HFES Policy Statement on
Electric Vehicle Infrastructure Design

The Important Role of Human Factors in the Design of EV Charge Stations

Background Challenge

Transportation is a major source of green-house gas production in the US. A key component of the White House plan to address this includes the promotion and rapid adoption of EV cars and trucks. There are currently 276 million cars registered in the U.S. and a little more than 1 million are EVs.[1,2] However, a large increase in EV numbers is anticipated over the next 20 years. To meet this growth, there is a need to rapidly expand the EV charge station infrastructure. When charge stations are available at home or work, EVs can be charged at those locations. But for those who do not have a charger at home or work and for those doing long-distance travel, appropriately distributed public charge stations will be critical. Workplace charge stations are not usually available to the public.

The White House has identified the need to increase the number of public EV chargers from the current 100,000 (at 30,000 different locations) to 500,000.[3] As a comparison, there are approximately 150,000 gas stations in the U.S., each with an average of 8 pumps (e.g., 1,200,000 pumps).[2] It takes an average of 3 to 5 minutes to pay and fill a car with gas. Currently, a DC fast charger takes 30-60 minutes to charge an EV. The public believes that there are too few EV charge stations, especially for long-distance travel or travel in rural areas.[4] Gas stations are everywhere, they are well marked, easy to use, and are conveniently located along freeways and major travel routes. EV charge stations will need to be as easy to use as gas stations.

The proper placement of EV charge stations will be critical for this roll out to be successful. The public has concerns about electric vehicle range limitations (e.g., range anxiety) and the perceived lack of appropriately placed DC fast chargers.[4] Although public charge stations are increasing in number, they may not be placed to match driver expectations, for example, close to major road or freeway intersections. They may also not be placed to optimally match vehicle flow patterns for local and long-distance travel. The location relative to other stores and services may also be important since customers will have to wait for 30 to 60 minutes for their EVs to charge and may need something to do during that time.

EV charging stations also need to be more consistent and user friendly. More than 10 companies own, operate and maintain public EV charge stations: ChargePoint (40%), Tesla (19%), Blink (9%), Sema (5%), EVgo (4%), etc.[2] They each have different equipment designs and different methods of collecting payments. There is little uniformity in charge station location, design, function, vehicle match, charging speed, charging cost, and billing methods which leads to confusion and reduced confidence in using EVs for long-distance travel.

Further confusion arises because there are 2 types of public charge stations, type 2 and DC fast. Most homes, apartments, workplaces, and public charge stations are type 2 (8 to 60 miles added per hour of charging - the wide range is dependent on available amperage: 24 to 100 Amps). Currently, only 20% of public charge stations are DC fast (100-1000 miles added per charge hour), and most of these are Tesla charge stations[2] which are only available to Tesla EVs. In the long run, DC fast will become the standard for public charge stations for long-distance travel because of the reduced charging time. A second matter creating user confusion is that DC fast chargers use one of three plug types: CHAdeMO, SAE Combo (CCS), and Tesla supercharger plug. This means drivers will need to carry an adapter to charge their car, or they will only be able to use a limited set of charge stations.

While several smart phone apps are available with maps to locate EV charge stations and have descriptions of the charge stations, the apps can be difficult and confusing to use.[4] Some apps are supported by companies that owns charge stations and they may not provide complete information on the status of a competitor charge station. The apps do not always have up-to-date information on whether the charge station is functioning, whether it is currently in use, or the charging speed (available amperage) all of which are important for motorist decision making and charge station usability. The apps need to provide easy to use information to prevent confusion and frustration and promote the growing use of EVs.

Opportunity

Applying Human Factors Engineering to the design of EV charging stations and support apps will lead to the enhanced adoption of EVs. It is important to maximize the usability of EV charge stations and establish their locations so as to minimize motorist errors, confusion, and frustration. When new technologies are introduced, early adopters tend to be knowledgeable about the technology and will devote the time needed to understand the system and deal with the complexities. However, the general public will likely have a different level of patience when using EV charge stations than early adopters.

When EV charge stations are used by the public currently there can be many negative experiences – the charge stations do not work with their EV, the charge station is malfunctioning or broken, the payment system works poorly, etc. This can easily discourage EV use when drivers are worried about whether they will make it to their destination. Early negative experiences will be communicated to others and can lead to a backlash against EVs. It is critical to understand how the public will interact with EV charging systems (apps, route selection, charging cables, billing, etc.) in order to design systems that minimize errors and frustration.

Human Factors Engineering involves improving human performance in order to reduce errors and improve success in interacting with technology. The way in which technology is designed significantly affects the performance of its human operator. Optimizing the relationship between humans and technological systems is the essence of Human Factors Engineering. When the system is easy to use, guards against typical human limitations and errors, and helps people to rapidly understand key information, high levels of human performance and satisfaction can be achieved. While poor systems design encourages errors, good systems design can prevent them. A key foundation for improving human performance, while minimizing error and frustration, is the design and development of the controls and displays associated with EV charging station using Human Factors Engineering principles.

Human Factors Issues Limiting EV Adoption

There are important gaps in our understanding of how the public will interact with EV charge stations. These gaps include:

- How does the public use apps to locate the proper charge station for their vehicle and to plan their travel route?
- What key information is needed by drivers and what are the are best methods for displaying information on apps, including: (1) charge station features (e.g., number of charge stations, charging type, charging speed, plug type, etc.); (2) how many charge stations are functioning; (3) the availability of hookups; (4) whether the information is current; (5) projected waiting time for a hookup; (6) projected time to complete charging; and (7) other services available (e.g. food services, shopping, restrooms, etc.)?
- How should EV charge sites be designed for high throughput of EVs and rapid use? What are optimal: (1) flow patterns of EVs through charge stations, (e.g., back-up parking, drive through, etc.); (2) methods to handle billing; and (3) methods to notify drivers that charging is complete?
- What EV charge station spacing is needed to minimize range anxiety?
- How are large EVs, such as EVs with trailers; RV-EVs; and large EV trucks best managed at charge stations?
- What are best methods for EV owners to communicate with charge station companies if they experience problems with hook up, charge station maintenance, blocked charge stations, or billing?
- What are the minimal common design features of charge stations (e.g., payment methods, problem reporting, plug or adapter types, etc.) that will make it easy for drivers to use the charge stations owned by different companies?
- What support is needed for driver safety and security while recharging?
- What support is needed for accessibility by users with disabilities?

Recommended Solutions

These concerns can be addressed with a well-designed national distribution of EV charge stations that are easy for drivers to use with equipment that will rapidly charge cars and trucks. To support this goal, Human Factors research is needed to identify EV charging station and app designs that will promote usability and the transition to EVs.

1) *Research is needed on improving the usability of high throughput charge stations in order to increase the uniformity of charge station designs and decrease end user confusion. Issues that need to be studied include:*
    - *Investigate how people use apps to locate the proper charge station for their vehicle.*
    - *Determine information needs to support route planning, and the selection and usage of EV charging stations.*
    - *Design and evaluate current smart phone apps for usability and ability to provide drivers with needed information for driver decision making.*
    - *Determine the minimal components of a national charge station data structure that will provide various apps with the up-to-date charge station information that EV drivers need.*
    - *Determine the optimal design of flow of vehicles through charge stations that allows for high throughput of vehicles with guidelines that will prevent driver confusion.*
    - *Determine the optimal design of EV chargers to provide design guidelines on charger location, plug in process, plug types and adapters, and billing. The studies should evaluate the behavior of humans while they interact with chargers and focus on maximizing usability and efficiency and minimizing errors.*
2) *Research is needed on the placement, integration, and size of public charge stations in order to optimize the ability to meet the needs of EV drivers.*
    - *Identify state and national vehicle travel data to plan placement and size of public EV charge stations to accommodate anticipated heavy usage routes and heavy usage dates while considering weekday, weekend, and holiday travel.*
    - *Determine needed density of public EV charge stations based on multiple factors, including travel patterns and anticipated availability of private charge stations at residential, work, and commercial base station sites.*
    - *Plan placement of public EV charge stations to minimize driver range anxiety.*
    - *Plan placement of EV charge stations to accommodate high traffic flow near major travel roads and highways.*

About the Human Factors and Ergonomics Society (HFES)

With over 4,600 members, HFES is the world's largest nonprofit association for human factors and ergonomics professionals. HFES members include psychologists, engineers and other professionals who have a common interest in working to develop safe, effective, and practical human use of technology, particularly in challenging settings. Members of HFES play a leading role on the development of guidelines and standards and are active in national standards organizations, such as ASTM, ANSI, NEMA, and ISO.

References

1. Gas stations in the U.S.: Dossier. Statista Inc., NY. 2020

2. Alternative Fuels Data Center; Fuels & Vehicles; U.S. Department of Energy; May 1, 2021.

3. Electric Vehicle Charging Infrastructure. White House Fact Sheet. April 22, 2021.

4. Consumer Views on Plug-In Electric Vehicles – National Benchmark Report. National Renewable Energy Laboratory; NREL/TP-5400-65279; 2016.