RELATIVE IMPORTANCE OF FACTORS IMPACTING ELECTRIC VEHICLE CHARGING STATION USER EXPERIENCE: AN AHP APPLICATION

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Highlights

- For novice electric car owners, "pricing" is the most important factor affecting the charging station user experience.
- "Ease of use" becomes more important as users' duration of electric vehicle ownership increases.
- "Convenience" and "accessibility" are factors that are consistently considered important across all user groups.

ABSTRACT

The widespread adoption of electric vehicles can only be achieved by increasing individual mobility based on electricity, that is, by designing charging stations that meet the needs of electric vehicle owners. According to models that address usage intention/behavior (e.g., Technology Acceptance Model or Theory of Planned Behavior), the usability of the technology, as well as the benefits it provides, positively influences customer satisfaction. This, in turn, contributes to greater acceptance of the technology by users. This study aims to identify the key user experience factors and their relative importance levels for charging station usage from the perspective of Turkish electric vehicle owners. A literature review is conducted to identify these factors, and the importance of each factor is then determined using the Analytic Hierarchy Process (AHP), a multi-criteria decision-making method. The importance of these factors is assessed across different groups based on the duration of electric vehicle ownership. Results show that, as the duration of ownership increases, ease of use becomes more important, while pricing slightly loses its significance, though it remains one of the top three factors for all user groups.

Keywords (3-6): electric vehicle charging station, user experience, AHP.

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1. Introduction

It is known that one of the most important causes of climate change, the effects of which we are increasingly experiencing today, is the rise in carbon emissions. International political organizations and countries are seeking ways to reduce these emissions. It is estimated that about a quarter of the greenhouse gases emitted in the European Union originate from the transportation sector (Fabianek and Madlener, 2023). Therefore, supporting the use of both commercial and individual electric vehicles is one of the most effective steps to reduce carbon emissions to targeted levels. The widespread adoption of electric vehicles also largely depends on expanding charging station infrastructure. In Turkey, government incentives are being used to develop charging infrastructure with the participation of the private sector, so that charging stations, which have not yet reached a sufficient number or prevalence, do not constitute an obstacle to the growth of the electric vehicle market. Prioritizing usability in the design of stations within the charging infrastructure—expected to expand with these incentives—is an important element that will support the widespread use of electric vehicles. Usability and user experience refer to the experience of the user when interacting with a product or system. If the experience is positive across multiple dimensions (ease of use, satisfaction, aesthetic perception, feelings, etc.), it makes it easier for the user to adopt that product or service and increases their loyalty. Every new technology needs to offer both a good user experience and good usability to guarantee its success with customers and in the market (Rajanen, 2021).

2. Literature Review

Usability refers to “the degree to which a product can be used effectively, efficiently, and satisfactorily by specific users in a specific context of use to achieve specific objectives” (ISO, 1998). Therefore, the concept of usability is based on an understanding of user needs and preferences. Other concepts used interchangeably or interrelatedly with usability in the literature are user experience and quality of experience (Lallemand et al., 2015). In particular, the concept of user experience has been widely discussed in recent years. Although there is no clear consensus in the literature, it can be considered that user experience consists of three components: instrumental attributes (e.g., effectiveness and learnability, similar to the concept of usability), non-instrumental attributes (e.g., visual aesthetics and tactile quality), and emotional reactions (e.g., subjective emotions and motor expressions) (Thüring and Mahlke, 2007). In major user experience models, usability concerns for effectiveness and efficiency are included as 'pragmatic' or 'instrumental' attributes of a system, while the concept of satisfaction encompasses non-instrumental and emotion-evoking attributes of a system (Lallemand et al., 2015).

Regarding user experience, there are studies that address user preferences—also the antecedents of usability—specific to electric vehicle charging infrastructure. Visaria et al. (2022) revealed the preferences of Danish electric vehicle users in terms of charging station usage and charging behavior. Potoglou et al. (2023) investigated the factors affecting users' preferences for charging their vehicles at stations instead of at home. Similarly, Brückmann and Bernauer (2023) examined the factors that influence users to use charging stations in Switzerland. Fabianek and Madlener (2023) used multivariate decision-making techniques to identify the factors influencing users' experiences with charging stations in Germany. Zhang et al. (2020) examined the service quality of public charging stations in China, also using multi-criteria decision-making, and found that service capacity and operational efficiency were the two most important factors. Figenbaum et al. (2022) examined user

needs within the Norwegian charging infrastructure ecosystem. They found that users need to interact with up to 20-30 applications, different plug types, power levels, charger interfaces, and 13 payment systems to access all chargers, which poses a serious usability challenge.

Considering that there may be cultural differences in the importance given to user experience factors, and that being in different phases of the innovation diffusion process for electric vehicles may lead to different needs, a study examining the user experience of charging stations in Turkey can contribute to the literature. The results of the study may also contribute to the design of charging stations by considering the factors with higher weight, thus providing a more usable charging ecosystem for electric vehicle owners.

3. Hypotheses/Objectives

This study aims to identify the factors affecting user experience at electric vehicle charging stations and to determine the relative importance of these factors. To achieve this, a multi-criteria decision model will be developed based on a review of the literature, and the ranking of factor importance will be determined through evaluations based on user opinions of charging stations.

4. Research Design/Methodology

The factors (criteria in AHP) for charging station user experience have been determined based on a literature review. The factors are primarily based on the work of Fabianek and Madlener (2023). AHP has been adopted to determine the relative importance of the user experience factors. The hierarchy is simple and consists of only one level, containing nine factors. Based on the hierarchy model, a pairwise comparison questionnaire was developed and administered online. The questionnaire was mainly distributed via social media groups where electric vehicle users communicate with one another. Brief explanations of the factors are provided below:

Ease of Use: This refers to the hardware and interfaces being easy to understand, straightforward, and simple to use. It ensures that the charging process is completed smoothly.
Environmental Friendliness: This refers to whether the charging station is providing power from environmentally friendly, sustainable green energy sources. It allows users to know that their environmental impact is reduced.
Convenience: This refers to the comfort provided to users during the charging process. It includes facilities to meet various needs, such as covered waiting areas, seating arrangements, etc. The most frequently mentioned facilities in the literature are toilets, markets, and restaurants.
Functionality: The functionality of charging stations includes features such as compatibility with different vehicle models, fast charging, and various charging connection options.
Pricing: This refers to how budget-friendly the pricing at the charging stations is.
Price Transparency: This refers to the awareness of how much one will be charged for the service received at a charging station. It includes clearly presenting the prices to users before the start of the charging process.
Availability: Availability refers to the presence of available spots at a charging station when needed.

Accessibility: It is important that the charging station is located on roads and routes that are frequently used and easily accessible by users.
Power Reliability: This refers to the reliability of the power supplied by the station, ensuring that interruptions during charging or failed charges due to technical faults or operating errors are avoided.

5. Results/Model Analysis

Out of 54 respondents, 45 completed the survey. Only 5 of the 45 respondents are living in a city other than Istanbul. Respondents were also asked to provide the duration of their electric vehicle ownership. We divided the respondents into three groups based on the duration of their electric vehicle ownership: novices (1 year or less of ownership), familiars (2 to 4 years of ownership), and knowledgeables (5 or more years of ownership). Respondents' judgments were aggregated using the geometric mean method. Inconsistency ratios were computed, and all were below the 10% threshold. The general importance of criteria for all aggregated evaluations and the importance levels based on the duration of electric vehicle ownership are given in Table 1.

Table 1. Importance of criteria based on duration of electric vehicle ownership

General		Novices (1>= years of ownership	
Criteria	Priorities	Criteria	Priorities
Pricing	19.55%	Pricing	28.47%
Ease of use	18.46%	Convenience	14.24%
Accesibility	16.72%	Availability	13.78%
Convenience	11.64%	Accesibility	11.63%
Availability	10.87%	Functionality	10.93%
Environmental friendliness	6.59%	Ease of use	9.10%
Functionality	6.32%	Price transperancy	5.24%
Price transperancy	5.74%	Environmental friendliness	4.84%
Power reliability	4.11%	Power reliability	1.77%
Familiars (1-5 years of ownership)		**Knowledgeables (5<= years of ownership)**	
Criteria	Priorities	Criteria	Priorities
Ease of use	22.89%	Ease of use	19.45%
Accesibility	19.00%	Pricing	18.60%
Pricing	15.94%	Accesibility	16.21%
Convenience	9.25%	Convenience	12.45%
Environmental friendliness	9.24%	Availability	11.87%
Availability	8.37%	Price transperancy	6.06%
Price transperancy	5.32%	Functionality	5.90%
Power reliability	5.18%	Environmental friendliness	4.90%
Functionality	4.81%	Power reliability	4.58%

6. Conclusions

In general, the three most important factors affecting user experience at electric vehicle charging stations are pricing, ease of use, and accessibility. However, when we look at user assessments based on the length of time they have owned an EV, we find that for novices, pricing is by far the most important factor, with a weight of 28.47%. As ownership duration increases, ease of use becomes the most important factor, which novices had ranked sixth in importance.

As of October 2024, the share of electric vehicles in all vehicles in Turkey has reached 1%, nearly doubling from 0.5% at the end of 2023 (Oruc, 2024). This suggests that Turkish EV users are still early adopters, and early adopters are often willing to tolerate inconveniences when they are interested in new technology (Fabianek & Madlener). As users become more familiar with the technology, what once seemed new becomes ordinary over time, and their expectations from the technology often increase. This may explain why ease of use becomes more important for users who have owned EVs for a longer time.

Pricing seems to be the most important factor for novices, while it remains one of the top three factors for other user groups, though with significantly less importance. One key reason users switch from gas-powered vehicles to electric ones is to save on fuel costs. This likely plays a major role in their decision to make the switch and may also influence what they prioritize in the charging experience early in their electric vehicle ownership—focusing more on pricing at first, with its importance decreasing over time as the benefits of electric mobility begin to pay off.

Accessibility and convenience remain among the top five factors for all user groups. On the other hand, power reliability and price transparency are consistently rated as less important across all groups.

7. Limitations

We did not ask users how often they use public charging stations or whether they have charging solutions at home and/or at work. These factors can impact users' perspectives on what affects their user experience. Hence, an analysis considering the availability of charging solutions at home or work could have provided more extensive insights into users' preferences regarding the public charging station experience.

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