significant advancements in their rescue documents, the rescue sheets are now a vital resource for first responders.[69]

While the NFPA effort to create a mobile application was scrapped only two years into production, three factors led to the failure of the application; cost, consistency of the documents, and public knowledge of the resource. Application production and maintenance were expensive in 2013. Current prices for something that can perform the same task sought after in the NFPA's 2013 endeavor have been quoted at around $20,000 for an application designer to produce.[70] A web-based platform not available on the app store, such as a PWA, can run a lower cost of $2,000 for construction. The emergency response guides ranged from three to over fifty pages and had varying designs and styles. QRG and ERG documents mostly follow a basic format: a normal QRG is around four pages and easy to navigate. Around 50% of the SMEs who participated in the testing done in this thesis did not know about an ERG or QRG until the testing; in 2013, even fewer were aware of this resource. The continuous updating of models and variants is still a consideration moving forward. The for-profit model has shown challenges in the previous effort, but flexibility and adaptability may be the best solution.

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[67] National Transportation Safety Board, *Safety Risks to Emergency Responders*, ?

[68] Ryan Woodward, "Electric Vehicle Manufacturers Are Improving Emergency Response Guidance for Fighting Lithium-Ion Battery Fires Per NTSB Recommendation," *IAFC Blog* (blog), June 8, 2022, 1, https://www.iafc.org/blogs/blog/iafc/2022/06/08/electric-vehicle-manufacturers-are-improving-emergency-response-guidance-for-fighting-lithium-ion-battery-fires-per-ntsb-recommendation.

[69] Woodward, "Electric Vehicle Manufacturers."

[70] Sukh Singh, Mobile Application Expert Interview with Sukh Singh from the Berkley Disaster Lab, interview by Evan Balcombe, Microsoft Teams, June 28, 2022.

2. Government Solutions

Bureaucracy can stifle progress to the point that solutions do not keep pace with the issues. The most significant variant between the previous options and the public/ government model is the considerable production time when dealing with the government. While application design in the private market is estimated at two to four weeks in production, the FDNY has adopted the idea and estimated their effort to take two years to bring to the market. When a small enterprise is involved in app design, it is easier to pivot and change direction during development. The government process takes far more time, effort, and consideration to get the idea into production. It required ten meetings over two months to move the project from an idea into consideration for the FDNY.

However, a government-based solution has potential benefits, including funding, resources, and future planning. The future process is considered in more detail during adoption in a government system. Funding and maintenance are considered for the system's life span, including system updates. The long-term plan can be projected and assigned to a group or team. Resources, including manpower and financial support, can be greater than they would be for a private enterprise startup. The stability of a government entity is more secure than private enterprise. The ability of the government effort to influence standards and adherence to standards is far superior to private enterprise.

3. Public Private Partnerships Solutions

Public-private partnership solutions also have good potential. The European and Australian models are based on private enterprise solutions. Both ANCAP and EuroNCAP are not-for-profit organizations that receive some government funding but are sustained by providing new car assessments. Consumers and government agencies base purchases on ratings, with some agencies having minimum standards scores to qualify for consideration for purchase. The influence a point deduction on a rating scale can have over car manufacturers is immense, bringing many ERG and rescue sheets up to standard worldwide.

The benefit of the private enterprise method connected with the new car assessment program is the influence that can help get compliance with manufacturers. EuroNCAP and

ANCAP used score incentives to achieve compliance with the international standard automobile schematic format, ISO 17840. Over five years, ANCAP went from advocating for proper ISO 17840 compliant rescue sheets to deducting points for noncompliant ERGs and Rescue Sheets supplied by the manufacturer. This incentive worked to get 80% compliance for the industry.[71] Similar testing bodies within the U.S. are IIHS and NHTSA, both providing similar but different 5-star crash test ratings. IIHS is a private corporation funded by insurance groups, and NHTSA is a government entity under the DOT umbrella. NHTSA and IIHS have shown zero interest in engaging in an application or web-based vehicle rescue document database but have massive potential for success if integrated into the solution network.

C. FINANCIAL RESOURCING

The financial cost of any solution will vary based on the exact solution selected and who implements it. The proposed solution of an online or web-based catalog of rescue sheets will evolve; future cost is unknown and can only be estimated. While web-based applications are convenient, the cost of production is greater than that of a PWA. If the production of the application is done by FDNY firefighters and officers, cost would be determined by the total amount of hours required to construct the supplication or site.

An ISO 17840 standard format simplifies the process for manufacturers and the online catalog host. Foreseen costs after production include updating the database continually as the rescue sheets are produced or changed. As the NFPA has found, manufacturers do not consistently update rescue sheets as they are created or updated. It is then up to the site owner or application host to update sheets. When new models are released to the market or rescue documents are updated, finding and replacing these sheets is incumbent. It will take significant time to update the database annually, and initial application construction can account for entry-level position tasks for the first year. As per seethroughny.net/patrols/ other computer specialists for the FDNY earned $133,000 in

[71] Australia New Car Assessment Program, "ANCAP Rescue Apps"; ANCAP Safety, *Australasian New Car Assessment Program (ANCAP) Testing and Assessment Protocol – Rescue, Extrication and Safety*, V 2.0 (Manuka ACT, Australia: ANCAP, 2021), https://s3.amazonaws.com/cdn.ancap.com.au/app/public/assets/34fd4d90273c043553b5e59c54dcf0e189a7845a/original.pdf?1633069898.

2022. The initial cost in the project's first year can be estimated at $133,000 if a specialized programmer is needed to see the project's fruition. After the initial stages, the tasks could account for 25% of a regular workload, so the initial cost following years can be calculated at $33,250 (1/4 salary for the position). Grants through the Federal Government's green initiative will be explored.

The three stakeholder groups here may consider the financial cost of this endeavor differently, and their buy-in and motivation are different. The stakeholders can be broken down into three categories; auto manufacturers, government and regulating bodies, and civilians and first responders. The project's funding may come from a combination of options, including government grants, manufacturer incentives, fees structured into the purchase, or for-profit monetization of the information by advertisers to first responders. All options need evaluation, and consideration should remain focused to not retard or single out EVs and cause adverse market effects.

For manufacturers, the cost of negative publicity from first responders' delays and inadequate hazard mitigation can harm future profits. Moreover, the potential downside incurred with a fatality from lack of product knowledge could be legally costly, in addition to the negative public perception. The project's cost can also appear as valuable when the potential liabilities are considered. Considering the possible reputation and financial cost savings that come with mitigating these liabilities, the program can provide a positive ROI, or, return on investment.

First responders and governing bodies can be grouped together when considering the cost. Aid to either is mutually beneficial to public safety. An effort to provide a data-sharing site that benefits the general population and reduces the liability of reputational loss removes the liability of not acting competently and prudently in handling EV hazards for the public. Beyond the organizational reputation, investing in an online application is prudent when considering human life. Mitigating liability and protecting life show that investment in an online catalog will have a good ROI.[72] The federal government plans to

[72] David Shepardson, "New York State to Adopt California 2035 EV Rules," *Reuters*, September 29, 2022, https://www.reuters.com/business/autos-transportation/new-york-state-adopt-california-2035-ev-rules-2022-09-29/.

end the purchase of gas-powered vehicles by 2035 under an executive order by President Biden.[73] California and New York introduced regulations that all light-duty vehicles purchased in-state must be electric by 2035. Other states plan to follow New York and California. Therefore, an increasing number of vehicular incidents nationwide will involve EVs within ten years. The hazard mitigation considerations far outweigh the effort and cost of prevention taken now.

Showing the potential cost of enhancing first responder knowledge benefits manufacturers and government/ first responders. The research has indicated that a public-private partnership (PPP) should be pursued. The argument should be made that a mutually beneficial relationship between the government and private enterprise can be achieved.

D. EXPECTED CHANGE/IMPACT AND COMMUNICATION PLAN

Reasonable expectations of the positive effects of the application can be judged with the rollout within the FDNY before the application is brought to the national level. The application would need an associated performance and communication plan.

After the application is in production, the intent is to share this innovation nationally by using social media and other sources to advertise the tool with minimal cost and use force multipliers with minimal effort. Using my professional social media sites profiles on LinkedIn, Twitter, and Facebook, I plan to share articles and short videos presenting the progress of the ERG sharing application. The FDNY social media presence will be utilized to present the application and can generate positive press for the civilian back-of-house staff that rarely gets recognized for their hard work. The application would be free to users, provided it finds the correct market fit. Other avenues to share the application include all auto manufacturers that have ERG and QRG rescue documents on the site. This news from the manufacturers would show the safety documents to the public, hopefully providing positive publicity for the industry. Professional conferences would be a great place to share information; these conferences usually allow speakers to share recent

[73] David Shepardson and Ben Klayman, "U.S. Government to End Gas-Powered Vehicle Purchases by 2035 under Biden Order," Reuters, December 8, 2021, https://www.reuters.com/world/us/biden-pledges-end-gas-powered-federal-vehicle-purchases-by-2035-2021-12-08/.

innovations in the field of hazard mitigation. The UNGTR committee and the Department of Transportation could be solid partners in spreading the message of the application's potential to the driving public of the country.

Potential communication avenues considered are the following:

- Social media
- Online chat forums
- Magazines and other educational journals on firefighting and automobiles
- Through the NFPA
- An online accreditation course to unlock the potential ERG and RDS catalog
- National TV commercials advertising the positive effort of manufactures

The FDNY has an office of public relations led by the PIO (Public Information Officer) and led by the strategic planning group at FDNY operations. The PIO has connections to all media outlets and has offered aid in disseminating material through local and national media outlets.

E. OBSTACLES

The application aims to promote the many benefits of a uniform rescue sheet compliant with ISO 17840. While this benefits passengers, it is important to consider first responders, and manufacturers, associated costs, and hardships. There will be a cost for the effort, and someone will have to foot the bill. The cost associated with ERG production and distribution can be forced on manufacturers by regulating mandatory involvement, or the burden can be placed on the EV consumer in fees or a tax. Potential challenges include regulators, manufacturers, taxpayers, green energy lobbyists, and first responders.

While influencing regulation is a long-term process that takes staying power, it will also require the ability to work with different stakeholders. To better understand the regulatory process and stakeholders involved, I attended the United Nations General

Technical Regulations committee meeting on EVs in December 2022 (EV25). The participants included global auto manufacturers, national transportation representatives from many countries, including DOT and NHTSA, other government representatives, individual research organizations, battery manufacturers, and myself as a first responder. The process of creating regulation that represents the interests of all parties is a delicate balance.

Trying to create a safer environment around EV emergencies can have negative consequences. While highlighting the potential dangers of battery-operated vehicles, it can give the false impression that electric cars are more dangerous than ICE vehicles. That is not true; from 2012 to 2021, Teslas were 11 times less likely than ICE vehicles to catch fire per mile driven.[74] While EV fires are less frequent than fires in ICE vehicles, they tend to be more complicated fire to extinguish, requiring more water and time to fight and extinguish. First responders need to know the type of vehicle and have considered labeling EVs with external badging to understand the dangers inside. External badging on an EV could cause a negative stigma and drive potential customers away. It would be unfair to single out just EVs, while ICE vehicles are proven to be more prone to incidents. Regulations targeting EVs can harm public support and hamper the safety progression of the technology.

Considering the incurred cost is crucial since auto manufacturers must commit to developing ISO 17840-compliant rescue sheets. With the benefits listed previously in this work, the ROI should be enough to incentivize the investment. With this in mind, requirements for creating rescue sheets should remain simple and non-labor intensive. The burden of taxpayer funding the application can be a potential friction point. Keeping costs reasonable will mitigate some of this potential difficulty. For this reason, I have joined the SAE first responder task force that creates recommendations for ISO 17840.

[74] Mark Kane, "Statistically, Tesla Car Fires Are Less And Less Frequent," *InsideEVs*, May 9, 2022, https://insideevs.com/news/584722/tesla-car-fires-statistic-2021/; William Davis, "Tesla Electric Cars Less Likely to Catch Fire than Petrol Cars – Report," *Drive*, August 24, 2021, https://www.drive.com.au/news/tesla-electric-cars-less-likely-to-catch-fire-than-internal-combustion-alternatives-report/.

F. TIMELINE

The timeline for constructing a functional application depends on a few variables: the producer, testing, and rollout of the product. According to estimates from Sukh Singh from Berkeley Disaster Lab, the timeline for the application creation can be as quick as two weeks. The estimated rough timeline from the New York Fire Department is approximately two years. The FDNY currently faces staffing shortages in the application designer positions and has a backlog of applications in the intake and development phases. After development, the safety precaution and back-end security features can take six months after production because of the number of other applications on the same internal network that present security concerns. Following the application production, internal testing and rollout within the FDNY will take six months to one year. It takes approximately two months to cover the entire 25-group working chart through an integrated training schedule that addresses numerous topics over time. Using previous rollouts of new technology to gauge the timeline gives a rough estimate of the six months on the low end with no difficulties.

Preventing a premature product launch is essential. First responders typically dislike two things: change and the way things are. First responders operate in life-threatening environments at every call. The tools and remedies used to solve problems must work every time to be considered viable. Research has demonstrated the web-based application delivery method as a timesaving and effective tool, but user acceptance in the fire service can be a challenge. The rollout must consider the low acceptance rate of technological solutions from first responders accustomed to classic physical solutions, such as guidelines printed on paper. According to the Rogers' Diffusion of Innovation Theory, the second hurdle to overcome in innovation is compatibility.[75] As technology can be very far from what the fire service community is comfortable with, and to account for the possible compatibility gap, the complexity must be low and have an intuitive nature to it.

[75] Wayne W. LaMorte, "Diffusion of Innovation Theory," Behavioral Change Models, accessed March 13, 2023, https://sphweb.bumc.bu.edu/otlt/mph-modules/sb/behavioralchangetheories/behavioralchangetheories4.html.

To ensure these issues are not overlooked, the testing phase is critical and must not be rushed.

G. ACTIONS TO SUSTAIN THE INITIATIVE PLUS LONG-TERM MAINTENANCE

Evaluations should be conducted to determine the best model for a long-term sustained initiative. Applications for grant funding for the application production must be submitted within the fiscal year and will ensure the burden of creation does not fall on the FDNY. After production, maintenance and updating require continued funding. I propose manufacturers and owners carry the cost, as $1 per car purchase sustains the initiative indefinitely. With almost 1 million EVs sold in the U.S. in 2022, a $0.50 tax would create a generous budget for safety initiatives, including rescue document sourcing, management, and distribution. The initiative is financially viable if manufacturers carry the cost of rescue sheet production, and tax revenue generates funds for rescue sheet management and further research and training.

The cost of application maintenance is only half of the endeavor. The application's backbone is built on adhering to ISO standards and continued rescue sheet production. The logical next step is regulation to produce standardized ISO 17840-compliant ERGs from all manufacturers to enhance the functionality of an application. The product's reliability is a critical factor. Emergency response tools risk losing credibility if they are not functional at every accident with every model. Part of this funding package should include support for a first responder advocate to permanently sit on the UNGTR committee for EVs.

H. POLICY EVALUATION AND REVISION

The application should be monitored at increased increments using the OODA loop process. Early in the rollout process, during the first four weeks, evaluation and user feedback must be gauged daily to ensure the technology is filling the information gap currently created by the market. After the first month, the working group, including two FDNY Firefighters, two FDNY Lieutenants, two FDNY Captains, and the application designers must meet to evaluate feedback from post-use incident surveys. In addition, the

training rollout will include feedback from users in the field to assess the product's performance.

After a six-month trial in the FDNY, the product will expand nationally. Again, the first month will have a complete working group monitoring daily. The following year, working group members will meet monthly to follow the application's performance. The primary metric the working group will use to evaluate application performance is mandatory survey feedback through the application platform. A standardized schedule for the working group to review feedback will be implemented, possibly of increasing or decreasing the meeting frequency as feedback informs future decisions. Extending the feedback process will allow for application evolution, but the case of an increased workload from feedback must be considered.

I. REGULATIONS

Mandates and regulations for all vehicles have not kept pace with today's technology. EVs complicate this scenario by bringing the boundaries of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) into question. Since vehicles are made around the world and sold in all markets possible, multiple global governing authorities create further difficulties for first responders to know what to expect. Influencing regulation can become complex and take long periods of time before enacted regulation becomes progress. The two main regulatory processes for certifying cars outside of China are the European Union and the United Nations Regulation methods.

The EU method of European Community Whole Vehicle Type Approval (ECWTVA) uses a whole vehicle approval. The vehicle is evaluated as a sum of its parts. Once all approved systems and components are approved, the vehicle will be tested as a representative for its "type," make, and model.[76] The EU method takes U.N. regulation into consideration but is its own approval system used mainly in Europe.

[76] Vehicle Certification Agency, "European Community Whole Vehicle Type Approval (ECWVTA)," Vehicle Certification Agency, accessed February 4, 2023, https://www.vehicle-certification-agency.gov.uk/.

The U.N. is broken into two separate methods: the U.N. agreement of 1958 and the United Nations Global Technical Regulation (UNGTR) established under the U.N. 1998 agreement. The difference is that the U.N. and UNGTR have no whole vehicle approval system. Parts and systems are approved as individual units, then put together to create a vehicle. The vehicle is not approved as one unit but approved in subcategories, for instance, braking, noise, and emissions.[77] The U.S. does not directly enforce U.N. standards, but the U.S. approval system has auto manufacturers self-certify that the automobile and its parts individually meet all federal standards and regulations, whereas the European method tests and certifies the vehicles as whole vehicles.[78] As the U.S. is a contracting party of the UNGTR (U.N. 1998 agreement), we here in the U.S. are affected most by the recommendations laid out by the UNGTR.

The federal standard in the U.S. does recognize the society of automotive engineers (SAE) and their documents, including the SAE-J2990 surface vehicle information report. The SAE produces documents with suggestions for manufacturers to follow, but they are not required standards unless adopted and become regulation. Standards and regulations both help influence a positive effect on the safety of first responders.

While internal combustion engines are still the majority of calls of first responders and the majority of vehicles that regulators oversee, the transition is likely to change quickly as the world transitions away from petroleum-fueled mobility devices.

Regulation is an essential part of enforcing best practices. As ISO 17840 evolves, it should be cited and required by regulation. The expectation is that an evolving uniformed rescue documents will aid in first responder adoption. Fire responders using these documents will provide funding for the development and maintenance of an online catalog for rescue documents. The potential problem with inconsistent documents is the loss of user confidence that comes with application inconsistency. Subject matter experts in our tests reported a lack of reliance on products that are not 100% effective in emergencies, meaning if a first responder is unable to locate necessary documentation at the scene of an

[77] Visvikis, "Safety Considerations for Electric Vehicles and Regulatory Activities," 2.

[78] Visvikis, 2.

EV emergency, it may be the last time they attempt to use the application as an aid to their efforts. Considering this, it is essential to have all EV rescue documents up to date and available for every model. Without NHTSA participating in an incentive program involving the 5-star crash test rating system, a regulation requiring ISO 17840 compliant documents before EVs are on the road in the U.S. may be the best option to ensure the success of this application.

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VI. CONCLUSION

This thesis served to educate emergency responders and developed a functional application for safe responses to crises. This chapter summarizes this thesis's notable findings and provides crucial guidance for future research in this area. The first section summarizes the benefits of lean and agile methodology versus classic waterfall design. The next section communicates the lessons learned from the interactions. Finally, the third section breaks down the recommendations from here.

A. LEAN AND AGILE DEVELOPMENT VS. WATERFALL DESIGN

Due to the emergent nature of this problem, lean and agile testing proved beneficial because it allowed the researchers to identify and implement a functional solution efficiently. As we advance, this would be a suitable method for public service professionals to use. The ability to pivot without much money or effort significantly benefits the FDNY and other departments. It is easy to make a personal connection to a product or action that members are testing and then champion the success of the product rather than performing an actual valid evaluation of a product. Agile testing and production can help departments across the country avoid the pitfall of considerable investments of unnecessary money and effort, often linked to waterfall design. In lean and agile development, the objective is to allow the iterative process to direct progress from validated or learned information rather than building a complete model based on biased or incorrect beliefs only to have a product that would never solve the pain points.

Application of the primary and intuitive lessons from our tests brought many positive course corrections. The iterative process informed our application production. The visit to Vance, Alabama, introduced our team to the idea of a PWA. The progressive web application allowed us to look for a web design instead of an application designer. As explained, the production of each is similar. Still, web design allows for cross-platform application, and application design usually lends itself to mobile device use with platform-

specific design.[79] We used the web design format, allowing us to look within the FDNY and find firefighters and fire officers with previous experience with website design, thus sticking to our agile methodology. While looking for an app designer, the prices and estimates went from $10,000 upwards, compared to website design that starts at hundreds of dollars.

Researchers implemented the lean and agile methodology through a hands-on approach in action research to find solutions through various trials. As the quote from Steve Blank goes, "There are no facts inside the building, so get the hell outside."[80] Getting outside the building and meeting people by going to UNGTR meetings, joining SAE regulatory working groups, going to the manufacturers, and talking with members from ANCAP created unexpected benefits. The connections the FDNY now has is fostering ideas and creating new pathways to collaborate and find potential solutions to the much larger complex issue of emergency responders keeping pace with the technological evolution in private enterprise. The connections made have placed fire service members in integral positions that will hopefully provide solutions to future problems.

B. LESSONS LEARNED

Progress on the FDNY application currently moves swiftly. The positive outcomes resulting from the addition of the icon to department mobile tablets are generating support for increased efforts and resources from the department. A PWA, as seen at the Mercedes-Benz testing site in Vance, Alabama, proves to be the fastest solution to the problem. The FDNY has allocated the digital space for a PWA and will be using the web address guidebooks.fdny.org/evds-pwa/. As of February 11, 2023, the FDNY application has more models than the NFPA web-based catalog and is functioning as a downloadable catalog. The added feature of the downloading capabilities of the catalog on mobile devices gives firefighters the added benefit of using the information when cellular service is not

[79] Priya Pedamkar, "Software Development vs. Web Development," *EDUCBA* (blog), June 9, 2018, https://www.educba.com/software-development-vs-web-development/.

[80] AJ Brustein, "Try 'Walking The Path' To Solve Your Startup Problems," *Forbes*, October 27, 2015, https://www.forbes.com/sites/theyec/2015/10/27/try-walking-the-path-to-solve-your-startup-problems/.

available. This early-stage mobile application is showing potential to deliver information to firefighters at accident scenes.

The key realization is that nine of nine subject matter experts questioned had not seen an ERG, QRG, or RDS. This information is currently being acted on as the FDNY produces a Tips From Training letter to share with the members. The bulletin will promote the use of rescue documents to utilize one of the best tools available to help first responders understand the dangers of EVs and bridge the current knowledge gap.

The lessons from experiences in the field have shaped the direction of the application. Through testing, the lessons were studied and built upon in further iterative testing. To minimize waste, this research aimed to evaluate what was within our control. For this reason, working within our circle of influence rather than our circle of concern was paramount. This research offered many insights into problems beyond this paper's scope. While these findings do not directly connect to our research question, the information will be useful and implemented in future efforts.

1. EV Recommendations

- Firefighters want quick identifiers on the outside of the car.
- Firefighters want quick access to the battery compartment via an FD connection for adding water into the batteries in case of an emergency. This idea is presented in two different ways:
- A fire department hose connection that firefighters could use to pump water into the battery; this access could possibly have a meltaway plug that would only allow water in after the battery had gone into thermal runaway and increased in temperature.
- A melt-away floor pan that, when heated, would allow firefighters to add water into the car and essentially fill it like a bathtub, preventing thermal runaway.

While both ideas may have merit, car, battery design, and immediate regulation were out of our control. It was prudent to have these discussions and document findings to use in future research.

It was apparent that the identification of vehicles in an emergency response is an issue for members, and this could be resolved in a number of ways.

2. External Identifiers Mandated on Cars

- Badging required on cars (stickers, emblems, insignias, antennas of distinct shape)
- Color coding
- Lights placed in designated areas
- License plate identifiers
- Bluetooth frequency signal transmitters

While these challenges are real, there are a few problems here. Firefighters do not write regulations and cannot mandate safety procedures upon manufacturers. Additionally, it became apparent at the UNGTR EV25 that any regulation implemented on EVs must be careful not to create an unfair market that punishes or requires extra cost placed on EVs that is not placed on classic ICE vehicles. Many of the solutions to the problem come with a cost, and to mandate extra costs on a manufacturer will slow the evolution of the technology. If the evolution of regulation strangles the market and stagnates progress, then this effort does a disservice to the community.

As the data shows, EVs are safer than ICE vehicles. With the tendency to focus on the negatives of new technologies, EVs have quickly been associated with a fear of fires. This fear is due to the nature of the fires in Lithium-ion batteries being stubborn, and firefighters:

- Lacking the correct tools to extinguish them
- Lacking basic knowledge of the vehicles

- Lacking directives on the technology
- Lacking experience with these incidents because there are so few incidents with them

To avoid adding to the negative stigma associated with EVs, it is always important to clarify that the intent is to be better informed and not add to the unrealistic fear of this new technology.

3. Recommendations for Application Production

When evaluating potential needs for future funding and effort, there are two apparent options: PPP and regulatory requirements. Future considerations would include maintenance, upkeep, and responsibility. While website or web application maintenance is critical, another essential factor is the continued production and use of the documents for emergency response. A combined effort of PPP and regulation enhances the outcome of both considerations. Future costs are unknown and need further research.

The UNGTR EV committee informed me that regulating these subjects is possible but will take time. I plan to continue to participate in EVS meetings and advocate for the requirement for ISO 17840-compliant documentation before vehicle models are brought to market in the U.S. Future additions to the UNGTR will work toward safer EV performance and post-crash response. The ability to get first responder feedback on the evaluation may aid in regulatory support for Rescue Documents and aid grant funding for an online catalog of rescue documents.

The other available option of working to bring together first responders and vehicle manufacturers is a viable option that is ripe for production. EVs are already under exaggerated scrutiny for every incident; every EV fire has the potential to make front-page news. EV fires are less likely to happen, but when they do, they present a more complicated situation.[81] With the potential reputational liability at every EV, emergency manufacturers

[81] Andrew Evers and Lora Kolodny, "Electric Vehicle Fires Are Rare, but Hard to Fight — Here's Why," *CNBC*, January 29, 2022, https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html.

have a vested interest in first responder success in every emergency. Besides these motivating factors, first responders working closely with manufacturers may provide manufacturers with better insight into emergency response details aiding in future innovations in the automobile-manufacturing industry. Creating a formal public-private partnership with manufacturers could be the mechanism that helps first and second responders stay informed in the future.

It is my recommendation that NHTSA takes control of a central rescue document hosting site. This site could maintain a full catalog of EV documents. The benefit of a hosting site by the NHTSA includes the following:

- Mandated submission of a 17840 compliant catalog before vehicles are sold in the U.S.
- Penalties can be imposed by the 5-star crash test rating system.
- Funding for the site is guaranteed for the future.
- Free access for departments across the country.
- Sharing of information the DOT and NHTSA are privy to, from investigations of after-accident investigations.

This is a national problem, not one exclusive to a single city or state. A national solution would be the best fit for a national problem.

Future iterations of an ERG delivery device should consider integrating:

- QR codes.
- All models of vehicles on the road, including gas and diesel vehicles
- The PWA concept
- Instant identifiers if models do not have shutoffs in ERG
- Bluetooth connectivity
- OnStar connections

- External battery temperature indicators
- Bluetooth BMS connectivity for first responders

C. THE FDNY'S PATH TO APPLICATION PRODUCTION

The FDNY has approved and adopted an in-house solution to this problem. Using the NFPA web-based catalog proved the utility of a tool to support the evolution of responses to EVs.

Constraints of this solution may prove unwieldy. For a department the size of the FDNY to produce and host an in-house application, the question is whether added design layers impact production. It comes down to timing. Compared to an outside app designer's two to four week timeline, the FDNY technical team estimates production time to be between two and six months. The New York City Fire Department suffers from a personnel shortage in all units, including app designers. New York City's policy requiring members to attend work in-person has caused IT personnel to leave the department.[82] For instance, on Monday, September 26, 2022, four days after the application was considered for production and put on the "in-take" list for the FDNY, two application designers left the department. The department has frozen all non-essential development for the foreseeable future.

One of the considerations for funding development was grant funding. Efforts from the Berkeley Disaster Lab aided initial efforts when considering to build an application to share rescue data sheets. A stripped-down application was created using the Figma app building and testing website. The representative from the disaster lab estimated the application to cost around $20,000 and two to four weeks to produce.[83] In comparison, the $20,000 is far less than the amount it would cost NYC when factoring in payroll and time of employees. Future costs are unknown but should be researched further. One potential

[82] Chris Sommerfeldt, "Mayor Adams' Administration Sets Strict Return-to-Office Policy for NYC Workers: 'Hybrid Schedules of Any Kind Are Not Permitted,'" *New York Daily News*, June 1, 2022, https://www.nydailynews.com/news/politics/new-york-elections-government/ny-nyc-mayor-eric-adams-return-to-office-city-employees-memo-20220601-jhupsedtsfginnkdk7u5y55bgq-story.html.

[83] Sukh Singh, Mobile Application Expert Interview with Sukh Singh from the Berkley Disaster Lab.

solution is having external designers build the application and the FDNY aid in the testing of functionality; this solution would be contingent on funding which must be researched further.

Considerations for public-private partnerships would leverage the potential influence and standing the FDNY has within the community. A memorandum of understanding, or MOU, with GM, Ford, Mercedes, and Tesla to gain buy-in on a PPP should be researched. The idea for collaboration will present the need for an accessible central catalog of rescue information. Mercedes and Tesla recognize the need for uniform documentation but have yet to act on a solution for a central warehouse. Mercedes may have found a potential solution with the PWA that allows all devices to utilize a website-based application instead of an Appstore signature creation. The benefits of a PWA versus an application should be examined for viability.

While the FDNY is working to create a data housing distribution application, it would be prudent to engage in outreach with manufacturers to evaluate the willingness to fund a privately developed web-based application or PWA. The lack of restrictions that a private corporation operates under may foster the agility to navigate the process and pivot quickly enough to be profitable. The structure that has found success for the ANCAP Rescue and EuroNCAP Rescue applications is connected to the ability to influence purchases with crash test safety ratings.

Given the success of the ANCAP and EuroNCAP Rescue mobile application, I believe this would be the best template to follow. The application design and build are not considered an overwhelming task, but upkeep and operating costs after initial construction have been an issue in the past. From conversations with the NFPA representatives, ANCAP representatives, and NHTSA, the continuing operational responsibilities can become a burden if not correctly accounted for.[84] President Biden's 2023 fiscal year budget has

[84] On Wednesday August 10, 2022 I had a web conference with Rhianne Robson and James Hurnall from ANCAP to discuss their application process. I have consulted with an NFPA representative about the old ERG application and future interest in one. Through phone and in person conversations, representatives from NHTSA have expressed their stance on ERG housing and regulation.

allocated over $3.2 billion for clean energy infrastructure and transition to clean energy technology for government fleets, transit agencies, and associated infrastructure.

D. NEXT STEPS

This application offers a foundation to start solving the current problem firefighters face. The application uses the best available materials to produce a simple solution to inform firefighters of real dangers. It is envisioned that this application will be the start of many connections nationally between first responders, auto manufacturers, the NFPA, regulators, and other government entities. The ideal plan for the future that starts as this document finishes will be laid out in the next few paragraphs. This is a hypothetical plan. It must be noted that learning at any stage of the process may change the trajectory of the plan. Regardless of the path this endeavor takes, I am confident that there will be advancements in the safety of first responders and civilians from these efforts.

This documentation ends with the demonstration of the prototype to a high-ranking FDNY chief. The feedback on the production of the application was positive. Recently, some updates on FDNY mobile devices have caused the loss of the NFPA icon that allowed connection to the ERG catalog.

- The immediate effort is going into the replacement of the NFPA ERG icon for use in the field.
- Produce “Tips from Training” to allow members to better utilize ERGs

The next steps on the FDNY ERG application are as follows:

- Integrate the three remaining manufacturers that are not currently on the NFPA site and get communicate with manufacturers that have stopped submitting Rescue Sheets to NFPA.
- Get the prototype functional.
- Remove a few technical glitches.
- Check navigation buttons that are not present.

- Evaluate where site aesthetics are lacking.
- Determine what other selection pages and panes must be added.

The FDNY ERG application will move forward in a fairly standard process, passing milestones and moving to the next step.

(1) I plan to announce the FDNY application effort in my presentation on Electric Vehicle Challenges for The Fire Service, at the Li-Ion Battery Symposium that is being hosted by the District of Columbia Fire and EMS Department and Fire Safety Research Institute (FSRI) on March 30, 2023.

(2) After the prototype is flushed out, hopefully within a month, we would like to demo it at the extrication unit in training.

(3) After a successful demo at the FDNY training academy, the product will be assigned as a trial program to a few companies to trial its use in the field. This is a process the FDNY has in place and is called a pilot program.

(4) From there, the application will be used citywide by all units on their associated mobile devices. It is foreseen that there will be many more days of comparative testing and improvements to the ideas that are just in their infancy here.

(5) Lastly, the FDNY would like to introduce and share the application at an electric battery symposium held in NYC in the fall of 2024.

The work associated with the application has led to some fruitful conversations and partnerships with multiple auto manufacturers. The lithium-ion battery working group is considering hosting a symposium involving all battery vendors and users. The possible date for this event is September 2024; it would be exceptional to have a working EV ERG catalog housing application that is ready to be shared nationally at that time. Many of the conversations around the sharing of ERGs have revealed this is a common goal. Other vendors, departments, and agencies could be better suited to build and host an application rather than the FDNY. If any group can achieve this sooner than the FDNY, that is a positive. The goal is not to be the first that produces this but to have the ability to keep first responders safe. Any application that makes the responses to EVs safer will satisfy the aim of this thesis.

E. OVERALL

This study examined current EV knowledge to improve safety. The research found unexpected opportunities to help first and second responders. The secondary connection may prove more beneficial than the initial intended goal. This research provides the foundation for addressing the complex problem of the knowledge gap between emergency responders and evolving technology. This research can be used as an outline and roadmap to understand and develop safer and more efficient responses to EV-related emergencies.

Action Research allowed me to get out of the building and create connections and learn helpful information outside the scope of the paper. The connections made will continue to help firefighters operate safely when interacting with EVs. The new connections born from the work done here will help integrate first responder safety into future regulation and design.

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APPENDIX. SALES OF EVS

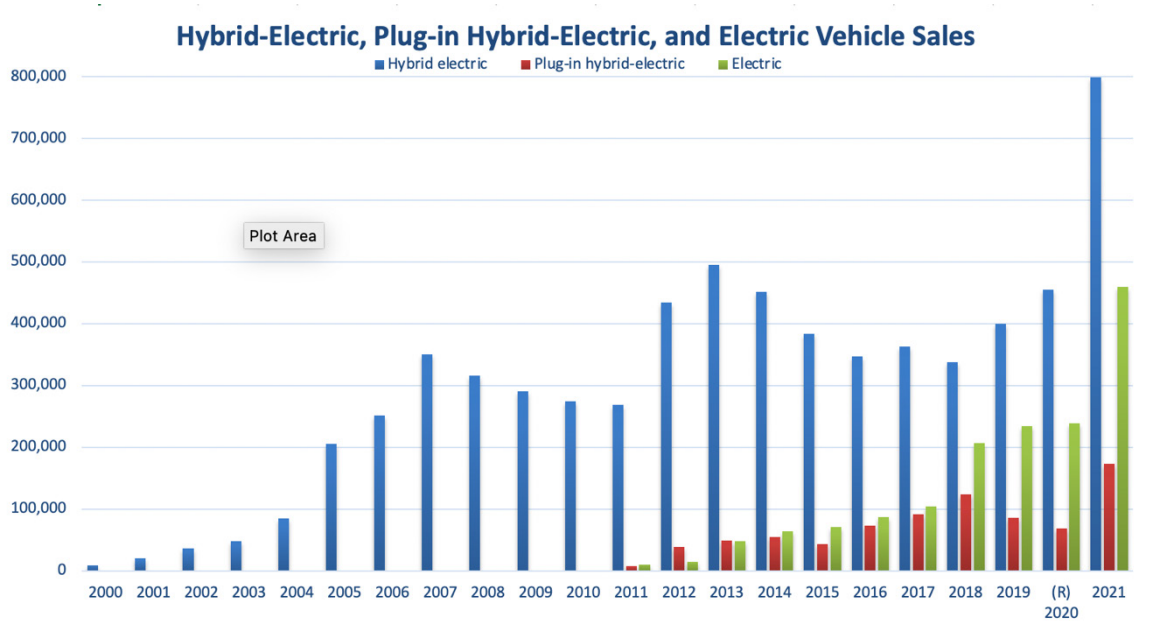

Figure 14. U.S. sales of EVs has steadily increased between 2000–2021[85]

[85] Bureau of Transportation Statistice, "Hybrid-Electric, Plug-in Hybrid-Electric and Electric Vehicle Sales."

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LIST OF REFERENCES

ANCAP Safety. *Australasian New Car Assessment Program (ANCAP) Testing and Assessment Protocol – Rescue, Extrication and Safety*. V 2.0. Manuka ACT, Australia: ANCAP, 2021. https://s3.amazonaws.com/cdn.ancap.com.au/app/public/assets/34fd4d90273c043553b5e59c54dcf0e189a7845a/original.pdf?1633069898

Archer, Brock. *Emergency Response to the Tesla Model 3*. Video, 2019. https://www.youtube.com/watch?v=2X_WorH4pUw.

———. *Tesla Model X First Responder Training – Advanced Extrication*. Video, 2016. https://www.youtube.com/watch?v=D4peF1EYke8.

Australia New Car Assessment Program. "ANCAP Rescue Apps." Accessed July 18, 2022. https://www.ancap.com.au/apps.

Baskerville, Richard, and Michael D. Myers. "Special Issue on Action Research in Information Systems: Making IS Research Relevant to Practice: Foreword." *MIS Quarterly* 28, no. 3 (2004): 329–35. https://doi.org/10.2307/25148642.

Bland, David J., and Alexander Osterwalder. *Testing Business Ideas*. Hoboken, NJ: John Wiley & Sons, Inc, 2020.

Bradbury, Hilary. "Action Research, Concept of." In *SAGE Research Methods Foundations*, edited by Paul Atkinson, Sara Delamont, Alexandru Cernat, Joseph W. Sakshaug, and Richard A. Williams, 1–31. London: SAGE Publications Ltd, 2020. https://doi.org/10.4135/9781526421036805697.

Bradbury, Hilary, ed. *The SAGE Handbook of Action Research*. 3rd ed. Los Angeles: SAGE Publications, 2015.

Brustein, AJ. "Try 'Walking The Path' To Solve Your Startup Problems." *Forbes*, October 27, 2015. https://www.forbes.com/sites/theyec/2015/10/27/try-walking-the-path-to-solve-your-startup-problems/.

Bureau of Transportation Statistics. "Hybrid-Electric, Plug-in Hybrid-Electric and Electric Vehicle Sales." National Transportation Statistics. Not Available, 2019. https://www.bts.gov/content/gasoline-hybrid-and-electric-vehicle-sales.

Davis, William. "Tesla Electric Cars Less Likely to Catch Fire than Petrol Cars – Report." Drive, August 24, 2021. https://www.drive.com.au/news/tesla-electric-cars-less-likely-to-catch-fire-than-internal-combustion-alternatives-report/.

Emir, Can. “Tesla Proves Dominance in the EV Market with a 75 Percent Market Share.” Interesting Engineer, April 29, 2022. https://interestingengineering.com/transportation/tesla-ev-market-75-percent-market-share.

Energy Security Agency. *Emergency Response to Lucid Air*. Video, 2023. https://www.youtube.com/watch?v=os6UbuTv0NI.

Engle, Brian, and Kurt Vollmacher. “Li-Ion Cell Venting Risks, Detection, and Countermeasures.” Presentation, SAE First and Second Responders Task Force, June 16, 2022.

Evers, Andrew, and Lora Kolodny. “Electric Vehicle Fires Are Rare, but Hard to Fight — Here’s Why.” CNBC, January 29, 2022. https://www.cnbc.com/2022/01/29/electric-vehicle-fires-are-rare-but-hard-to-fight-heres-why.html.

Fahy, Rita, Ben Evarts, and Gary P. Stein. U.S. *Fire Department Profile 2020*. Quincy, MA: National Fire Protection Agency, 2022. https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osfdprofile.pdf.

Figma. “Figma: The Collaborative Interface Design Tool.” Accessed December 5, 2022. https://www.figma.com/.

Fire Department of New York City. “Tips from Training: Tesla First Responder Loop.” New York: FDNY Fire Academy, March 22, 2021.

Halbesleben, Jonathon R. B., Holly K. Osburn, and Michael D. Mumford. “Action Research as a Burnout Intervention: Reducing Burnout in the Federal Fire Service.” *The Journal of Applied Behavioral Science* 42, no. 2 (June 2006): 244–66. https://doi.org/10.1177/0021886305285031.

Heilweil, Rebecca. “Why Teslas Keep Catching on Fire.” Vox, January 27, 2023. https://www.vox.com/the-highlight/2023/1/17/23470878/tesla-fires-evs-florida-hurricane-batteries-lithium-ion.

Hurst Jaws of Life. *HURST Jaws of Life Demo on 2018 Tesla Model 3*. Video, 2019. https://www.youtube.com/watch?v=_gLVBcY2rXc.

International Organization for Standardization. “ISO 17840-3:2019(En), Road Vehicles — Information for First and Second Responders — Part 3: Emergency Response Guide Template.” International Organization for Standardization. Accessed October 8, 2022. https://www.iso.org/obp/ui/#iso:std:iso:17840:-3:ed-1:v1:en.

Johnson, Peter. “2022’s Top 10 Best-Selling Electric Vehicles in the US: Find out Why They Made the Cut.” Electrek, January 10, 2023. https://electrek.co/2023/01/09/the-top-10-best-selling-electric-vehicles-in-the-us-of-2022/.

Kane, Mark. "Statistically, Tesla Car Fires Are Less And Less Frequent." InsideEVs, May 9, 2022. https://insideevs.com/news/584722/tesla-car-fires-statistic-2021/.

Kim, Sangwook, Tanvir R. Tanim, Eric J. Dufek, Don Scoffield, Timothy D. Pennington, Kevin L. Gering, Andrew M. Colclasure, Weijie Mai, Andrew Meintz, and Jesse Bennett. "Projecting Recent Advancements in Battery Technology to Generation Electric Vehicles." *Energy Technology* 10, no. 8 (August 2022): 2200303. https://doi.org/10.1002/ente.202200303.

Klock, Andrew. *Emergency Responder Training for Advanced Electric Drive Vehicles*. Quincy, MA: Fire Protection Research Foundation, 2013. https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EVTrainingEmergencyResponders.ashx.

LaMorte, Wayne W. "Diffusion of Innovation Theory." Behavioral Change Models. Accessed March 13, 2023. https://sphweb.bumc.bu.edu/otlt/mph-modules/sb/behavioralchangetheories/behavioralchangetheories4.html.

Latham, Catina B. *Federal Vehicle Fleets: Observations on the Transition to Electric Vehicles*. GAO-23-105635. Washington, DC: Government Accountability Office, 2022. https://www.gao.gov/products/gao-23-105635.

Long, Jr., R. Thomas, Andrew F. Blum, Thomas J. Bress, and Benjamin R.T. Cotts. *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*. Quincy, MA: Fire Protection Research Foundation, 2013. https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EV-BatteriesPart-1.ashx.

Manyara, Charles G. "Combating Road Traffic Accidents in Kenya: A Challenge for an Emerging Economy." In *Kenya After 50*, edited by Mickie Mwanzia Koster, Michael Mwenda Kithinji, and Jerono P. Rotich, 101–22. New York: Palgrave Macmillan U.S., 2016. https://doi.org/10.1057/9781137574633_7.

Marchant, Gary Elvin, Braden R. Allenby, and Joseph R. Herkert. *Growing Gap between Emerging Technologies and Legal-Ethical Oversight: The Pacing Problem*. International Library of Ethics, Law and Technology, v. 7. New York: Springer, 2011.

Marino, Joe, Kyle Schnitzer, and David Meyer. "NYC Firefighter's Leg Crushed When SUV Tips over after Crash." *New York Post*, July 17, 2022. https://nypost.com/2022/07/17/nyc-firefighters-leg-crushed-when-suv-tips-over-after-crash/.

Mercedes-Benz. "Mercedes-Benz Rescue Sheets." The Digital Rescue Assistant as a PWA. Accessed October 7, 2022. https://rk.mb-qr.com/en/pwa/.

Moditech Rescue Solutions. "Crash Recovery System Standard Full Edition." Rescue – Vehicle Extrications, 2022. https://www.moditech.com/crash-recovery-system/rescue-vehicle-extrication/standard-full-edition/.

Musk, Elon. "Model S Fire." *Tesla* (blog), October 4, 2013. https://www.tesla.com/blog/model-s-fire.

National Fire Protection Association. "Emergency Response Guides." Alternative Fuel Vehicles Safety Training. Accessed March 23, 2022. https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides.

National Highway Traffic Safety Administration. "Early Estimate of Motor Vehicle Traffic Fatalities in 2021." Washington, DC: National Highway Traffic Safety Administration, April 2022. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813283.

———. "Traffic Safety Facts 2012." Washington, DC, May 2014. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812016.

National Transportation Safety Board. *Lithium-Ion Battery Fires in Electric Vehicles: Safety Risks to Emergency Responders*. Video, 2021. https://www.youtube.com/watch?v=J6eS6JzBn0k.

———. *Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles*. NTSB/SR-20/01. Washington, DC: National Transportation Safety Board, 2021. https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf.

Pedamkar, Priya. "Software Development vs. Web Development." *EDUCBA* (blog), June 9, 2018. https://www.educba.com/software-development-vs-web-development/.

Polestar U.S. "Polestar 2: 5dr Hatchback (2020)." Polestar Emergency Response Guide. Gothenburg, Sweden. Accessed November 17, 2022. https://euroncaprescuesheets.blob.core.windows.net/rescuesheets/Polestar/Polestar_2__Hatchback_2020_4d_Electric_EN.pdf.

Potts, Michelle R. "When 9-1-1 Is Not Enough: Transitioning the 9-1-1 Center into a Multi-Channel Emergency Communications Center." Master's thesis, Naval Postgraduate School, 2019.

Ries, Eric. *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. New York: Crown Business, 2011.

Riswick, James. "Vehicle Types, Car Body Styles Explained." *Car and Driver*, August 1, 2019. https://www.caranddriver.com/shopping-advice/g26100588/car-types.

Savoia, Alberto. *Pretotype It: Make Sure You Are Building the Right It before You Build It Right*. 2nd ed. Mountain View, CA: Albert Savoia, 2011. https://www.pretotyping.org/uploads/1/4/0/9/14099067/pretotype_it_2nd_pretotype_edition-2.pdf.

Shepard, Willard. "Lawsuit: Tesla's Door Handles Blamed for Broward Doctor's Death." NBC, May 25, 2022. https://www.nbcmiami.com/news/local/lawsuit-teslas-door-handles-blamed-for-broward-doctors-death/2770024/.

Shepardson, David. "New York State to Adopt California 2035 EV Rules." Reuters, September 29, 2022. https://www.reuters.com/business/autos-transportation/new-york-state-adopt-california-2035-ev-rules-2022-09-29/.

———. "New York State to Adopt California 2035 EV Rules." Reuters, September 29, 2022. https://www.reuters.com/business/autos-transportation/new-york-state-adopt-california-2035-ev-rules-2022-09-29/.

Shepardson, David, and Ben Klayman. "U.S. Government to End Gas-Powered Vehicle Purchases by 2035 under Biden Order." Reuters, December 8, 2021. https://www.reuters.com/world/us/biden-pledges-end-gas-powered-federal-vehicle-purchases-by-2035-2021-12-08/.

ShotSpotter. "ShotSpotter Mobile App." Accessed January 25, 2023. https://www.shotspotter.com/shotspotter-mobile-app/.

Sommerfeldt, Chris. "Mayor Adams' Administration Sets Strict Return-to-Office Policy for NYC Workers: 'Hybrid Schedules of Any Kind Are Not Permitted.'" *New York Daily News*, June 1, 2022. https://www.nydailynews.com/news/politics/new-york-elections-government/ny-nyc-mayor-eric-adams-return-to-office-city-employees-memo-20220601-jhupsedtsfginnkdk7u5y55bgq-story.html.

Vehicle Certification Agency. "European Community Whole Vehicle Type Approval (ECWVTA)." Accessed February 4, 2023. https://www.vehicle-certification-agency.gov.uk/.

Visvikis, Costandinos. "Safety Considerations for Electric Vehicles and Regulatory Activities." In *26th Electric Vehicle Symposium 2012,* Los Angeles, 2012.

Wisch, Marcus, Julian Ott, Robert Thomson, and Michael Abert. "Recommendations for Safe Handling of Electric Vehicles after Severe Road Traffic Accidents." In *24th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*. Gothenburg, Sweden: National Highway Transportation Safety Administration, 2015. https://www-esv.nhtsa.dot.gov/proceedings/24/files/24ESV-000361.PDF.

Woodward, Ryan. “Electric Vehicle Manufacturers Are Improving Emergency Response Guidance for Fighting Lithium-Ion Battery Fires Per NTSB Recommendation.” *IAFC Blog* (blog), June 8, 2022. https://www.iafc.org/blogs/blog/iafc/2022/06/08/electric-vehicle-manufacturers-are-improving-emergency-response-guidance-for-fighting-lithium-ion-battery-fires-per-ntsb-recommendation.

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