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How Electric Vehicle Drivers Navigate the Real and Virtual Worlds of Vehicle Charging

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Executive Summary

Electric vehicle drivers throughout the US described their search for and use of charging facilities via interviews conducted during the first half of 2022. To impose indirect controls on socio-economic factors, e.g., income and home ownership, buyers of higher end electric vehicles were interviewed. The purpose was to understand electric vehicle drivers' charging at-home, at-work, and out-in-public including how they use information resources such as in-vehicle information systems including navigation as well as smartphone apps from automotive manufacturers, charging providers, and third-parties to manage, navigate, and pay for charging. Interviews also cover desired functionality for vehicle charging and information systems, charging fails and pain points, and ideal charging functionality or "dream features." Results provide insights into how to better address electric vehicle drivers' charging experience.

Keywords: driver experience, charging, infrastructure, ICT (information and communication technology), reliability

1 Motivation and Background

Electric vehicle (EV) charging infrastructure is touted as a key facilitating condition for EV market growth. It argued charging infrastructure may encourage consumers to purchase EVs, perhaps especially consumers who haven't already and may increase the use of EVs by those who drive them [1]. While it may seem apparent that to accomplish these goals an initial condition—the existence of charging—must be true, we describe how other conditions—charging discoverability, availability, accessibility, and functionality—shape EV drivers' charging experiences. Taken together, how EV drivers experience these conditions and manage their use of charging within these conditions shapes their evaluations of EV charging and desired improvements.

There is a large and diverse literature on planning where to build EV charging—often within the implicit intent to solve the narrower question of where to locate public charging. [3] provide a recent review of modeling approaches to this problem. [4] provide a detailed description of where EV drivers charge given the charging infrastructure available to them. A 2018 review of the literature on consumer preferences for EV charging stated while public charging was less important to EV market growth than home and workplace charging, nevertheless, public charging was "still important in encouraging consumers to purchase EVs" [2].

Researchers have examined which charging location EV drivers use (for example, [5]) and the effect of time-of day pricing on when EV drivers charge (for example, [6]), among many other questions. [7] propose a general dictum of driver behavior to underly their model of charger location and the spatio-temporal solution of charging (including at-home and away-from-home locations): how long drivers and thus their vehicles dwell at stops.

In contrast to the extensive literature on EV charging, there has been little examination of EV drivers' use of information systems to support their charging. i.e., finding chargers and successfully completing a charge. Searches for literature on EV charging and information systems return studies of how the different technical systems communicate with each other, e.g., chargers and vehicles, or chargers and financial transaction systems. Only [8] provides a descriptive overview of smartphone app functionality but provide no description or analysis of how these apps are used by EV drivers. Further, there have been many changes since [8] was published in 2013 in terms of the number of apps and charging network companies.

Few analyses of EV charging offer any discussion of the lived experience of EV drivers managing their charging [9]. Certainly, there have been reports from EV drivers about where and when they charge [2, 10]. However, there has been no description of what user interfaces EV drivers use, e.g., those provided by their EV's manufacturer via phone apps (apps) in-vehicle information systems (IVS) including navigation, apps from charging network operators, or apps from third parties. How do EV drivers experience the physicality of charging their EV from pulling into parking spaces to handling the charging cable? How does experience differ across charging contexts defined by charger location, parking design, weather, charger type, charging network, and more? Under what circumstances to do they look for information about chargers and for what information do they search? How do they find chargers? What does any of this have to do with their thoughts on what would improve EV charging?

These are the questions this research poses to EV drivers. This research describes how a sample of EV drivers charge their EVs while at home, workplaces, and public chargers, including drivers' use of information systems provided by automotive original equipment manufacturers (OEMs), charging providers, and third-parties to manage, navigate, and pay for charging. We describe some of the many—sometimes taken for granted—assumptions about what it takes beyond the existence of EV chargers for EV drivers to experience charging as a useful and used resource.

2 Methods

Data are from interviews with EV drivers conducted in early 2022 via an online meeting platform. All interviewees are drivers of electric vehicles recently released in the U.S., i.e., Audi e-tron, Ford Mach-E, and Jaguar I-PACE, as well as their longer established competitors, Tesla's Models 3 and Y. All interviews were conducted by the first author. The choice of vehicles was based on limiting the sample to drivers of vehicles that may be construed as competitors in the premium passenger car segment.

2.1 Interview Overview

Seventeen interviews were completed between October 2021 and January 2022. We do not argue the small sample is representative of a population. Rather, it is descriptive of a range of behaviors and suggestive of avenues of further research. As with the EV market in the US, the sample is concentrated in California—the US state with the highest number of on-road EVs, annual EV sales, and public charging locations. However, EV drivers from the US states of Arizona, Georgia, Maine, Massachusetts, and New Jersey also participated. Interviews lasted approximately one-hour. The sample is described by vehicle and state in Table 1.

EV drivers described their use of information systems to discover chargers, remotely query the accessibility and availability of a desired charging location, and to initiate and successfully complete charging. Their accounts describe their creation and use of charging itineraries for novel long-trips, how creating these itineraries prior to a trip may serve as confirmation a trip can be made and as the basis for enroute modification during the trip. The EV drivers interviewed for this study report instances in which faults or breakdowns somewhere in the supply-side chain from presence to functionality have resulted in a failed charge attempt and the need to create a new charging solution. The EV drivers interviewed here describe information systems to mediate their experience of EV charging. Improvements to this overlay may be useful, but improvements to the underlying supply-side of Electric Vehicle Service Equipment (EVSE) are desired.

Table 1: Study Sample Vehicles and States

Vehicle	State	Count
Audi e-tron	California	1
	California and Georgia	1
Ford Mach-E	California	1
	Massachusetts	1
	Maine	1
	New Jersey	1
Jaguar I-Pace	Arizona	1
	California	6
Tesla Model 3	California	4 (One is same interview as Model Y below.)
Tesla Model Y	California	1 (Same interview as one Model 3 above.)

2.2 A Note on the Effects of COVID-19

As these interviews were conducted in the first half of 2022, these EV drivers report two on-going effects of COVID-19 on their travel. First, households in which there were employed persons generally reported they now worked from home—either mostly or solely. As they were not presently commuting to work, they were making fewer car trips per day, driving fewer miles, and not using workplace charging (if it was available to them). As a result, while their total amount of charging (measured as energy across all charging locations) was reduced, a higher proportion of their charging events were at their residence (or at another routine location as described in Section 3.2). Second, the incidence of automobile trips requiring an overnight stay at away-from-home accommodations were also fewer than typical for pre-pandemic times though almost all these households had recently made such trips. As such, there were still many examples of using, or attempting to use, away-from-home charging.

3 Results

There are two main results that frame all others. One, there is a clear divide in the experience of charging between drivers of Tesla EVs and drivers of all other EVs in this sample. Two, though no single EV driver describes an overall framework for thinking about EV charging, such a framework is synthesized from all these drivers' descriptions.

3.1 A Framework for Understanding EV Drivers' Charging Experience

These EV drivers' descriptions provide empirical evidence of a framework for thinking about EV charging as drivers experience it. The usefulness and useability of EV chargers may be described by a chain of events linking from those most abstract and removed from a specific instance of charging to that specific instance: *selection, discovery, availing, accessing, and charging* (possibly plus other activities). The right side of Figure 1 illustrates this chain from EV drivers' perspectives, moving from abstract (top) to specific (bottom). Discovery is made from the EVSEs present in the environment but does not include all EVSEs in the environment. The relevant set is established when the EV driver acquires a specific EV—whether they're fully aware of this or not. As of the writing of this paper, different EVs have access to different subsets of all chargers, DC Fast chargers in particular. Tesla Motors only recently agreed to make some of its chargers available to drivers of non-Tesla EVs, presumably in exchange for the prerogative to apply for new US federal funding for EV charging infrastructure deployment [11]. When implemented, this will change the existing situation in which there is a hard division between which DC fast chargers (DCFC) were available to EV drivers depending on whether they drive a Tesla or not. The choice of an EV also shapes access to and use of user interfaces and information resources for discovering, navigating to, accessing, and using chargers. Further, though the effects have been more to incentivize which charging networks to use rather than to proscribe who may use the network, many other automotive OEMs have been encouraging their EV drivers to use a particular public charging network by providing an allotment of free charging.

The left-side of Figure 1 illustrates the supply-side actors who give *presence* to EVs and EV charging: deciding the location and number of EVSE at each location, make charging networks *discoverable* by multiple means that may also convey information about a charger's *availability, accessibility,* and *functionality* and possibly information about other activities a driver may wish to accomplish while at the charging location. Availability relates to whether the driver can use an intended charger; the primary reason reported for the unavailability of a charger was the charger was occupied by another vehicle. Another reason is that a non-functioning charger, while present, is not available. Accessibility refers to physical layout and design of the charging location. Instances of inaccessible chargers are described in terms of how difficult it is to park in such a way as to be able to plug in a car. Other reasons may include timed access, i.e., a charger may not be accessible for public use at all hours, every day. Functionality is experienced in the acts of initiating and completing a charge.

To connect prior events leading to a successful charging event, it may be useful to think in terms of a timeline. An EV driver's universe of potential charging locations is proscribed when they buy a particular EV. (Note this may be a conscious decision. Some Tesla drivers talked about Tesla's charging network as an attribute in their decision to buy a Tesla. The selection may also be unconsidered; an EV driver may give no attention to whether their vehicle purchase will affect which chargers are available to them.). The period for discovery may start any time before a trip begins and extend to a few minutes before charging is desired. Availability—even if it is assessed during discovery—appears to be reassessed between when a trip commences to a few moments before arriving at an intended charging location. Accessibility is assessed in those last few moments as a driver approaches a specific charger until they successfully (if they successfully) plug in their EV. Finally, functionality extends from the time an attempt is made to initiate a charge to the successful completion of charging at an expected power level and for an expected price.

If an instance of an EV driver successfully charging their car is located at lower right of Figure 1, all their antecedent events and all the actions of the suppliers and operators of systems which facilitate and constrain those events are implicated in that specific charging event. We use Figure 1 to organize the presentation of results relating to how drivers move along this chain of events and how they use information to guide them.

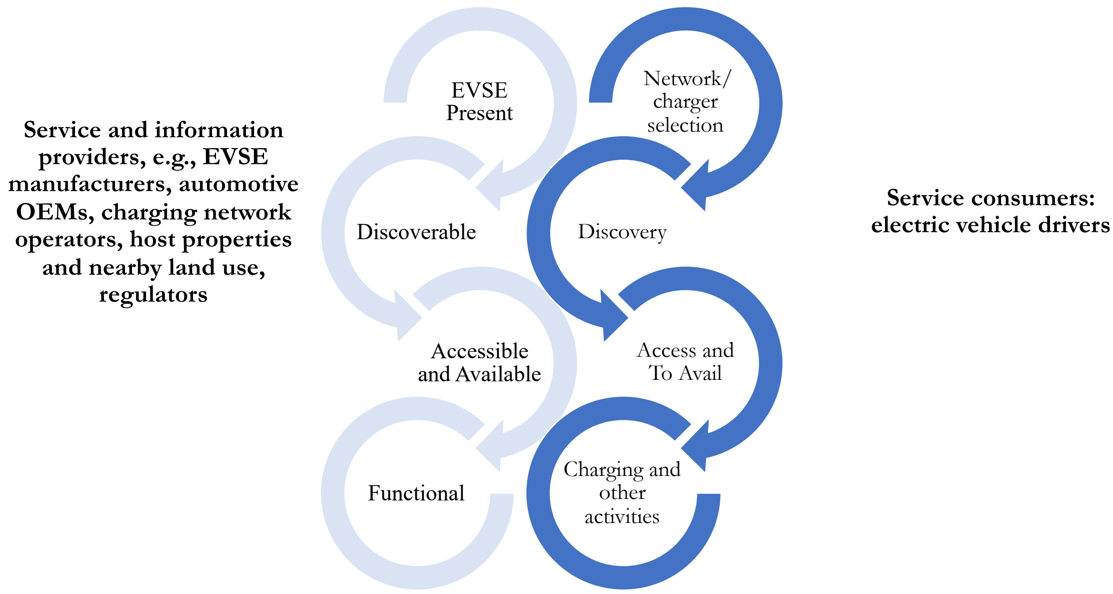

Figure 1: Conceptual Model of relationships between charging providers and charging consumers in electric vehicle charging.

3.2 At-Home and Routine Charging

"At-home and Routine Charging" is charging that supports daily driving; it includes both charging an EV at a residential location as well as how and where an EV driver routinely charges their vehicle if they don't have access to charging at their residence. The main distinction in terms of drivers' use of information systems is that routinely charging at a non-residential location entails the use of different information systems than those used for charging at a residence.

Once any initial installation of an EVSE at their residence is complete (if one is installed at all), those EV drivers need not conduct any further discovery related to their home charging. These drivers report using their OEM charging apps and in-vehicle interfaces to set a couple charging parameters, but beyond that charging at home becomes a matter of daily routine involving very little thought or effort. The two parameters mentioned by most of these EV drivers are charging start time and maximum battery state of charge (SOC). None of these EV drivers reported setting a charging end time as they believed their vehicles were always fully charged before any reduced night-time electricity price period expired the next morning.

Routine away-from-home charging to support daily driving for those EV drivers unable to charge at their residence was accomplished at workplace or public chargers. While both may require an initial search for the presence of EVSE, once one or a few favored locations are identified, little on going discovery was reported. Discovery of the presence of EVSE was described as a matter of visually locating chargers along desired or routine routes, i.e., seeing charging locations in the physical environment rather than searching virtual environments via information systems.

Both workplace and public locations are subject to conditions of availability, accessibility, and functionality. An Audi e-tron driver, the one EV owner in the sample who was entirely reliant on away-from-home charging, reported having one preferred DCFC location on her way to work and one back-up location in case her preferred location was unavailable. While there was charging at her workplace, the one EVSE most conveniently located to her office was challenging to access as the physical design of the parking space, the EVSE location, a too-short EVSE power cord, and location of the power port on her EV made parking close enough to the EVSE to plug in her car difficult. Further, as the charger was at her workplace rather than a public charger she was confused about who to call about this or a problem with charger functionality: a facilities manager for her workplace or the EVSE network provider?

3.3 Away-from-Home Charging

While away-from-home charging includes both public and workplace charging, the latter is discussed in the prior section on routine charging. Here, we relate how these EV drivers talk about using public charging. Away-from-home charging is most often associated with long trips, defined here as any trip requiring at least one charge to return home (or some other base of routine charging). A long trip which has not been made before (either in any vehicle or in the EV) is novel. If the trip has been made more than once, it is a routine long trip.

3.3.1 Presence

In the lived experience of these EV drivers the presence of EV charging is limited because as a practical matter they access only a subset of all charger locations. EV drivers access only a subset of all locations in a system corresponding to their vehicle brand. Tesla drivers tend to operate entirely within a single, integrated vehicle-charger-information system, i.e., they describe using only Tesla chargers and using only Tesla's IVS and app. The non-Tesla drivers were much more likely to report using a variety of charging networks other than Tesla. This variety flows through the entire chain of events leading to any specific instance of charging. Non-Tesla drivers are using multiple information systems to discover chargers (and possibly across multiple charging network providers), assess EVSE availability during specific trips, and initiate and complete charging transactions. One interviewee (I-Pace, southern California) interrupted his interview briefly to count the charging apps on his phone—13—though he offered he "only uses three or four." The use of multiple charging apps, as well recommendations for which apps to use, appear to be learned. Either EV drivers learn these apps during their experience driving a different non-Tesla EV prior to the one they are now driving or, if they are new EV drivers, then in online EV driver forums while shopping for their EV.

3.3.2 Discovery

Tesla drivers use either the Tesla app or IVS to discover the location of charging. Because they use these sources, they know what they can do. Tesla drivers describe these capabilities with reference to specific trips including charging itineraries, dynamic trip planning, and real-time charging information display.

In contrast, none of the non-Tesla EV drivers could describe the capabilities of their OEM-provided apps or IVS beyond the basic setting of charging parameters for home charging (described in Section 3.2) because these EV drivers don't use the OEM systems to discover away-from-home charging. A different I-Pace (California) driver than in the previous example said,

> "I-PACE has EV charging stations built into the nav [navigation] system. It is an option to list EV charge stations. I assume if you select one, the nav system is going to give me the route…But I haven't used [the I-PACE's navigation]. So, I don't know what it does."

This uncertainty extends to the drivers' beliefs about how current the information is in their OEM IVS. The typical belief of non-Tesla EV drivers is the maps and other information in their OEM IVS are updated only when the vehicle is taken to a dealer for service—if then.

To discover chargers, non-Tesla drivers report using either a charging network app or a third-party aggregator of charging location information. The choice of a specific network app was prompted by the vehicle OEM offering an allotment of free charging in the network, e.g., Audi e-tron drivers being offered free charging within the Electrify America network. PlugShare and A Better Route Planner (ABRP) were the most mentioned third-party information providers for discovering charging locations. While the app versions of these can, in principle, be displayed on the IVS display, for at least one OEM the drivers (who are also iPhone users) were unable to display the ABRP map layer. Though perhaps limited to one vehicle OEM and one smartphone operating system, the example indicates again how the choice of a vehicle flows through the whole chain of events leading to using a public charger.

3.3.3 Linking Discovery and Availability

The chain of events from discovery to a specific charging event are most likely to form a single set of events during novel long trips. That is, EV drivers will be looking for charging opportunities, checking on intended chargers as they approach from several minutes away, pulling into a parking spot, attempting to plug in, and initiating and completing a charge.

For novel, long trips most of these EV drivers described such a chain of events that starts with them creating a pre-trip charging itinerary. No matter the information platform they used—Tesla, PlugShare, ABRP, or some other—these itineraries identify a set of recommended charging locations required to complete the indicated journey, a description of the charging available at each location (number of chargers by connection type/ power level), the operational status and availability of each charger at a location (at the time the itinerary was created), and potentially general information about amenities at or near the charging location.

Creating such an itinerary prior to the trip provides assurance the trip can be made in their EV. However, during the trip the use of the itinerary may shift from a specific list of stops to a framework for the driver—rather than an app or IVS—to dynamically manage charging during the trip. Reasons to deviate from the pre-trip charging itinerary included actual charging occurring at a higher than anticipated power, route deviations, and a driver's knowledge of charging availability at the destination.

In the case of higher than anticipated charging power, this may allow a driver to linger at that charger for a longer time than indicated by the pre-trip itinerary if the itinerary had advised them to leave that location at a relatively low state of charge. It appears this behavior is a hedge against the uncertainty of the charging rate at the next charging location: if the charging rate in one instance can be faster than anticipated, it can be slower in another.

The power level of DCFC charging is sharply curtailed for charging a battery beyond an SOC of approximately 80 percent; this is done to protect the battery from high temperatures. Some EV drivers may learn the implications of this while making a long trip, i.e., they may not incorporate it into a pre-trip itinerary.

- On the first trip an I-Pace driver in Arizona made to Los Angeles, he followed the recommended charging itinerary. By doing so, he experienced how much longer charge duration can be if waiting for the battery to reach 100% SOC. It occurred to him that total trip time might be less if he charged more often but to lower SOC. He confirmed this hunch by overriding the charging itinerary on the return trip to Arizona. Despite an additional charging stop, the total travel time to home was less.

This example also highlights another charging management "trick" some EV drivers use. As this I-Pace driver had done, many of the EV drivers report that for long trips they use their OEM app or IVS to override their routine charging SOC maximum threshold, shifting up from the range of 80-90 percent to 100 percent. This change can be provided to the information system used to create the pre-trip itinerary.

In the following example, another I-Pace driver made a pre-trip itinerary for a round-trip starting from home.

- This I-Pace driver from the San Francisco Bay Area made a long journey of several hundred miles over three days and requiring multiple charging events. At one point, he realized he could avoid a long stretch of the itinerary's suggested route which he was not interested to see if he was willing to deviate from the route onto a secondary highway and drive the car to a lower SOC than his usual minimum threshold. He made the deviation.

In contrast, a driver may make a one-way itinerary between home and a non-home destination. In this case, the question of charging discovery can feedback from an instance of anticipated charging back to charging presence.

- A Mach-E driver living in Massachusetts travelled to a vacation cabin in the state of Maine. The trip was made without incident but only upon arriving did they discover they would not be able to charge at their destination—not even at Level 1. The solution turned out to be to drive to a nearby town to charge for a few hours at a public Level 2 charger.

In the case of this one-way itinerary, the information system appears to assume the driver would only drive to a destination with charging. In such a case as this, lack of knowledge of charging at a destination might require an EV driver to arrive at the destination with a higher SOC than the pre-trip itinerary recommended—because they still must travel to a charger. An EV driver must arrive at a specified destination with enough charge to arrive at their next charging opportunity—whether that is at their destination or not.

The information tools used for discovery in the case of *novel*, long trips may be used to assess availability for *routine*, long trips. These EV drivers will use their OEM IVS (Tesla drivers only in this sample of drivers) or third-party apps (non-Tesla drivers) to assess the availability of chargers as they approach their intended charging location. If a long trip is made routinely, these EV drivers substitute experience for a pre-trip charging itinerary. Known charging locations become their default charging locations, with exceptions for the discovery of new favorite locations not originally recommended by an itinerary, learning about the effects of SOC on charging duration, comfort with how low a battery SOC a driver is willing to tolerate, the unavailability of a known charger, and other causes.

- One of the Tesla drivers routinely travels between San Diego and Los Angeles, CA. He has learned to ignore recommended charging locations during these trips. He has learned a charging location that allows him to walk on the beach for 20 minutes while his car charges—an amenity not accounted for by the information system.

3.3.3 Accessibility and Functionality

Assessing accessibility occurs in those few moments approaching a charger when the driver assesses whether they will be able to park and connect their vehicle. Accessibility and functionality implicate the physical design and layout of charging locations and where they are situated within local land use. For example, much of what concerns accessibility relates to the layout of the parking space and the charger. The Audi e-tron driver described in Section 3.2 reported the most conveniently located charger to her office was not positioned relative to its associated parking space in a way that allowed her to plug-in. She encountered this during her routine charging. However, an EV driver who is a visitor to her campus may encounter that same charger in the context of a novel long trip and find it equally inaccessible.

Though in a paper describing EV charging, one might assume functionality relates to whether and how well the charger works, EV drivers often talk about charging stops in terms of charging plus one or more other activities. In this way, *functionality* is more general. It includes both whether an EV driver was able to successfully charge their vehicle and how well the location serves the EV driver's desire to accomplish other activities. Regarding charger functionality, charging location design, and local land use, these EV drivers offer these suggestions for better design of, and amenities at, charging locations:

- Improve charger design: DC Fast charger cords are heavy, awkward to handle, and often dirty.
- User interface screens rendered unusable: typically, this is reported as illegible interface screens. Drivers attribute this to environmental conditions, e.g., exposure to heat and light. Chargers that were difficult or impossible to use because screens have become hazy or completely opaque were reported by drivers from hot and sunny Phoenix, Arizona to colder and cloudier Portland, Maine.
- Shade/rain/snow structures covering the parking/charging area, both for the comfort of drivers and to shelter chargers from the elements. Further, such covers could provide structures to install solar arrays to provide ancillary power, e.g., lighting.
- Unknown problems with initiating a charge: the driver can physically connect the charge cable to their car and the charger interface screen is legible, but some other fault prevents charging. Such instances may require a call to a support line, which in turn does not always solve the problem.
- Better layout of the charger vis-à-vis the parking spot: pull-through parking (as is common for gasoline station pumps) rather than pull-in or back-in parking (as is common in parking lots).
- Simplify payment options so that the same payment method is used at all chargers rather than the current situation in which many different charging network providers requiring their own accounts and payment systems.
- Clean bathrooms and regularly serviced trash cans.
- Discoverable (i.e., during a discovery phase prior to a charging event) food and beverage options including user reviews of those options.

3.4 EV Drivers Use and Assessment of Information Systems

No EV driver interviewed here stated they chose their EV based on information systems. Some Tesla EV drivers do cite Tesla's EV charging network as crucial to their decision to acquire a Tesla rather than any other EV. Within this Tesla/non-Tesla split, information systems including automotive OEM apps and IVS, charging networks, and third-party apps are used in the following ways:

- Regardless of vehicle manufacturer, automotive OEM charging apps are used to manage a small number of charging pre-sets for at-home and routine charging.
- All other use of information systems to manage public charging is differentiated by whether the EV driver drives a Tesla vs. any of the non-Tesla EVs represented in this study.
  - Tesla owners operate within an integrated vehicle-charging-information system, using the OEM apps and in-vehicle interface to manage charging at Tesla chargers.
  - Non-Tesla EV drivers use:
    - Third-party apps to discover and access public chargers.
    - Charger network apps to manage the function of charging.
    - Barriers to non-Tesla EV drivers using their OEM IVS include:
      - Among EV drivers with experience driving other EVs, their use of third-party phone apps is portable from their past EVs to their new one. Rather than learn the information system native to their new EV, they continue their past behavior using third-party phone apps.
      - Some EV drivers faced incomplete integration of phone-based third-party apps with the automotive OEM's in-vehicle display. These EV drivers default to using their familiar apps on their phones rather than learning their OEM's information system.

EV drivers interviewed for this project desire improved information content regardless of how they get it. Most of their desired improvements pertained to availability, accessibility, and functionality (as we have defined it broadly to include charging and other activities to be accomplished while charging). Drivers cited instances in which the information to precisely locate charging facilities is missing. This typically arises when charging is located at a large, multi-unit facility such as a regional shopping mall or corporate campus. The location information may provide only a street address for the entire facility, not the location within the facility. This leaves EV drivers, especially those engaged in first-time charging discovery, searching parking lots and garages.

During discovery, EV drivers may see information about amenities at or near charging locations, but this information may be generic. For example, the presence of restaurants and coffee shops may be noted but not specifically which ones. In addition to more specific and complete information, for some amenities these EV drivers would also like to see reviews and—if they are interested in food and beverage options—be able to place reservations or pre-order food and beverages to be ready upon their arrival. Ideally, this would all be done through the same interface used to discover chargers.

One feature of the PlugShare app was cited by several users as something they'd like to see more broadly across information systems was the ability of users of charging locations to leave information based on their experience. These "driver check-ins" are valued by some EV drivers for two reasons. One, these check-ins create the appearance of accurate up-to-date information on the accessibility and functionality of chargers. Two, for those EV drivers who value participating in a "community" of EV drivers, this feature is one way they do so.

Discussion

How might we expect the experiences of the EV drivers interviewed here to inform decisions about EV charging and information system development for the many more people are not yet EV drivers? A common feature of these EV drivers' accounts of their use of public EV charging is their willingness to tolerate "hassle." The study of hassle addresses the "irritating, frustrating, distressing demands and troubled relationships that plague us day in and day out" [12]. This study is intended to improve charging and information systems and as such, we emphasise the hassle experienced by this set of EV drivers and some possible solutions rather than emphasizing the occasions charging worked well. Still, of the 17 interviewees the only one who did not relate stories of their hassles using public charging is the one who had yet to use it.

Within the diffusion of innovation framework, Rogers describes innovators as "able to cope with the high degree of uncertainty about an innovation…the innovator must be willing to accept the occasional setback…" [13]. One can interpret this as innovators require a willingness to accept the ways an innovation can create hassles. The case that the EV drivers interviewed here—even those who are only now acquiring their first EVs—are innovators includes their willingness to assume risk, accept setbacks, and live with the ways in which an EV can be a hassle, including the need to discover chargers and the possible subsequent occurrence of an unavailable, inaccessible, or non-functional charger. These EV drivers' willingness to tolerate hassle and solve problems are not characteristics that diffusion of innovations assumes for any later market segments. However, even early EV buyers have limits on the hassle they are willing to tolerate. In contrast to improved information system functionality and more useful content, some EV drivers sought a different solution. They don't want EV charging to be one more thing they must actively manage. As a Tesla driver in Southern CA put it,

> "I just want to leave home and not have to think about it. I just want to leave home knowing there is charging if I need it."

The suggestions given by EV drivers for design improvements to chargers and public charging locations make the idealized charging location sound more like a modern gasoline station than a charger at the edge of an existing parking lot. To these suggestions we might add a few other general features of gasoline stations—obvious signage and predictable locations. However, many of these design changes and their implied the presence of a human attendant—all have ramifications for creating sustainable business models for EV charging.

Conclusions

Much analysis of EV charging infrastructure assumes that if EV charging exists, then EV drivers can and do find it without fail, the chargers work, and EV drivers successfully initiate and complete charging to their desired state of charge. Reports from EV drivers point to places in this chain of assumptions that require further interrogation. While specific improvements to information systems as well as charger design, location, and accessibility are suggested by these EV drivers, perhaps most useful of all is the overall framework these EV drivers reveal for stakeholders to think about EV charging. Every specific act of charging is the result of a chain of events that leads back as far as EV drivers' selection of which EV they are going to drive and from that action each subsequent link in the user-side of the chain of events from discovery, through availability and access to charging involves a parallel supplier-side chain of events. Viewed this way, improvements to EV charging—at-home, at-work, and out-in-public—implicate connected socio-technical networks of businesses, regulators, and drivers. Even as the results reported here describe only a small sample of EV drivers, the conceptual framework suggested by these EV drivers can organize research to address questions about the lived experience of reliable charging by individual EV drivers and sustainable business models for providing charging to all EV drivers.

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