Transportation Research Part D 121 (2023) 103824

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Public charging choices of electric vehicle users: A review and conceptual framework

Dimitris Potoglou [*], Rongqiu Song, Georgina Santos

School of Geography and Planning, Cardiff University, CF10 3WA Cardiff, UK

ARTICLE INFO

Keywords:
Electric vehicles
EV charging
Public charging choices
Stated choice experiment
Revealed and stated preferences
EV charging speed

ABSTRACT

Studying electric-vehicle public-charging choices is an important aspect of accelerating electric-vehicle adoption. Understanding which factors would entice existing and potential users to charge their electric vehicles at public locations would provide important evidence for policy-makers, vehicle manufacturers and charging providers. The academic and grey literature has now matured to a point where a critical synthesis of the current state of knowledge is necessary. To fulfil this, this review provides a synthesis and critical discussion of the most up-to-date evidence on public charging choices based on which a conceptual framework to match choices and their determinants is devised. Research gaps and further empirical evidence required in this area, as these emerged from this review, include better understanding of the temporal patterns of public charging, users' preferences for different types of charging locations, payment models (monthly subscription, pay as you go) and payment methods.

1. Introduction

Increasing the market share of electric vehicles (EVs) is a potentially effective route to decarbonise road transport and improve air quality in cities (European Environment Agency, 2022). To successfully achieve this, reliable and sufficient charging infrastructure needs to be developed (Coffman et al., 2017; Liao et al., 2017). Charging points and associated services are currently divided into home, work, and public charging, with home charging being the most popular worldwide (Baresch and Moser, 2019; Chakraborty et al., 2019; Delmonte et al., 2020; Hardman et al., 2018). In 2018, for example, private chargers accounted for over 90% of global charging points (International Energy Agency, IEA, 2019). Although, home and workplace charging plays a fundamental role in fulfilling most potential and existing EV users' charging requirements, this does not mean public charging is not important (Hopkins et al., 2023; Jochem et al., 2022).

The study of public charging choices regarding the availability of public charging is important for building confidence in future EV purchases and in terms of addressing range anxiety and thus facilitating a faster transition to electric vehicle adoption (Greene et al., 2020; Kester et al., 2018; Santos and Davies, 2020). It is also crucial to study public charging choices for infrastructure planning in order to accommodate the existing demand for charging, and especially for EV owners without access to a driveway or a parking space with an EV charger. A better understanding of the public charging preferences of potential and existing EV users is of utmost importance for: the deployment of public chargers, such as where they should be placed; what charging speeds and public

---

[*] Corresponding author at: School of Geography and Planning, Cardiff University, Glamorgan Building, Room: 2.79, King Edward VII Avenue, Cardiff CF10 3WA, Wales, UK.

E-mail addresses: potogloud@cardiff.ac.uk (D. Potoglou), songr3@cardiff.ac.uk (R. Song), santosg@cardiff.ac.uk (G. Santos).

https://doi.org/10.1016/j.trd.2023.103824
Received 20 November 2022; Received in revised form 14 June 2023; Accepted 16 June 2023

Table 1
Review articles related to electric vehicle charging infrastructure.

Topic	Reference
The comparison of infrastructure across countries	Funke et al. (2019)
System architecture and international standards	Rajendran et al. (2021)
Players of infrastructure provision	LaMonaca and Ryan (2022)
Models of optimal charging locations	Kchaou-Boujelben (2021); Metais et al. (2022)
Infrastructure and grid integration	Das et al. (2020)
Charging strategy for freight	Teoh (2021)
Determinants of infrastructure economics for public charging	Zhang et al. (2018)
Consumers' charging preferences	Hardman et al. (2018)

infrastructure designs would be required; how they should be priced; how many and when they should be deployed; and what public charging information system should be made available to customers. Such knowledge would greatly benefit government decision-makers to tailor policies to regulate and support the deployment of public charging infrastructure, vehicle manufacturers to design and produce EV models that meet customers' preferences and maximise the efficiency of charging infrastructure, and public charging providers to plan future infrastructure and make related investment decisions. All of these together will support the development of an adequate public charging infrastructure for the future.

The inadequate provision of public EV charging infrastructure is a pressing problem, especially in the light of the announcements by several governments to bring forward more stringent CO_2 emission targets and restrictions on conventional petrol and diesel vehicles in urban areas. For example, the UK Government plans for at least 50% of new registrations to be low emission vehicles by 2030. This target requires the number of charging points to increase tenfold – i.e., from 25,000 public charging points currently available to 280,000 by 2030 (Competition & Markets Authority, CMA, 2021). More generally, this is an emerging challenge, particularly for high-density urban areas. For example, nearly half of households in Europe live in multi-family buildings and would face significant challenges to install a home charging point due to the type of dwelling they live in (Azarova et al., 2020). For many of these households, workplace and public charging would be essential. As a result of all this, it is imperative that the coverage of public charging infrastructure is maximised.

The literature on public charging choices has now reached a mature stage with a substantial amount of empirical evidence being published in the academic and grey literature (see Tables A1 and A2 in the Appendix A). This literature review is designed to provide a synthesis of the current-state-of-knowledge and do so beyond anecdotal evidence or an unstructured pull of references. The synthesis generated in this study provides solid evidence for researchers entering this field of study and would benefit charging point operators, vehicle manufacturers and decision-makers to help them plan, design and supply public charging. Better knowledge of public charging choices in turn will: (a) attract potential EV users who have less knowledge about EV and EV charging, (b) attract existing and potential EV users who are risk-averse towards range, and (c) attract potential EV users who would be unable to charge their vehicles at home because of the type of dwelling they live in.

Table 1 summarises previous literature reviews on charging infrastructure focused on a comparison of infrastructure across countries (Funke et al., 2019), system architecture and international standards (Rajendran et al., 2021), players of infrastructure provision (LaMonaca and Ryan, 2022), models of optimal charging locations (Kchaou-Boujelben, 2021; Metais et al., 2022), infrastructure and grid integration (Das et al., 2020), and charging strategy for freight (Teoh, 2021).

To the best of our knowledge, only the review by Zhang et al. (2018) focused on examining the determinants of the economic aspects of public charging points, which differs from the subject of enquiry in this present paper. Hardman et al. (2018) reviewed studies on consumers' charging preferences more generally rather than for public charging. The usage habits of home charging and public charging are completely different in terms of temporal patterns (e.g. time and frequency of use). This is not trivial, and therefore conducting a literature review to understand the factors of existing and potential EV users' choices regarding public charging is in order. This is particularly important and it needs to be examined separately from home charging considerations. In addition, Zhang et al. (2018) and Hardman et al. (2018), although very informative, are now five years old, which, in a context of a rapidly developing field, calls for an update on the 'stock of knowledge'. This is exactly what this article intends to do, by providing an up-to-date source of reference to an emerging and increasingly important aspect of the electrification of road transport and the deployment of public charging infrastructure for electric vehicles.

This critical review of the literature is aimed at synthesising the published academic and grey literature on public charging choices and answering the following questions: (1) How were public charging choice studies designed, implemented and analysed? (2) What factors are likely to determine public charging preferences? (3) Are preferences heterogeneous? If yes, what are the factors that may explain heterogeneity in preferences? (4) What are the areas for future research?

In the remainder of this paper, Section 2 provides a summary of studies including study design and analytical approach, respondent profiles, countries of study, and type of choices studied. Section 3 discusses the explanatory factors found to be associated with public charging choices. Section 4 presents findings regarding observed and unobserved heterogeneity in choices for public charging. Section 5 summarises the findings and offers a conceptual framework, which captures how explanatory factors are linked with public charging choices. Finally, Section 6 summarises the research gaps in the area of public charging choices and provides recommendations for future research.

2. Methodology

This targeted critical literature review identified relevant academic publications via three repositories: Web of Science, Scopus and Google Scholar. The keywords used to identify these studies were: 'charging preferences' OR 'choices' and 'electric vehicles'. The searches were limited to journal articles published in English from 2016 onwards to obtain an up-to-date picture of the literature and its emerging findings. In addition to academic sources, the study targeted relevant grey literature from government, research institutes, and national laboratories.

2.1. Overview of the literature related to public charging choices

Table A1 in the Appendix A summarises relevant studies on public charging choices and preferences. The majority of studies utilised stated choice experiments, including experiments where preferences were elicited in a hypothetical electric-vehicle charging scenario. There were also a few of studies that employed revealed preferences, where actual charging choices were observed. For example, some studies collected data from EV trials, such as Chakraborty et al. (2019), Kim et al. (2017), Lee et al. (2020), Sun et al. (2016), Xu et al. (2017), and Yu and MacKenzie (2016).

Participants involved battery electric vehicles (BEV) users (e.g. Li et al., 2023; Visaria et al., 2022; Zhang et al., 2022), plug-in hybrid electric vehicle (PHEV) users (e.g. Chakraborty et al., 2019; Sheldon et al., 2019), and potential EV users (e.g. Gutjar and Kowald, 2023; Ma et al., 2022). In terms of study recruitment strategies, some studies used social-media platforms such as LinkedIn, Facebook, Twitter, and Wechat (Ge and MacKenzie, 2022; Latinopoulos et al., 2017; Pan et al., 2019; ten Have et al., 2020), EV driver associations and forums (Ge et al., 2018; Ge and MacKenzie, 2022; Latinopoulos et al., 2017; Visaria et al., 2022; Wen et al., 2016), and charging service network providers (Kim et al., 2017; Visaria et al., 2022). In many cases, researchers collaborated with sample service providers (e.g. internet panels, professional survey companies, online crowdsourcing platforms) to recruit respondents (Latinopoulos et al., 2017; Ma et al., 2022; Moon et al., 2018; Nienhueser and Qiu, 2016; Sheldon et al., 2019; Zhang et al., 2022), whereas others used official vehicle registration databases (Anderson et al., 2018; Chakraborty et al., 2019; Lee et al., 2020) or lists of postal addresses to send invitations, which were then followed with phone calls (Gutjar and Kowald, 2023).

Sample sizes ranged from hundreds to thousands of respondents. The sample sizes of EV users were usually in the hundreds, but if there were official registration databases available, then the number of respondents could reach several thousands (Anderson et al., 2018; Chakraborty et al., 2019; Lee et al., 2020). The reviewed evidence comes from the US (Ge et al., 2018; Ge and MacKenzie, 2022; Nienhueser and Qiu, 2016; Wen et al., 2016; Yu and MacKenzie, 2016), with the state of California being the focus of some papers (Chakraborty et al., 2019; Lee et al., 2020; Sheldon et al., 2019), China (Li et al., 2023; Ma et al., 2022; Pan et al., 2019; Wang et al., 2021; Zhang et al., 2022), and its capital, Beijing (Pan et al., 2019; Wang et al., 2021), Japan (Sun et al., 2016; Xu et al., 2017), South Korea (Moon et al., 2018), the Netherlands (Kim et al., 2017; ten Have et al., 2020; Wolbertus and van den Hoed, 2019), Denmark (Visaria et al., 2022), Germany (Anderson et al., 2018; Wolff and Madlener, 2019), and the UK and Ireland (Latinopoulos et al., 2017).

All reviewed studies involved choices of public charging infrastructure with slow, fast or ultrafast charging with the study outcome (choice studied) being: (1) charging (or not) at public charging stations (Ge et al., 2018; Ge and MacKenzie, 2022; Li et al., 2023; Pan et al., 2019; Wang et al., 2021; Wen et al., 2016; Yu and MacKenzie, 2016; Zhang et al., 2022); (2) choice of type of public charging (Anderson et al., 2018; Gutjar and Kowald, 2023; Ma et al., 2022; Moon et al., 2018; Nienhueser and Qiu, 2016; Sheldon et al., 2019; ten Have et al., 2020; Visaria et al., 2022; Wolbertus and van den Hoed, 2019), and (3) choice across home, place of work or public charging point, or a mix of locations (Chakraborty et al., 2019; Lee et al., 2020; Wolff and Madlener, 2019; Xu et al., 2017).

In terms of type of charging, the majority of published articles did not specify whether it was en route or destination charging. Only four studies focused on en route charging (Ge and MacKenzie, 2022; Li et al., 2023; Sun et al., 2016; Visaria et al., 2022), while five articles looked at destination charging (Latinopoulos et al., 2017; Ma et al., 2022; Pan et al., 2019; Wang et al., 2021; Wen et al., 2016). Regarding charging power, only two articles focused specifically on fast charging (Sun et al., 2016; Visaria et al., 2022), which was generally adopted for charging, while the five studies that looked at destination charging, three of which mentioned the power of public charging infrastructure, were mainly focused on both slow and fast public charging (Ma et al., 2022; Wen et al., 2016).

Only three studies specified the type of trips made by EV users, with two studies focusing on long-distance trips (Ge and MacKenzie, 2022; Visaria et al., 2022), and one study looking at commuting trips (Chakraborty et al., 2019). Four studies did not specify the type of trip in their charging scenario, but did mention that these trips were to home (Ma et al., 2022; Pan et al., 2019; Wang et al., 2021), workplace (Ma et al., 2022; Wang et al., 2021; Zhang et al., 2022), shopping (Pan et al., 2019; Wang et al., 2021) or recreation (Zhang et al., 2022). The type of trip (commute, leisure, long-distance) was closely associated to the type of charging, with long-distance trips mainly associated with en route charging (Ge and MacKenzie, 2022; Visaria et al., 2022), and commute and leisure trips in the context of a shopping centre/workplace/home mainly associated to destination charging (Ma et al., 2022; Pan et al., 2019; Wang et al., 2021).

In general, very few studies extended their analyses to derive the relative value of attributes such as willingness-to-pay (WTP). As shown in Table A1 (see, Appendix A), only five studies, which focused exclusively on EV users (Ge and MacKenzie, 2022; Nienhueser and Qiu, 2016; Visaria et al., 2022; Wang et al., 2021; Wen et al., 2016), and three studies on current and potential EV users (Ma et al., 2022; Sheldon et al., 2019; Wolff and Madlener, 2019) estimated the WTP for different attributes related to public charging choices, although many studies involved 'payment vehicles' (e.g. charging cost) as part of their stated choice experiment (Ge et al., 2018; Latinopoulos et al., 2017; Moon et al., 2018; Pan et al., 2019; ten Have et al., 2020; Wolbertus and van den Hoed, 2019).

The WTP estimates computed in these eight studies are summarised by country (i.e., Denmark, US, China, and Germany) in Table A3 in the Appendix A. The relative valuation was estimated for charging location (Sheldon et al., 2019; Wolff and Madlener, 2019), cost in relation to detour time (Visaria et al., 2022), power (Sheldon et al., 2019; Visaria et al., 2022; Wen et al., 2016) and

Table 2
Temporal attriutes associated with public charging choices.

Attribute	Effect [positive / negative]	(Association) Study
Time of day	Midnight [−] Charging hours [+]	Xu et al. (2017) **[1]**: 23:00––7:00; Ma et al. (2022) [2]: 10:00–17:00, 17:00–22:00, 22:00–10:00 + 1
Weekday vs. weekend	Working day [+]	Xu et al. (2017) **[1]**: for commercial BEVs using slow company and fast public charging
	Trip chain on working days [+]	Zhang et al. (2022) **[2]**
Charging interval/ frequency	Weather conditions (high temperatures, strong winds, heavy precipitation) [−]	Kim et al. (2017) **[3]**
	Days interval for next trip [−]	Xu et al. (2017) **[1]**: only important for commercial BEVs

Notes: references marked in bold refer to results that are specifically applicable to EV users, including Plug-in Electric Vehicles (PEVs)[1], BEVs, or PHEVs users, while studies in regular fonts were relevant to potential users; the superscripts in the table represent: [1] Japan; [2] China; [3] Netherlands.

[1] PEVs refers to plug-in electric vehicles and includes BEVs and PHEVs.

duration (Ge and MacKenzie, 2022; Wolff and Madlener, 2019), number of chargers (Visaria et al., 2022), amenities (Ge and MacKenzie, 2022; Visaria et al., 2022), state of charge and excess range (Wang et al., 2021), waiting (Wolff and Madlener, 2019) and access time (Ge and MacKenzie, 2022), renewable energy (Nienhueser and Qiu, 2016; Wolff and Madlener, 2019), inductive charging technology (Wolff and Madlener, 2019), deviation from planned route (Ge and MacKenzie, 2022), and time period of day (Ma et al., 2022).

The analyses of choices mainly employed discrete choice models and included binary logit models (Li et al., 2023; Pan et al., 2019; Wang et al., 2021), multinomial logit (MNL) models (Gutjar and Kowald, 2023; Lee et al., 2020; Ma et al., 2022; Sheldon et al., 2019; Wolff and Madlener, 2019), mixed logit (MXL) models (Gutjar and Kowald, 2023; Ma et al., 2022; Moon et al., 2018; Nienhueser and Qiu, 2016; Sheldon et al., 2019; Sun et al., 2016; ten Have et al., 2020; Visaria et al., 2022; Wang et al., 2021; Wen et al., 2016; Wolbertus and van den Hoed, 2019; Xu et al., 2017; Yu and MacKenzie, 2016), and latent class discrete choice (LC) models (Ge et al., 2018; Ge and MacKenzie, 2022; Pan et al., 2019; Wang et al., 2021; Wen et al., 2016; Yu and MacKenzie, 2016), random parameter logit (RPL) models and random parameter logit with error components (RPLEC) models (Li et al., 2023), recursive simultaneous bivariate probit (RSBP) models (Zhang et al., 2022), and dynamic discrete choice (DDC) models (Ge and MacKenzie, 2022).

Many binary logit and MNL models captured respondents' taste heterogeneity, i.e. how choices varied across respondents given observed characteristics (e.g., socio-economic or demographic characteristics). Some MXL and LC models captured the effect of unobserved characteristics (e.g., level of risk aversion or charging concerns) assuming continuous or discrete distribution of related parameters (weights) of charging attributes. Similar to MXL, RPL and RPLEC models also examine unobserved heterogeneity in individual preferences for route and charging-or-not choices en route, by modelling the random parameters and error components.

Trip chain choices and charge-or-not choices were analysed using the RSBP model, which is a statistical model used to analyse the relationship between two binary dependent variables that may be jointly determined (Zhang et al., 2022). To take into account the effect of time, DDC models were used to analyse how EV users made charging decisions over time with a sequence of charging opportunities en route, which allows to understand how past decisions affect future charging choices (Ge and MacKenzie, 2022). Kim et al. (2017) estimated a latent class hazard duration (HD) model, which allowed for the inclusion of duration dependence, unobserved heterogeneity and the effects of time-varying covariates, and for the treatment of charging regularity as a latent variable. There was also a study in which the heterogeneity of respondents' attitudes towards risk was captured using "Expected Utility Theory", "Rank-dependent Expected Utility Theory", and "Prospect Theory" models (Latinopoulos et al., 2017). These approaches, as the authors argued, were suitable for choices with uncertain outcomes (e.g. presence of dynamic charging prices; charge now or wait for lower price).

In parallel, there have been several initiatives across government departments and agencies to capture and report aspects of public transport infrastructure choices for potential and existing EV users. Examples include the California Air Resources Board (2019), the California Energy Commission (Bedir et al., 2018), and the National Renewable Energy Laboratory (Wood et al., 2017) in the United States. In the UK, there have been several studies undertaken by the Department for Transport (Department for Transport, 2022b; Department for Transport, 2022a), the Electric Vehicle Association, England (Hink, 2021), Transport Scotland (2021), and the National Grid ESO (Dodson and Slater, 2019). Also, another study was undertaken on behalf of the Energy Efficiency and Conservation Authority in order to understand public charging choice and improve the user experience in New Zealand (Burroughs et al., 2021). The determinants examined in these studies, the number of respondents, and the modelling approach are summarised in Table A2 in the Appendix A.

Most of these reports conducted stated preference surveys involving potential and existing EV users (Department for Transport, 2022b; Department for Transport, 2022a; Hink, 2021). Only the New Zealand (Burroughs et al., 2021) and the National Grid ESO (Dodson and Slater, 2019) studies analysed actual charging choices (releveled preferences) and charging events of existing EV users, respectively. The survey-based samples of potential and existing EV users across these studies were around 1,000 whereas those involving the study charging events of EVs reached several million records. The reports presented descriptive statistics instead of statistical models to identify the factors driving public charging choices.

3. Determinants of individual public charging choices

The thematic analysis of the literature identified four categories of determinants associated with public charging choices: (1) temporal, (2) vehicle, (3) charging infrastructure, and (4) individual attributes. These are discussed in detail in the following subsections.

3.1. Temporal attributes

The temporal characteristics of public charging for electric vehicles (EVs) refer to the patterns of charging-point usage over time, including when and how often charging occurs. Understanding these temporal characteristics is essential for designing and managing efficient and accessible public charging to meet the needs of existing and potential EV users (Gellrich et al., 2022). A summary of temporal attributes and their levels is listed in Table A4 in the Appendix A. The value that potential and existing EV owners place on the 'time of the day' and 'day of the week' can inform the pricing strategies of charging service providers.

Table 2 presents a summary of positive and negative effects of temporal attributes. These temporal attributes can be further categorised into three groups: (a) time of day, (b) weekday (vs. weekend) and (c) charging interval/frequency. In the corresponding studies, the 'time of day' either considered day vs. midnight charging choices or different time periods for public charging during the day. 'Weekday vs. weekend' attribute refers to public charging preference variations between weekdays and weekends. The 'charging interval/frequency' attribute was used to capture the effect of environmental conditions and on charging choices.

Unlike private home charging, which is more likely to occur overnight (Langbroek et al., 2017; Sun et al., 2018), public charging was the preferred method of EV charging during the day (Ma et al., 2022; Moon et al., 2018). This is evident by both observed charging data at charging points and preference-based studies. For example, Helmus and Wolbertus (2023) examined over 2 million charging sessions at 1,689 public charging stations in Amsterdam, the Netherlands, and confirmed that public charging was more popular between 8:00 and 23:00, with a peak between 16:00 and 19:00. Also, the National Grid ESO report in the UK (Dodson and Slater, 2019) analysed 8.3 million charging events across the country and found that slow/fast public charging contributed to a smaller secondary peak in the morning between 9:00 and 10:00 on weekdays.

Another source of real-world charging data is the BEVs themselves. For example, Märtz et al. (2022) studied 2.6 million charging sessions from approximately 21,000 BEVs across Germany for over a year. The analysis of the vehicles' charging patterns provided insights on the distance driven between charging sessions, charging frequency and energy requirements per BEV. Based on these data, the authors were able to identify different vehicle-user groups ('clusters') according to their vehicles' temporal charging patterns and inferred the demand for potential charging points according to identified electricity load curves. Observed charging sessions can complement revealed and stated preference studies when investigating potential demand for public charging points.

As shown in Table 2, Xu et al. (2017) modelled actual (revealed) charging choices across three options: home-slow, public-slow and public-fast charging of EV users in Japan. Their study found a positive association between home charging and a negative association with fast public charging during midnight. Also, Ma et al. (2022) introduced two different charging plans, as part of a stated choice experiment for public charging, with each plan proving the time period during which charging would occur, the cost of charging, 'walking distance to home/work', and the 'type of charger (slow/fast)'. Ma et al. (2022) showed that WTP for public charging was highest between 17:00–22:00 on weekdays and lowest for that same time period at weekends (see, Table A3 in the Appendix A).

In Japan, Xu et al. (2017) found no significant difference in choices made by EV users across slow-home, slow-public and fast-public charging between working days and weekends. However, relative to weekends, business EV users exhibited a significantly higher preference for fast charging at public stations and then slow charging at the workplace during working days. These findings were consistent with the report by Dodson and Slater (2019) for the UK, which found that the overall demand for charging at weekends was approximately 25 lower %, on average, than on weekdays.

The difference in public charging preferences between weekdays and weekends could be associated with travel purpose/type of travel (Xu et al., 2017; Zhang et al., 2022). For example, long-distance travel usually takes place at weekends and local commute/business travel normally occurs on weekdays. Longer and more complex trip chains involving two or more destinations are more likely to occur on working days, and this observation may explain the corresponding preferences for public charging (Zhang et al., 2022). As a result, it is important to consider travel purpose when studying public charging choices.

The study of 'inter-charging times,' which can be defined as the time-interval between charging sessions, also offers interesting insights. For example, Kim et al. (2017) reported data from charging sessions at public charging stations over a four-year period in the Netherlands and found that 90% of their sample charged their EV randomly at public charging stations, and 10% of their sample did so regularly. The inter-charging times were, on average, 5.65 days and 2.75 days, respectively, with the regular users being more likely to charge their vehicle at a specific charging station (Kim et al., 2017). Charging intervals were significantly associated with weather conditions such as high temperatures, strong winds, and heavy precipitation. These weather conditions might have caused EV users to postpone charging at a public charging point. The authors suggested that providers might mitigate the negative impact of weather on public charging choices by 'minimising exposure' to harsh weather; for example, by reducing walking distance and/or improving shelters (Kim et al., 2017).

3.2. Vehicle attributes

Several studies reported that public charging demand was significantly associated with driving range due to EVs' different battery capacities (Chakraborty et al., 2019; Li et al., 2023; Xu et al., 2017) and charge status, such as low battery state of charge (SOC) (Pan

Table 3
Vehicle attriutes associated with public charging choices.

Attributes	Effect	Studies
Driving range	• Long driving range[1] [−]	• Xu et al. (2017) **[1]:** for commercial BEVs using fast public charging
	• Tesla owner [+]	• Chakraborty et al. (2019) [4]
	• Electric range for PHEVs [+]	• Chakraborty et al. (2019) [4]
	• Electric range for PHEVs × Multi−point charging [−]	
Charge status	• Current state of charge (SOC) [−]	• Li et al. (2023) [2]; Wang et al. (2021) [6]; Pan et al. (2019) [6]; Xu et al. (2017) [1]; Ge and MacKenzie (2022) [5]; Zhang et al. (2022) [2]
	• Mean of initial AR at origin [+], mean of average AR at the destination [+], mean of AR uncertainty [−] (the range of the AR interval)	• Li et al. (2023) [2]: **not to charge preference**
	• BEV remaining range [−]	• Zhang et al. (2022) [2]
	• Excess range [−]	• Wang et al. (2021) [6]
	• Excess range to home [−], range is enough to next charging opportunity [−]	• Wen et al. (2016) [5]

Notes: AR: available range; references marked in bold refer to results that are specifically applicable to EV users, including PEVs, BEVs, or PHEVs users, while regular fonts indicate studies of potential users; the superscripts in the table represent: [1] Japan; [2] China; [4] California, US; [5] US; [6] Beijing, China.

[1] The 'driving range' is the distance an EV or a PHEV can travel using the electricity stored in its battery, thus a higher battery capacity will result in a higher average driving range. In the case of PHEVs, of course, the vehicle will be powered on fuel once the battery has depleted.

et al., 2019; Wang et al., 2021; Xu et al., 2017; Zhang et al., 2022), available/remaining range (Li et al., 2023; Zhang et al., 2022), and insufficient excess range to the planned destination (Pan et al., 2019; Wang et al., 2021; Wen et al., 2016) or the next opportunity to charge the vehicle (Wen et al., 2016). Whilst the capacity of the battery and driving range are fixed, the SOC and the excess range are not. The positive and negative effects of these determinants on public charging choices across countries or cities in the reviewed studies are shown in Table 3 and a summary of attributes and their levels is presented in Table A5 in the Appendix A.

As shown in Table 3, Chakraborty et al. (2019) found that a higher driving range of PHEVs might entice drivers to use public charging (vs. home or workplace), which is a counter-intuitive result. The reason behind this counter-intuitive result could be one of PHEVs in the study included in the study, namely the BMW i3s (with the range extender). This particular car model can potentially benefit from fast (and possibly free) charging sessions at public locations. On the other hand, the authors found that multiple stops for public charging along the route were less likely to occur when the driving range of the PHEV was higher, which is an intuitive result, as PHEV drivers can start and finish their trips on electric mode with a single charge. The study also showed that owners of a Tesla with a relatively larger battery capacity were more likely to use public charging stations than owners of other EVs available on the market (Chakraborty et al. 2019). In Japan, although Xu et al. (2017) reported no significant association between public charging and the availability of fast chargers, they did find that company EV car users were less likely to use a fast public charger when a slow charger was available at the workplace.

Insufficient charge status of EVs can trigger range anxiety and incentivise users to opt for public charging (Pan et al., 2019; Wang et al., 2021; Wen et al., 2016; Xu et al., 2017). The charge status of an EV is commonly expressed by three attributes, including the current SOC, the remaining range/ available range and the excess range. SOC is the current charge level displayed on the dashboard of an EV whereas the remaining range / available range shows the distance that the vehicle can travel at the existing SOC, and the excess range is defined as the difference between the range at SOC and the distance to the destination.

Previous studies showed users' decisions to use public charging were negatively associated with SOC (Pan et al., 2019; Wang et al., 2021; Xu et al., 2017), initial available range at the origin, average remaining range at the destination (considering any uncertainties such as traffic conditions) (Li et al., 2023), excess range to the destination (Wang et al., 2021; Wen et al., 2016) and next charging opportunity (Wen et al., 2016). In terms of driver characteristics, BEV users with little driving experience (less than1.5 years) were more concerned about average remaining range at the destination and therefore were more likely to use public charging than those with more driving experience (Li et al., 2023).

In terms of the relative valuation of vehicle characteristics, Wang et al. (2021) reported: (a) when the SOC decreased by 10%, users were willing to pay an increased charging rate of £0.083/kWh (or 0.7 yuan/kWh), and (b) when the excess range decreased by 10 kms, users were willing to pay additional charge of £0.041/kWh (0.346 yuan/kWh). Finally, Li et al. (2023) reported that higher uncertainty regarding the remaining/available range of a BEV at destination would entice users to charge their BEV at a public charging point and the effect was higher for women and those on lower incomes.

3.3. Charging infrastructure attributes

Important attributes of charging infrastructure as reported in the reviewed studies included: (1) physical attributes, (2) charging price, (3) speed, (4) accessibility, (5) convenience, and (6) charging-point information. As shown in Table 4, several studies suggested that EV users would prefer public charging points that are cheaper to use, equipped with high-power chargers and thus shorter

Table 4
Infrastructure charging attributes associated with public charging choices.

Attributes	Effect	Studies
Physical attributes	Priority of charging points at: • Home (base/reference) vs. (1) work [−], (2) road: charging as side activity [−], (3) road: charging as main activity [−]; • Entertainment (base/reference): (1) Grocery store [+], (2) shopping centre [+], (3) short, near home [+], (4) short, by freeway [+], (−1) gym [−], (−2) school [−]; • Gas stations [+];	• Wolff and Madlener (2019) [9] • Sheldon et al. (2019) [4] • Sun et al. (2016) [1]
	Amenities: • Toilets [+], all facilities (toilets, restaurant and supermarket) [+]; • Toilets, dining and WiFi compared with no amenities at all [+]; • No facilities nearby for slow and fast public charging [+], shopping area for slow public charging [+], small shop/café for slow public charging [−]	• Visaria et al. (2022) [10] • Ge and MacKenzie (2022) [5] • ten Have et al. (2020) [3]
	• Charging power [+]	• Ma et al. (Ma et al., 2022) [2] • Wen et al. (2016) [5]
	• Harsh weather [−]	• Kim et al. (2017) [3]
	• Number of charging points [+]	• Visaria et al. (2022) [10]
Prices	• Public charging prices [−]	• Please see Table A7 in the Appendix
	• Home charging, at electricity rate paid at home [+] for BEV and not significant for PHEV users	• Lee et al. (2020) [4]: for BEV owners
	• Free workplace charging, not significant for BEV and [−] for PHEV users	• Lee et al. (2020) [4]: for PHEV owners
	• Electricity cost if charge at this stop after the travel day [−], gasoline (petrol) cost if charge at this stop after the travel day [−]	• Ge et al. (2018) [5]: for PHEV
	• Parking price [−]	• Pan et al. (2019) [6]
	• Network membership [+]	• Lee et al. (2020) [4]; Chakraborty et al. (2019) [4]
Charging station level of service	• Charging time [−]	• Ge and MacKenzie (2022) [5]; Sheldon et al. (2019) [4]; Wolbertus and van den Hoed (2019) [3];Wolff and Madlener (2019) [9]; Moon et al. (2018) [7]
	• Waiting time [−]	• Wang et al. (2021) [2]; Wolff and Madlener (2019) [9];
	• Certainty of charging point availability [+]	• ten Have et al. (2020) [3]: for slow and fast public charging
	• Parking time [+]	• Wang et al. (2021) [2]
	• Dwell time > 30 min [+]	• Wen et al. (2016) [5]
Accessibility	• Coverage of charging facilities in trip chain [+]	• Zhang et al. (2022) [2]
	• Density of public charging stations [+]	• Xu et al. (2017) [1];
	• Distance to access public charging stations [+]	• Ma et al. (Ma et al., 2022) [2]; Moon et al. (2018) [7]
	• Access time [−]	• Ge and MacKenzie (2022) [5]
	• Detour to public charging stations [−]	• Sun et al. (2016) [1]
	• Not having to make a detour [−]	• ten Have et al. (2020) [3]: for ultrafast charging
	• Deviation from the original plan [−]	• Ge and MacKenzie (2022) [5]
Convenience	• Inductive charging [+]	• Wolff and Madlener (2019) [9]
	• Self-service charging [+]	• Moon et al. (2018) [7]
	• Plug and charge authentication [+]	• Gutjar and Kowald (2023) [9]
	• The availability of card-based payment [+]	• Gutjar and Kowald (2023) [9]
Charging point information online	• Location, price, status [+]	• Moon et al. (2018) [7]
	• Share of renewable resources [+]	• Wolff and Madlener (2019) [9]; Nienhueser and Qiu (2016) [5]

Notes: references marked in bold refer to results that are specifically applicable to EV users, including PEVs, BEVs, or PHEVs users, while regular fonts indicate studies of potential users; the superscripts in the table represent: [1] Japan; [2] China; [3] Netherlands; [4] California, US; [5] US; [6] Beijing, China; [7] South Korea; [8] New Zealand; [9] Germany; [10] Denmark.

charging times, offering convenience and accessibility to other activities and amenities and enhanced information systems (see, also Tables A6 – A11 in the Appendix A).

3.3.1. *Physical attributes*

The physical infrastructure attributes of a public charging station include location, power, number of charging points, and nearby amenities. Previous studies showed that, when modelled against home and workplace charging, public charging was the least popular option across EV drivers (Chakraborty et al., 2019; Lee et al., 2020; Xu et al., 2017), PHEV drivers (Chakraborty et al., 2019; Lee et al., 2020) and potential EV drivers (Wolff and Madlener, 2019) (see, Table A6 in the Appendix A).

In general, it is hard to derive a universal order of location preferences for public charging due to the geographic differences in data and varied location alternatives considered in the reviewed studies (Anderson et al., 2018; Department for Transport, 2022b; Philipsen et al., 2016; Sheldon et al., 2019; Wolff and Madlener, 2019). Table A6 in the Appendix A summarises the findings regarding public charging preferences of current and potential EV users for different locations. As shown in Table 4, the choice of location involved the choice between public charging, workplace charging and home charging, or a choice across several public locations (Sheldon et al., 2019; Sun et al., 2016; Wolff and Madlener, 2019). For example, using a choice experiment, Sheldon et al. (2019) found that potential EV users in California were more likely to charge their vehicle at home than at work or at a public charging point. Wolff and Madlener (2019) reported that potential EV users in Germany were more likely to choose grocery stores and shopping centres to charge their EVs and less likely to do so at gyms and schools when compared to entertainment venues, which was the reference category.

The relative valuation of location preferences expressed in terms of WTP were reported either at the charging session level (Sheldon et al., 2019) or as monthly payment as part of a subscription with a charging provider (Wolff and Madlener, 2019). Californian respondents were willing to pay up to £2.31 ($2.81) to charge at a grocery store (the highest valuation in the study) whereas they would be seeking compensation, reported as willingness to accept, of up to £1.01 ($1.23) to charge their vehicle at a school. Under a monthly payment model, German EV users would accept between £19.70/month (€22.31/month) to charge their vehicle at work and £40.84/month (€46.26/month) to charge their vehicle on the road and while en route instead of their home.

Overall, several studies reported a significantly higher preference for faster charging speeds both amongst EV users (Wen et al., 2016) and also potential EV users (Ma et al., 2022). For example, in a stated choice study for the US, Wen et al. (2016) found that owners of plug-in electric vehicles (PEVs, which include BEVs and PHEVs) prioritised charging their vehicles at stations with the highest (50 kW) and second highest power (6.6 kW) over stations with the lowest charging power (1.9 kW). Similarly, in a stated choice study for China, Ma et al. (2022) found that Chinese consumers preferred fast charging compared to slow charging. The willingness to pay (WTP) for fast charging was also estimated in a number of studies. Danish EV drivers, for example, were willing to detour for 0.28 min for an extra km per minute of charging, equivalent to £0.052 (0.44 DKK) using the 2020 official Danish value of travel time (Visaria et al., 2022). US drivers were willing to pay, on average £0.041 ($0.05), for an extra mile per minute of charging (Sheldon et al., 2019), and £1.58/hr ($1.91/hr) to use Level 2 instead of Level 1 charging (Wen et al., 2016).

The number of charging points, also expressed as the ratio of available over unavailable chargers, was an important attribute for BEV users' public charging choices (e.g. Visaria et al., 2022). Similar findings were reported across studies by the National Renewable Energy Laboratory (Wood et al., 2017) and the California Energy Commission (Bedir et al., 2018), and the Energy Efficiency and Conservation Authority in New Zealand (Burroughs et al., 2021). The relative valuation for charging points was expressed as WTP for an available charger. For example, Visaria et al. (2022) estimated that Danish EV users were willing to make a 7.87-minute detour (valued at £1.46 or 12.32 DKK) to reach an available charger, and a 0.53-minute detour (valued at £0.099 or 0.83 DKK) to reach an occupied charger, respectively.

Amenities around public charging stations are expected to compensate for longer waiting times relative to refuelling and, unsurprisingly, have been reported as being important for public charging choices (Ge and MacKenzie, 2022; ten Have et al., 2020; Visaria et al., 2022). As shown in Table 4, examples of preferred amenities included shopping areas around slow public charging points (ten Have et al., 2020) or different attribute-levels with a mix of points of interest such as toilets, supermarkets, and restaurants. Studies also reported significant observed variations in preferences across the surveyed participants. For example, EV users over 60 years of age or households with children were more likely to use public charging services where toilets, supermarkets, and restaurants were available (Visaria et al., 2022). However, there were some counterintuitive findings too. For example, ten Have et al. (2020) reported that the absence of amenities near slow, fast, and ultra-fast charging increased the likelihood of EV users charging at these charging points.

The relative valuation of amenities was expressed in terms of WTP to charge at a location with a specific type of service. Visaria et al. (2022) estimated that relative to 'no amenities nearby', EV users in Denmark were willing to make a 1.23-minute detour (valued at £0.23 or 1.93 DKK) to have toilets at the charging station, and a 9.55-minute detour (valued at £1.78 or 14.97 DKK) to have toilets, restaurants and supermarkets. EV users in the US were willing to pay, on average, £17.25 ($21) for the availability of toilets, dining facilities and Wi-Fi (Ge and MacKenzie, 2022).

3.3.2. Price

The price to charge the battery of a vehicle at public charging stations was introduced using various payment arrangements including: (1) a charging time based fee (Ge et al., 2018; Nienhueser and Qiu, 2016; Wen et al., 2016) (e.g., 5.00 $/h), (2) a kWh based fee (Ge and MacKenzie, 2022; Latinopoulos et al., 2017; Ma et al., 2022; Moon et al., 2018; Pan et al., 2019; Wang et al., 2021; Wolbertus and van den Hoed, 2019) (e.g., €0.40/kWh), (3) a flat rate monthly charging fee (Wolff and Madlener, 2019) (e.g., €50/month), (4) a payment for certain ranges (Sheldon et al., 2019; ten Have et al., 2020) (e.g., €5 for 100 km or $0.04 per mile). Among these payment models, around half of these studies used kWh-based fees, which seemed to be popular, probably because they were analogous to the price per litre or gallon of petrol (Hardman et al. 2018). Also, if parking charges applied at public charging points, EV users would be less likely to charge their vehicle at those points (Pan et al., 2019).

In terms of what 'type of payment' for public charging users would prefer, Gutjar and Kowald (2023) found that relative to a flat-rate charging option (e.g. unlimited charging at a fixed monthly price), kWh-based payment was the most preferred, while a duration-based fee and a fixed-fee per charging session were the least preferred among German consumers. Also, Visaria et al. (2022) found that among Danish EV users the flat fee pricing model for both public and home charging was the most popular payment method, followed by the 'no contract with the charging provider' (pay as you go) and the monthly subscription fee and kWh-based charging price per session. Danish EV users were willing to trade off 5.59 min of detour (valued at £1.04 or 8.76 DKK) to save £0.12 (1 DKK) per kWh in the price they paid at the charging station (Visaria et al., 2022). Also, EV users who were male, with a higher education qualification, or owned a Tesla, exhibited higher sensitivity to charging prices relative to other EV users (Visaria et al., 2022).

Several studies also included other related costs and fees. For example, Ge et al. (2018) included petrol prices within a scenario involving a decision to charge before or after a day of travel. Lee et al. (2020) specified 'home charging at the electricity rate paid at home' and 'free charging at the workplace' in two models studying the likelihood of public charging by BEV and PHEV users. As shown in Table 4, BEV users in California were more likely to use a public charging point if home charging was paid at the home electricity rate. PHEV users were less likely to charge their vehicle at public charging points when free charging was available at their workplace.

While various public charging opportunities may offer a certain charging fee depending on their payment model, EV owners with network membership can access all public charging stations under the control of the same operator at a special/discounted charging rate. Chakraborty et al. (2019) and Lee et al. (2020) found that EV users who subscribed to a specific EV public charging provider were more inclined to use public charging points. That said, network membership may also pose network incompatibility issues within the public charging market. Visaria et al. (2022), for example, measured the effect of interoperability on the choices of different charging pricing schemes and found that in Demark, BEV users were willing to pay £6.76/month (57.1 DKK/month) to have network access in all of Denmark and a similar price, £7.06/month (59.6 DKK/month), to have access anywhere in the EU, rather than have access to just one network.

Charging prices can be dynamically adjusted by operators to generate more revenue in response to fluctuating customer demand for electricity (Limmer, 2019; Limmer and Rodemann, 2019). This also provides an opportunity for cheaper rates during off-peak periods. Many consumers are risk averse and prefer to charge "now" at a nominal price rather than wait for an uncertain price reduction (Latinopoulos et al., 2017). Visaria et al. (2022) also reported that the monthly subscription model, which included peak and off-peak charging price differences for public charging, was the least preferred option for Danish EV users. Both Latinopoulos et al. (2017) and Visaria et al. (2022) suggested the importance of considering potential and existing EV users' attitudes towards these pricing differences.

3.3.3. *Charging station level of service*

The level of service at a charging station was expressed in terms of charging and waiting time, certainty of finding an available charging point, parking time and dwell time (see, Table A8 in the Appendix A). Charging time was defined either as 'the time it takes to fully charge the vehicle' (Ge and MacKenzie, 2022; Moon et al., 2018; Sheldon et al., 2019; Wolff and Madlener, 2019) or 'the time it takes to obtain a certain level of battery charge' (Wolbertus and van den Hoed, 2019), which indirectly reflected its charging power. The relative valuation of charging duration was reported either at the charging session level (Ge and MacKenzie, 2022) or as monthly payment as part of a subscription with a charging provider (Wolff and Madlener, 2019). EV users in the US were willing to pay £0.33 ($0.4) for a 1 min reduction of charging time (Ge and MacKenzie, 2022) and under a monthly payment model, potential EV users in Germany were willing to pay £0.14/month (€0.16/month) for a reduction of 1 min in charging time (Wolff and Madlener, 2019).

Queueing or waiting time was negatively associated with public charging choices (ten Have et al., 2020; Wang et al., 2021; Wolff and Madlener, 2019); that is, EV users would prefer to use public charging when waiting times were short (Wang et al., 2021). This was in line with a government report from New Zealand, which examined the preference of 932 EV users (Burroughs et al., 2021). Waiting times were generally measured in the range of 0——30 min (Wang et al., 2021; Wolff and Madlener, 2019). Waiting 30 min to charge an EV was the least preferred option for German drivers, who were willing to pay £0.72/month (€0.82/month) for every 1 min reduction in waiting time. On the other hand, respondents were indifferent between a 5-minute wait, 10-minute wait or no wait at all (Wolff and Madlener, 2019). This finding is also in line with ten Have et al. (2020), who reported that a 'certain' waiting time of up to 5 min was preferable to unknown or uncertain waiting times. Finally, parking (Wang et al., 2021) and dwell times (Wen et al., 2016) had a significant positive effect on public charging choices, as longer dwell and parking time induced drivers to actively make full use of that time.

3.3.4. *Accessibility*

Accessibility to charging stations has been measured either as the distance between the home or destination and charging stations (Ma et al., 2022; Moon et al., 2018; Xu et al., 2017; Zhang et al., 2022) or as the excess distance (time) required to travel in order to access a charging station (Ge and MacKenzie, 2022; Sun et al., 2016; ten Have et al., 2020). Several reports also confirmed that accessibility is an important factor for public charging choices (Burroughs et al., 2021; Department for Transport, 2022b; Department for Transport, 2022a, Hink, 2021) (see, also Table A9 in the Appendix A).

Overall, EV users preferred public charging stations involving shorter distances (Ma et al., 2022; Moon et al., 2018; Wolbertus and van den Hoed, 2019) and access times (Ge and MacKenzie, 2022). For example, Ma et al. (2022) reported that Chinese consumers were more likely to use public charging when the distance between the charging station and home/workplace/requested locations was shorter. Meanwhile, shorter detours were preferred by EV users when they employed en route charging in Japan (Sun et al., 2016) and Denmark (Visaria et al., 2022). The Danish study also revealed that EV users would opt-in for shorter detour times in order to charge their vehicle at a public charging point (Visaria et al., 2022).

In terms of the relative valuation of accessibility, Ge and MacKenzie (2022) found that EV users in the US were willing to pay £2.05 ($2.5) for a reduction of 1 min to access a charging station. They were also more likely to avoid charging en route if they could reach the next charging station without deviating from the originally planned route and were willing to pay £200.37 ($244) to avoid the

Table 5
Unobserved heterogeneity in choices and segmented groups.

Subject	Reference	Segments	Personal characteristics
EV users	Wang et al. (2021)	**Group 1 Charging service concerned group (76.2%):** value SOC, queueing time, and satisfaction	Younger, female, have richer driving experience, higher income, more risk averse
		Group 2 Pragmatic concerned group (23.8%): SOC, ER, parking time, charging fee	Senior, male, low income, less risk aversion
	Pan et al. (2019)	**Group 1 Risk averse group (30%):**value ER	Male, earning more than £600/month (5,000 yuan/month), purchased EVs more than a year
		Group 2 Risk seeking group (70%): SOC, charging price, and parking price	Female, with income less than £600/month (5,000 yuan/month), purchased their EV in the past year
	Wen et al. (2016)	**Group 1 (20.3%):** value charging price, ER, if the vehicle has enough battery to reach the next EVSE	–
		Group 2 (58.7%): price, ER, charging point power, cost at home, and dwell time	Number of vehicles owned or leased
		Group 3 (21%): value cost at home	Higher income level
PHEV users	Ge et al. (2018)	**Gas anxiety group (66%):** have higher willingness to charge at public places to avoid using petrol	Had a longer using experience, buy PHEVs not only by financial benefits
		Cost-minimizing group (34%): value recharge and refuel cost the same	Had a shorter using experience, buy PHEV because of financial benefits
Consumers	Latinopoulos et al. (2017)	**Risk averse (pricing) group (67.9%)**	Aged over 60, employed, not having children, lower education level, not owning or leasing an EV, have multiple trip chains, doing work-based tour, driving EV < 1 year, higher EV loyalty, EV daily mileage < 40 miles,
		Risk seeking group (32.1%)	Characteristics are in the opposite with risk averse group

Note: The percentages in the brackets refers to the proportion of the sample being allocated into a specific group.

deviation (Ge and MacKenzie, 2022). Finally, an indirect measure of accessibility relates to the coverage (or density) of public charging stations, which was expressed as the number of charging points within an areas. For example, Zhang et al. (2022) found that when the coverage of charging facilities at the parking locations in the trip chain increased, Chinese BEV users were more likely to use public charging as part of the trip chain.

3.3.5. *Convenience*

Convenience involves a number of features that a public charging point may exhibit and which improve the user experience. These features may also facilitate a more effective use of the infrastructure. The features, listed in Table A10 in the Appendix A, include inductive charging, serviced charging, plug and charge authentication and card-based payments.

Most, although not necessarily all, of these features were found to have a positive association with public charging choices (Gutjar

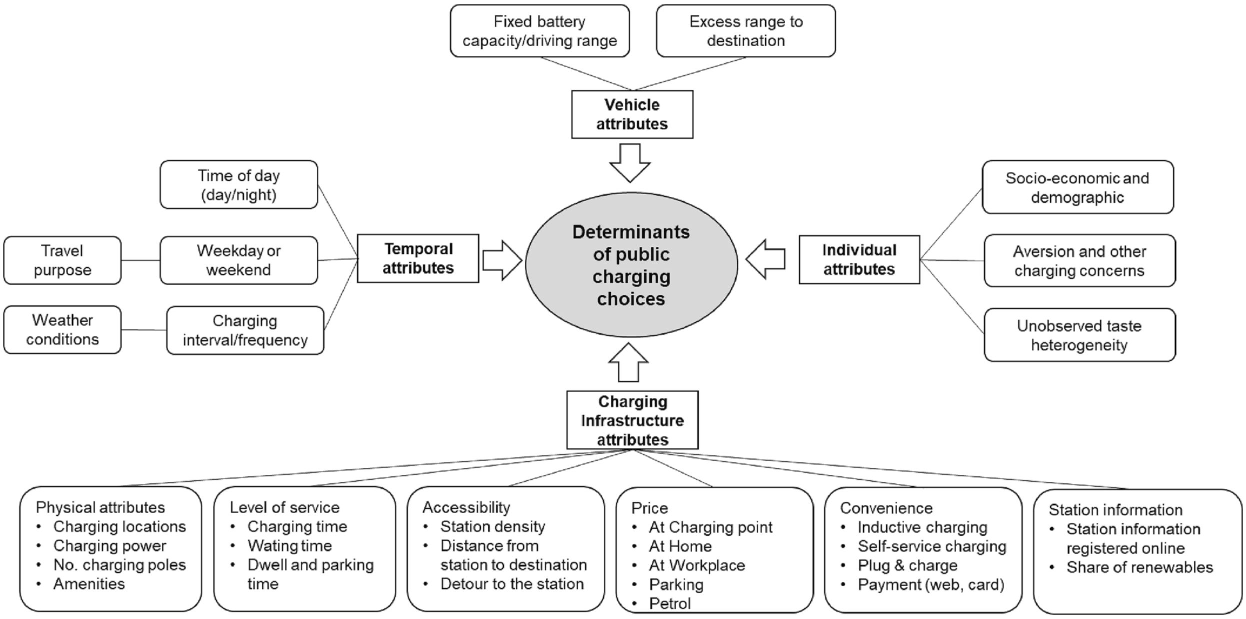

Fig. 1. A conceptual framework of determinants of public charging choices.

Table A1

Overview of empirical studies on public charging preferences.

Author(s) (year)	Research object	Type of charging	Type of travel	Charging power	Willingness to pay	Data	Respondents	Country	Modelling approach
Gutjar and Kowald (2023)	Choices across different public charging options	Not specified	NA	Not mentioned	No	SC	450 users and potential users	Germany	MNL, MMNL
Li et al. (2023)	Charge or not along the route	En-route	NA	Not mentioned	No	SC	308 BEV users	China	BL, RPL, RPLEC
Visaria et al. (2022)	Choices among three public charging options	En-route	Long trip	Fast	Yes	SC	558 BEV users	Denmark	MXL
Zhang et al. (2022)	Travel and charge or not charge, or cancel travel	Not specified	Work, recreation	Not mentioned	No	SC	494 BEV users	China	RSBP
Ge and MacKenzie (2022)	Charge or not at stations along route	En-route	Long-distance trip	Slow, fast	Yes	SC	309 PEV users	US	DDC, LC
Ma et al. (2022)	Charge choices among two options	Destination	Home, workplace, request locations	Slow, fast	Yes	SC	2,637 potential EV users	China	MNL, MXL
Wang et al. (2021)	Charge or not at a destination	Destination	Home, work, shopping	Not mentioned	Yes	SC	300 EV users	Beijing, China	BL, LC
Lee et al. (2020)	Choices across home, workplace, public, and mix use of these locations	Not specified	NA	Slow, fast	No	RP	7,979 PEV users	California, US	MNL
ten Have et al. (2020)	Choices across destination charging (22 kW), fast charging (50 kW), ultrafast charging (>350 kW), and no preference	Not specified	NA	Slow, fast, ultrafast	No	SC	171 EV users	Netherlands	MXL
Pan et al. (2019)	Charge or not at a destination	Destination	Home, shopping centre	Slow	No	SC	160 EV users	Beijing, China	BL, LC
Wolff and Madlener (2019)	Charging choices across home, work, roadside	Not specified	NA	Slow, fast	Yes	SC	4,101 holders of a driving license	Germany	CL
Wolbertus and van den Hoed (2019)	Choices between standard slow charging stations, charging hub, fast charging stations	Not specified	NA	Slow, fast	No	SC	100 EV users	Netherlands	MXL
Chakraborty et al. (2019)	Choices among home, work, public, multiple locations, not charge	Not specified	Commute trips	Not mentioned	No	RP	1,769 BEV users, 1,432 PHEV users	California US	ECL
Sheldon et al. (2019)	Choices among public charging stations at different locations	Not specified	NA	Not mentioned	Yes	SC	1,261 potential PHEV users	California US	MNL, MXL
Anderson et al. (2018)	Choices among public charging infrastructure	Not specified	NA	Slow, fast	No	SP	843 BEV users	Germany	FA
Ge et al. (2018)	Charge or not	Not specified	NA	Slow	No	SC	157 PHEV users	US	LC
Moon et al. (2018)	Choices among public charging infrastructure	Not specified	NA	Slow, fast	No	SC	418 current and potential EV users	South Korea	MXL
Latinopoulos et al. (2017)	Charge now or later under dynamic charging pricing	Destination	NA	Not mentioned	No	SC	118 current and potential EV users	UK & Ireland	EUT, DEU, PT
Xu et al. (2017)	Choices between slow home/workplace and fast public charging	Not specified	NA	Slow	No	RP	234 BEV users	Japan	MXL
Kim et al. (2017)	Public charging choices	Not specified	NA	Not mentioned	No	RP	9,027 EV users	Netherlands	HD
Sun et al. (2016)	Choices between fast charging stations	En-route	NA	Fast	No	RP	24 BEV users	Japan	MXL
Wen et al. (2016)	Charge or not at the destination in given situation	Destination	NA	Slow, fast	Yes	SC	315 PEV users	US	MXL, LC
Nienhueser and Qiu (2016)	Choices for public charging options	Not specified	NA	Slow, fast	Yes	SC	181 PEV users	US	MXL

Notes: Binary logit model (BL); Multinominal logistic regression (MNL); Latent class logit model (LC); mixed logit model (MXL); Discounted expected utility (DEU); Expected utility theory (EUT); Prospect theory (PT); Hybrid choice model (HCM) latent class logit model (BL); Hybrid choice model (HC) latent class logit model (LC); Error component logit model (ECL); Conditional logit model (CL); Frequency analysis (FA); Dynamic discrete choice models (DDC); Random parameter logit model (RPL); Random parameter logit with error components model (RPLEC); Recursive simultaneous bivariate probit model (RSBP); Mixed multinomial logit model (MMXL); Ordered logit model (OL); Ordered probit model (OP); Hazard-based duration model (HD); SC: revealed preference study with an experiment, RP: revealed preference study without an experiment, RP: stated preference study.

and Kowald, 2023; Moon et al., 2018; Wolff and Madlener, 2019). For example, consumers in South Korea were more likely to opt-in for self-charging instead of serviced charging by station employees (Moon et al., 2018). German EV users were more likely to use inductive charging than traditional cable charging, and they were willing to pay £7.40/month (€8.38/month) extra for that feature (Wolff and Madlener 2019). Inductive charging only requires a driver to park their EV at a specific location for charging to commence automatically.

EV authentication refers to the ability of the operator to automatically identify an EV and its user to enable faster charging and payment. Gutjar and Kowald (2023) found that German consumers intending to buy an EV perceived 'plug and charge' (i.e., automatic authentication and payment) as the most convenient method compared to app-based solutions, which rely on mobile phones and may therefore not work due to internet connection issues, low battery or cold weather. The 'plug and charge' option also came on top of the RFID-card (Radio Frequency Identity Card) solution, which is often incompatible across different charging networks. Finally, Gutjar and Kowald (2023) also found that potential EV users in Germany preferred web-based (e.g, PayPal) and card-based (e.g. credit card) payment methods rather than automatic debit transfer.

3.3.6. Charging station information

Charging station information may include location, price and availability of charging spaces but also the energy source of electricity. As shown in Table 4, these features were also associated with users' and potential users' decision to charge at a public station. Similarly, open data (websites such as Zap-map in the UK, an app from the charging provider, or vehicle onboard maps) and sustainability of public charging points were identified as important considerations (Hink, 2021).

Offering more information would be likely to attract EV users at those public charging stations (Moon et al., 2018; Wolff and Madlener, 2019). For example, Moon et al. (2018) found that potential EV users in South Korea were more likely to use public charging when station information (e.g. location, charging fees, charging station status) was available online (via Korea's EV Charging Station Monitoring System, an online information platform). Information on energy sources was also important for public charging choices for potential and existing EV users. For example, Wolff and Madlener (2019), Nienhueser and Qiu (2016) and Wolff and Madlener (2019) found that charging stations with a higher share of renewable energy were more likely to be chosen.

The relative valuation of renewable energy preferences expressed in terms of WTP were reported either as a payment per hour (Nienhueser and Qiu, 2016) or as a payment per month (Wolff and Madlener, 2019). PHEV users in the US were willing to pay £0.50 ($0.61) per hour for a 1% increase in renewable energy at Level 2 chargers and £1.49 ($1.82) per hour for a 1% increase in renewable

Table A2
Overview of grey literature.

Author(s) (year)	Research object	Determinants	Data	Respondents	Country	Modelling approach
Department for Transport (2022b); Department for Transport (2022a)	Key aspects of public charging	Dependability, proximity, cost and speed, sustainability	SP	1,006 non-EV users	UK	FA
Department for Transport (2022b)	Survey about public charging	Charging behaviour (accessibility, frequency, reliability), charging satisfaction, improvements needed	SP	848 EV users	UK	FA
Hink (2021)	Key aspects of public charging	Payments, pricing transparency, open data, reliability, weatherproofing and lighting, signage, accessibility	SP	1,216 PEV users	UK	FA
Burroughs et al. (2021)	Choices of the factors that can improve the public charging experience	Access (27%), quantity (20%), location (19%), miscellaneous (11%), queue (8%), power (8%), cost (7%)	RP	932 EV users	New Zealand	FA
Dodson and Slater (2019)	Charging choices of empirical charging events	Time of day,Time of week,Time of season	RP	8.3 million charging events	UK	FA
California Air Resources Board (2019)	Regulations for all public level 2 and fast charging infrastructure	Payment methods and security;clear information about all fees; clear pricing models; no compulsory membership; interoperability billing standards; sharing station information.			California, US	–
Bedir et al. (2018)	Predict the number of chargers needed by 2025 for the state's ZEV goals	99,000 to 133,000 destination chargers, including at workplaces and public locations, and 9,000 to 25,000 fast chargers			US	EVI-Pro
Wood et al. (2017)	Predict necessary amount and ideal types of locations for charging stations	Charging locations (corridor fast-charging stations for long-distance travel, urban and rural communities); About 8,000 fast-charging stations would be required to provide a minimum level of coverage nationwide;			US	EVI-Pro

Notes: The Electric Vehicle Infrastructure Projections (EVI-Pro).

Table A3
Overview of willingness to pay estimates in previous literature (in UK pounds).

Determinants	Denmark [1]	US[2][6][7][8]	China [3] [4]	Germany [5]
Less charging cost	5.59 min of detour or £1.04 (8.76 DKK) against 1 less DKK/kWh in charging cost;			
Higher charging power	0.28 min of detour or £0.052 (0.44 DKK) for an extra km/min	£1.58/h ($1.91/h) for level 2 vs. level 1 [7]; £0.041 ($0.05) for an extra mile from charging [6]		
Number of chargers	7.87 mins of detour or £1.46 (12.32 DKK) for an available charger; 0.53 min of detour or £0.099 (0.83 DKK) for an occupied charger			
Amenities	1.23 min of detour or £0.23 (1.93 DKK) for availability of toilets vs. no toilets; 9.55 min of detour or £1.78 (14.97 DKK) for the availability of toilets, restaurants, and supermarket vs. none of that	£17.25 ($21) for toilets, dining facilities and Wi-Fi vs. none [2]		
Increase SOC			£0.083/kWh (0.7 yuan/kWh) for 10%[4]	
Increase of excess range			£0.041/kWh (0.346 yuan/kWh) [4]	
Shorter charging duration (min)		£0.33 ($0.4) [2]		£0.14/month (€0.16/month)
Shorter waiting time (min)				£0.72/month (€0.82/month)
Shorter access time (min)		£2.05 ($2.5) [2]		
Higher share of renewable energy (%)		[£0.50 ($0.61) per hour for Level 2 EVSE; £1.49 ($1.82) per hour for Direct Current Fast Chargers (DCFC);] [8]		£0.37/month (€0.42/month)
Inductive charging technology vs. cable charging				£7.40/month (€8.38 /month)
Charging locations		[£2.31 ($2.81) for grocery; £1.35 ($1.65) for mall, £1.13 ($1.38) for quick charge near home; £1.03 ($1.26) for quick charge near freeway; £0.0082 ($0.01) for at transit; - £0.78 (−$0.95) for gym; - £1.01 (− $1.23) for school] [6]		- £40.84/month (−€46.26/month) for en-route charging on the road vs. at home;−£31.46/month (−€35.64/month) for destination charging on the road vs. at home;−£19.70/month (−€22.31/month) for charging at work vs. at home;
Avoid having to deviate from the originally planned route		£200.37 ($244) [2]		
Time of day			[Workday: £0.19 (CNY 1.614) for 10:00–17:00; £0.24 (CNY 2.042) for 17:00–22:00; £0.14 (CNY 1.194) for 22:00–10:00 + 1; weekend: £0.18 (CNY 1.527) for 10:00–17:00; £0.22 (CNY 1.838) for 17:00–22:00; £0.28 (CNY 2.372) for 22:00–10:00^{+1}] [3]	

Notes: [1] Visaria et al. (2022); [2] Ge and MacKenzie (2022); [3] Ma et al. (Ma et al., 2022); [4] Wang et al. (2021); [5] Wolff and Madlener (2019); [6] Sheldon et al. (2019); [7] Wen et al. (2016); [8] Nienhueser and Qiu (2016).

energy at Direct Current Fast Chargers (DCFC) (Nienhueser and Qiu, 2016). Also, German potential EV users were willing to pay £0.37 per month (€0.42/month) for a 1% increase in renewable energy at public charging points (Wolff and Madlener, 2019).

Gutjar and Kowald (2023) also found that potential EV users in Germany, who were young, female, or male but with high environmental awareness, were more sensitive to the share of renewable energy at public charging points. Nienhueser and Qiu (2016) found that for PEV drivers in the US, the WTP for renewable energy at public charging stations increased with income and age, decreased with years of education and was higher for women.

Table A4
Overview of explanatory factors for public charging choices: temporal attributes.

Respondents	Measurement of attributes (+/−)	Levels/supplement information	Reference
BEVs	Midnight (−)	Less likely to occur at midnight between 23:00 to 7:00	Xu et al. (2017)
	Working day (+)	A working day indicator	Xu et al. (2017)
Potential EV users	Time period *	High demand time periods: 6AM-9AM, 9AM-12PM, 6PM-9PM	Moon et al. (2018)
	Time of day	High demand time periods: 17:00–22:00 > 10:00–17:00 > 22:00—10:00 for workday, 22:00—10:00 > 17:00–22:00 > 10:00–17:00 for weekend	Ma et al. (Ma et al., 2022)
EV users	Time of day *	Fast charging sessions concentrated around the centre of the day;level 2 charging sessions show asmall peak in the morning and a larger peak in the afternoon	Wolbertus and van den Hoed (2019)
	Length of trip chain (+)		Zhang et al. (2022)
	Complex trip chain (+)		

Notes: '+' indicates a significant positive effect on public charging choices, and '−' represents a significant negative effect, * refers to the results of the descriptive analysis and they are not significant.

4. Preference heterogeneity for public charging

As potential and existing EV users are the subjects making public charging choices, it is also useful to examine the personal (observed) characteristics and efforts to capture unobserved heterogeneity of public charging choices (see Table A12 in the Appendix A).

EV users most likely to use public charging were identified across the reviewed studies as younger (Wang et al. 2021), female (Lee et al., 2020; Pan et al., 2019; Wang et al., 2021; Zhang et al., 2022), with lower education qualifications (Pan et al., 2019) and lower income (ten Have et al., 2020). They were also more experienced drivers (Wang et al., 2021) and had owned an EV for more than a year (Pan et al., 2019), lived in a flat (Chakraborty et al., 2019; Lee et al., 2020), did not have a home charging point (Zhang et al., 2022), often made long chained trips (Zhang et al., 2022), and held risk-averse attitudes towards EV range (Pan et al., 2019). EV users with previous experience (Xu et al., 2017) and those who used public charging frequently (ten Have et al. 2020) were more likely to use fast charging. Also, those who placed importance on driving comfort and had higher education qualifications preferred ultra-fast charging (ten Have et al. 2020).

As shown in Table 5, some studies captured unobserved heterogeneity in public charging choices by dividing the sample into different groups via latent class discrete choice modelling (Ge et al., 2018; Latinopoulos et al., 2017; Pan et al., 2019; Wang et al., 2021; Wen et al., 2016). Differences in public charging choices were explained by charging concerns (Wang et al., 2021; Wen et al., 2016) and risk-taking attitudes (Pan et al., 2019). For example, Wang et al. (2021) found that 76.2% respondents in their sample were 'charging-service concerned' and valued SOC, queuing time and charging station satisfaction. These respondents were younger, female, had driving experience, a higher income, and were risk averse. The reference group, which comprised the remaining 23.8% of the sample, were pragmatic about their charging needs and valued SOC, ER, parking time and charging fee. Similarly, Wen et al. (2016) identified three subgroups of EV users based on their charging concerns: those who: (1) 'chose to charge based on price and charging needs'; (2) 'charged at every opportunity'; and (3) 'charged taking into consideration other factors such as SOC, dwell time and home charging price'.

When considering risk attitudes towards SOC, Pan et al. (2019) showed that most EV users belonged a 'risk-seeking group' (70% of the sample), and their choices were driven by price, SOC and parking price. The choices of the 'risk averse group' (30% of the sample) were driven by the ER and its members were males, those earning more than 5,000 yuan/month ($687/£600), and had owned an EV for more than 12 months.

PHEV users may act differently compared to EV users when facing the same charging options, as they can either use a public charging point or refill their cars at petrol stations. Ge et al. (2018) segmented PHEV users into two groups: 'petrol anxiety' and 'cost-minimising' users. The majority of PHEV users were more likely to be in the 'petrol anxiety' group, and would avoid using petrol as much as possible, and, due to their environmental attitudes, would be willing to pay four times the cost of charging rather than refuel. The 'cost-minimising group', only 34% of the sample, was more pragmatic and placed equal importance on charging and refilling and would charge or refuel depending on the relative costs of electricity and petrol.

EV users charge-or-not decisions for public charging were influenced by risk-averse attitudes towards dynamic pricing (Latinopoulos et al., 2017). The results showed that the majority of current and potential EV users were more likely to be risk-averse and preferred to charge immediately at the prevailing tariff at the time rather than charge strategically, which would have entailed waiting for a better price.

5. Conceptual mapping of public charging choices

This section proposes a conceptual framework to capture the determinants of public charging choices for potential and existing EV users. Fig. 1 reveals that public charging has and will continue to have an increasingly important role in road transport. The empirical work examined in this study has the odd outlier and counterintuitive conclusion, but there is a clear set of common themes that emerge. The determinants of public charging choices can be categorised into four levels: (1) temporal, (2) vehicle, (3) charging

Table A5

Overview of explanatory factors for public charging choices: vehicle attributes.

Attributes	Respondents	Measurement of attributes (+/−)	Levels	Reference
SOC	EV users	SOC (−)	7%, 10%, 13%, 17%, 20%, 23%, 27%, 30%, 33%, 40%, 50%, 53%, 57%, 60%, 67%, 80%	Pan et al. (2019)
	EV users	SOC (−)	0%; 20%; 40%; 60%; 80%	Wang et al. (2021)
	BEV users	SOC (−)	45 km (23%), 65 km (33%), 85 km (43%), 105 km (53%), 125 km (63%), 155 km (78%)	Zhang et al. (2022)
	PEV users	SOC (−)	State of charge at station t for respondent I (%)	Ge and MacKenzie (2022)
		Initial SOC (−)	Revealed study: values are different among respondents	Xu et al. (2017)
Excess range	PEV users	ER remaining in vehicle battery (−)	3–70 mi	Wen et al. (2016)
	EV users	ER (−)	0; 5 km; 20 km; 50 km	Wang et al. (2021)
		ER (−) *	−5 km, 5 km, 10 km, 20 km, 40 km	Pan et al. (2019)
	PEV users	Whether the current range is enough to next charging opportunity (−)	0: if current range < distance to next charging opportunity; 1: if current range ≥ distance to next charging opportunity	Wen et al. (2016)
Driving range	BEV users	Battery capacity (+)	Revealed study: values are different among respondents	Xu et al. (2017)
	PHEV users	Electric range (+)	Revealed study: values are different among respondents	Chakraborty et al. (2019)
	BEV users	Initial available range at origin (+)	30, 50, 60, 70 km	Li et al. (2023)
		Available range uncertainty (interval) at destination (−)	2, 10, 20, 30, 40 km	

Notes: '+' means significant positive effect for public charging choices, and '−' represents significant negative effect; '*' means the result is not significant.

Table A6

Explanatory factors for public charging choices: physical infrastructure attributes.

Attributes	Respondents	Order of preference	Reference
Charging location	PEV owners	Home only (53%), home & public (16%), home & work (13%), work only (8%), all (4%), public only = work & public (3%)	Lee et al. (2020)
	BEV owners	Home, work, not charge, multi-location, public	Chakraborty et al. (2019)
		Activities during charging (77%) (shopping and leisure (18%), work (16%), chores (5%), house/apartment (3%), education/day care (1%)), stop-to-charge (19%)	Anderson et al. (2018)
		Prefer to use chargers located at gas stations F	Sun et al. (2016)
	Private BEV owners	Home, public	Xu et al. (2017)
		Prefer to charge at fast stations encountered earlier on working days, then prefer stations encountered later when choosing a station in peak hours F	Sun et al. (2016)
	EV users	Public car parks (4%), supermarkets (3%), retail stores/malls (2%), petrol stations (1%), street side/roadside (1%), private car parks (1%), other destinations (1%) G	(Burroughs et al., 2021)
		Motorway service areas (28%), at other destinations (26%), near home (10%), at workplace/education (9%) G	(Department for Transport, 2022b)
	PHEV owners	Home, multi-location, work, not charge, public	Chakraborty et al. (2019)
	Potential EV users	**At home, at work, on the road: charging as side activity, on the road: charging as main goal**	Wolff and Madlener (2019)
		Grocery, at work, mall, quick chargers near home, quick chargers by freeway, gym, school	Sheldon et al. (2019)
		Motorway service stations; workplace, gas stations and shopping facilities; leisure facilities and education institutions	Philipsen et al. (2016)
Charging power	BEV owners	Fast (level 3), normal (level 1 & level 2)	Xu et al. (2017)
	EV users	Ultrafast (>350 kW), fast (around 50 kW), standard charging (up to 22 kW)	ten Have et al. (2020)
	BEV owners	Semi-fast charging power (22 kW AC), slow (3.7 kW AC) = fast (50 kW DC) stations	Anderson et al. (2018)
	PEV owners	DC fast chargers, public L2 chargers, public L1 chargers	Lee et al. (2020)
		50 kW, 6.6 kW, 1.9 kW	Wen et al. (2016)
	Potential EV users	**Fast chargers (+)**	Ma et al. (Ma et al., 2022)
Amenities	EV users	**Slow charging: near shopping area, without facilities**Fast charging: without facilities	ten Have et al. (2020)
		Amenities with toilets, supermarket and restaurants	Visaria et al. (2022)
	PEV users	**Amenities with toilets, dining and WIFI**	Ge and MacKenzie (2022)
Number of vacant chargers (+)	EV users	None	Visaria et al. (2022)

Note: Order of preference in bold imply that the results of the study were significant, while the order of preference not in bold represent the descriptive analysis results and they are not significant, and the superscript F refers to studies focused on fast charging stations, superscript G refers to the grey literature.

Table A7

Public charging price levels.

Attributes	Respondents	Measurement of attributes (+/−)	Attribute levels / supplement information	Reference
Charging price	Potential EV users	Refuelling cost per mile (−)	[$ per mile, like $ X gal petrol]^{4}: e.g. $0.04, $0.08	Sheldon et al. (2019)
		Charging cost (−)	[KRW/ kWh] ^{2}: 150, 200, 250, 300	Moon et al. (2018)
		The total price of the charging session (−)	[Booking now: £0.29/kWh–£0.42/kWh;booking later: £0.08/kWh–£0.72/kWh]^{2}	Latinopoulos et al. (2017)
		Charging cost per month (−)	[€50, €100, €150, €200]^{3}	Wolff and Madlener (2019)
		Charging price (−)	[CNY/kWh]^{2}: 1.5, 2.25, 3	Ma et al. (Ma et al., 2022)
	EV users	Charging price (−)	[Yuan/kWh] ^{2}: 0.5, 1.5, 2, 2.5;	Pan et al. (2019)
		Charging price (−)	[€5, €8.49, €11.76, €15.25 for 100 km] ^{4}	ten Have et al. (2020)
		Fast charging price (−)	[€/kWh, €0.20/kWh, €0.40/kWh, €0.60/kWh] ^{2}	Wolbertus and van den Hoed (2019)
		Charging fee (−)	[1.2 yuan/kWh, 1.6 yuan/kWh, 2 yuan/kWh] ^{2}	Wang et al. (2021)
	PEV owners	Charging price per hour (−)	[0.50, 1.00, 1.50, 2.00, 5.00 $/h]^{1}	Wen et al. (2016)
		Charging price per hour (−)	[$1/hour, $1.12/hour, $1.24/hour, $1.06/hour, $1.24/hour for AC level 2 EVSE; $5.30 /hour, $5.15 /hour, $5.60 /hour, $5.15 /hour, $5.60 /hour for DC fast charger] ^{1}	Nienhueser and Qiu (2016)
		Charging price (−)	[Free; $0.50/kWh; $1.00/kWh] ^{2}	Ge and MacKenzie (2022)
	BEV users	Working days: free charging (+)	Free/not free	Sun et al. (2016)
	PHEV owners	Charging price (−)	[$0.50/h, $1.00/h, $1.50/h, $2.00/h, $5.00/h]^{1}	Ge et al. (2018)
		Free workplace charging (−)	Yes/no	Lee et al. (2020)
Parking price	EV users	Parking price while charging and while not charging (−)	Yuan/h: 8 and 8, 8 and 6, 8 and 4, 4 and 0, 0 and 0	Pan et al. (2019)
Home electricity price	BEV owners	Cost of electricity at home (+)	[cents/kWh] ^{2}	Lee et al. (2020)
	PHEV owners	Electricity cost at home at the end of the travel day (−)	Continuous variable. Max: $9.93; Min: $0.18; Mean: $2.05	Ge et al. (2018)
Workplace charging price		Free workplace charging (−)	Yes/no	Lee et al. (2020)
Petrol price		The cost of petrol that will be used to complete the travel day (−)	Continuous variable. Max: $1.824; Min: $0; Mean: $0.1156	Ge et al. (2018)
Network membership	EV owners	Network membership (+)	Yes/no	Lee et al. (2020), Chakraborty et al. (2019)

Note: ‘+’ indicates a significant positive impact on public charging choices, ‘−’ represents a significant negative impact. The level ‘[]’ in square brackets and superscript numbers indicate different payment models, 1 – charging time based, 2 - kWh based payments, 3 – fixed monthly charging fee, 4 – pay for a certain range.

Table A8
Charging and waiting times attributes related to public charging infrastructure.

Attributes	Respondents	Measurement of attributes (+/−)	Levels	Reference
Charging time	Potential EV users	Full charge time (−)	30 min, 1 h, 4 h, 8 h	Moon et al. (2018)
		Full charging time (−)	10 min, 30 min, 4 h, 8 h	Wolff and Madlener (2019)
		Refuelling time (−)	Petrol/status quo: 10 min, 15 min;Full charge time:Slow charge: 60 min, 120 min;Medium charge: 30 min, 60 min;Fast charge: 15 min, 30 min;	Sheldon et al. (2019)
	EV drivers	Fast charging time (−)	5 min, 10 min, 15 min, 20 min, based upon a session in which 24 kW needs to be charged	Wolbertus and van den Hoed (2019)
		Full ranging time (−)	50 kW; 100 kW; 150 kW; 300 kW	Ge and MacKenzie (2022)
Waiting time	EV drivers	Queueing time (−)	0, 15, 30 min	Wang et al. (2021)
		Certainty of charging point availability: ultrafast charging (−), fast and slow public charging (+)	Certain: <5 min waiting time, uncertain: waiting time unknown	ten Have et al. (2020)
	Potential EV users	Waiting time 30 min (−)	0, 5, 10, 30 min	Wolff and Madlener (2019)
Parking time	EV drivers	Parking time (+)	2 h, 4 h, 8 h	Wang et al. (2021)
Dwell time	EV drivers	Dwell time > 30 min (+)	0.25, 0.5, 1, 2, 4, 8 h	Wen et al. (2016)

Note: ‘+’ means significant positive effect on public charging choices, and ‘−’ represents significant negative effect.

Table A9
Accessibility attributes related to public charging infrastructure.

Attributes	Respondents	Measurement (+/−)	Levels	Reference
Density of public charging stations	BEVs	BEVs registered and driven in Tokyo and Kanagawa (+)	Tokyo/Kanagawa area (more than 55 stations per 1,000 km^2) compared to other area (less than 30 stations per 1,000 km^2)	Xu et al. (2017)
		Coverage of charging facilities (+)	With or without charging facilities at parking points	Zhang et al. (2022)
Distance to from the charging stations to home/consumers	EV owners	Fast charging distance to home (+) *	150 m, 400 m, 550 m, 700 *m*	Wolbertus and van den Hoed (2019)
	Potential EV users	Station accessibility (−)	Average distance a consumer must travel to reach the nearest public charging points: 2 km, 10 km, 20 km	Moon et al. (2018)
	Potential EV users	The distance of public chargers from home/ workplace/frequent (−)	Within 1 km, 1–2 km, 2 km away	Ma et al. (Ma et al., 2022)
Detour	EV users	Not having to make a detour for ultrafast charging (−)	Detour (5 min driving or walking), no detour	ten Have et al. (2020)
	BEV users	Detour (km) (−)	Working days (threshold = 1750 m), non-working days (threshold = 750 m)	Sun et al. (2016)
	EV owners	Detour (minutes) (−)	0/5/10	Visaria et al. (2022)
Access time to the charging station	PEV users	Access time to the charging station (−)	5 min; 15 min; 30 min	Ge and MacKenzie (2022)
Deviation		Deviation from the original plan (−)	Whether to deviate from the original plan if they choose not to charge (yes or no)	
Type of charging stations	BEV users	Accessibility *	Public accessible areas and public street (94%)	Anderson et al. (2018)

Note: ‘+’ means significant positive effect for public charging choices, and ‘−’ represents significant negative effect; ‘*’ means the result is not significant.

infrastructure, and (4) individual attributes. Public charging tends to take place during the day rather than during the night and may be different during weekdays or weekends, or holidays. Vehicle attributes include battery capacity and driving range, which are fixed, but also the SOC, remaining range, and the excess range to destination. According to Fig. 1, charging infrastructure attributes are categorised into physical attributes, price, charging station level of service, accessibility, convenience, and station information. Individual attributes refer to the observed heterogeneities reported across studies and include socio-economic and demographic characteristics, and level of risk aversion.

The lines and arrows in Fig. 1 show how the four levels of determinants (temporal, vehicle, infrastructure, and individual attributes) are linked with public charging choices. Temporal attributes are an important consideration as the daily, weekly, and in-between recharging patterns are essential for understanding public charging preferences of EV drivers. Vehicle attributes are also important because higher fixed battery capacity/mileage creates more opportunities for EVs to use public charging. As some public charging networks are (still) free and have high efficiency compared to home and workplace charging, while constantly changing SOC, remaining range and excess range to destination may be influenced by range anxiety, which drives EV users to use public charging.

Table A10
Convenience attributes related to public charging infrastructure.

Attributes	Respondents	Measurement (+/−)	Levels	Reference
Self-service availability	Potential EV users	Availability of self-charging services (+)	Yes, no (employee charging)	Moon et al. (2018)
Authentication	Potential EV users		Plug & charge (+) > RFID (+) > app (ref.)	Gutjar and Kowald (2023)
Payment methods			Card-based (+) > debit transfer (ref.) > web-based (−)	
Whether use inductive charging	Potential EV users	Inductive (+)	Tethered charging (with cable), Inductive charging (without cable)	Wolff and Madlener (2019)

Note: '+' means significant positive effect for public charging choices, and '−' represents significant negative effect.

Table A11
Information attributes related to public charging infrastructure.

Attributes	Respondents	Measurement (+/−)	Levels	Reference
Information about source of energy	PEV users	Renewable fraction (+)	0%, 25%, 50%, 75%, 100%	Nienhueser and Qiu (2016)
	Potential EV users	Share of renewables (+) (wind or solar energy in the electricity mix used for charging)	25%, 50%, 75%, 100%	Wolff and Madlener (2019)
		Renewable energy (+)	0%, 50%, 100%	Gutjar and Kowald (2023)
Whether the public charging point is registered in an information system	Potential EV users	Availability of station information (location, charging fee, status of public charging points) (−)	Yes, no	(Moon et al., 2018)

Note: '+' means a significant positive effect for public charging choices, and '−' represents a significant negative effect.

However, this does not mean that they will necessarily charge at public stations, as temporal and vehicle attributes, and the characteristics of the public charging infrastructure in terms of physical aspects, price, level of service, accessibility, convenience, and station information also influence charging choices. At the same time, individual attributes, including socio-economic and demographic characteristics and level of risk aversion, contribute to preference heterogeneity. Vehicle manufacturers are all too aware of what EV users want, but this review is a reminder that range is absolutely crucial when it comes to electric vehicle choice (Potoglou et al., 2020; Song and Potoglou, 2020). The indirect evidence provided in this review is clearly saying that range is an important determinant in charging choices as well.

The individual and temporal attributes identified determine public charging choices, but they cannot be changed with policy. Policy, can, however, seek to adapt public charging infrastructure to better satisfy EV users' requirements. All in all, public infrastructure needs to be easily accessible, frequent, and with enough fast charging points to satisfy demand at peak times, especially morning and afternoon. It needs to be sheltered somehow, to protect drivers from harsh weather conditions, and amenities, especially toilets, are important. The slower the charging speed, the more important extra amenities, such as shopping and leisure facilities, are. All information regarding the public charging station, including pricing and methods of payment needs to be clearly and quickly accessible, and payment needs to be hassle-free. There is also incipient evidence that EV users prefer electricity generated in a clean manner, which is not surprising, as they are likely to be environmentally conscious. Clean electricity generation is, in any case, a must when it comes to road transport electrification, as there is plenty of evidence that shows that emissions will increase, rather than decrease, otherwise (Cox et al., 2022; Gómez Vilchez and Jochem, 2020; Liu and Santos, 2015; Woo et al., 2017). An open area for further investigation here is also how potential preferences may be affected by a wider grid integration (e.g. vehicle-to-grid) (e.g.

Table A12
Explanatory factors for public charging choices: user (incl. potential) attribute.

Respondents		Personal characteristics
EV users	Who prefer public charging	Young (Wang et al. 2021), female (Pan et al. 2019; Lee et al. 2020; Wang et al. 2021), with lower level of education (Pan et al., 2019) and lower level of income (ten Have et al., 2020), purchased EV more than a year (Pan et al., 2019), had rich driving experience (Wang et al., 2021), living in an apartment (Chakraborty et al., 2019) and not having a house (Lee et al., 2020), without home charging point (Zhang et al., 2022), with long and complex trip chains (Zhang et al., 2022), and holding risk-averse attitudes towards EV range (Pan et al., 2019)
	Who prefer slow public charging	Lower level of income (ten Have et al. 2020)
	Who prefer fast charging	Young (Wang et al., 2021), and rich fast charging experience (Xu et al., 2017), lower level of income (ten Have et al. 2020), higher current frequency of using fast charging (ten Have et al. 2020)
	Who prefer ultra-fast charging	Have lower level of income, put higher importance of driving comfort, and have higher level of education (ten Have et al. 2020)
PHEV users	Who prefer public charging	Less vehicle ownership (Lee et al., 2020), long time of using PHEVs and buy PHEVs not only by financial benefits (Ge et al., 2018)
Potential users	Who prefer public charging	White, believe local air quality is poor, and politically liberal leaning (Sheldon et al., 2019)

Ensslen et al., 2020; Sachan et al., 2020).

The recommendations above are blindingly obvious and intuitive, and one may wonder what the point of even listing them is. The point is threefold: (a) as of 2023, no country has public charging stations that fulfil the requirements set above, so, as obvious as they may seem, action has not been taken yet; (b) academics and policy makers have devoted substantial time and resources over the last ten years trying to identify what these requirements are, and the present study synthesises them all in one place; and (c) ensuring these requirements are met will guarantee that EV users' demand is satisfied.

6. Conclusion

This paper provides an up-to-date critical review of the academic and grey literature on public charging choices and their determinants. Findings from this critical analysis and synthesis of the literature show what determinants contribute to the public charging choices of potential and existing EV users. This evidence will not only benefit public charging providers in the planning of and investment decisions on charging infrastructure, but will also facilitate government policy measures to further deploy public charging infrastructure and promote electric vehicle uptake. The synthesis of the empirical evidence is also integrated into a conceptual framework that illustrates the complexities and dimensionality of public charging choices and shows how these are linked with the range of determinants identified. This framework explains the importance of temporal, vehicle, charging infrastructure, and individual attributes for current and potential EV users, who make or will potentially make those choices.

On the basis of the reviewed material there are also a number of research gaps that can be identified. Firstly, the evidence regarding temporal charging preferences is far from conclusive, with different patterns across and within different countries, which in itself is not a problem per se, except that it is difficult to find any reasons for these differences given the number of studies, the different sampling strategies and the different approaches used. Temporal charging preferences therefore should be further explored, especially in relation to travel purpose, trip length and charging speeds. Secondly, further research is needed to fully understand EV users' preferences for charging locations and payment models (e.g. monthly, pay as you go), especially in relation to safety, battery size of EVs, type of charging (destination or en route charging), and travel purpose. Preferences for charging locations are influenced by those factors but the evidence is sparse. Thirdly, more research is needed on preferences for different charging models and compatibility of payment methods. Exploring those themes further would allow to build a more solid evidence base.

CRediT authorship contribution statement

Dimitris Potoglou: Supervision, Writing – review & editing, Conceptualization, Writing – original draft. **Rongqiu Song:** Writing – review & editing, Conceptualization, Investigation, Resources, Writing – original draft. **Georgina Santos:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

The authors are grateful to Patrick Jochem (Associate Editor) and the four anonymous referees for their guidance and constructive comments that helped improve this manuscript. Rongqiu Song wishes to thank the China Scholarship Council for the financial support. This work was supported by the Engineering and Physical Sciences Research Council [EP/S032053/1].

Appendix A

See Table A1-A12.

References

Anderson, J.E., Lehne, M., Hardinghaus, M., 2018. What electric vehicle users want: Real-world preferences for public charging infrastructure. Int. J. Sustain. Transp. 12, 341–352. https://doi.org/10.1080/15568318.2017.1372538.

Azarova, V., Cohen, J.J., Kollmann, A., Reichl, J., 2020. The potential for community financed electric vehicle charging infrastructure. Transp. Res. Part D Transp. Environ. 88, 102541 https://doi.org/10.1016/j.trd.2020.102541.

Baresch, M., Moser, S., 2019. Allocation of e-car charging: Assessing the utilization of charging infrastructures by location. Transp. Res. Part A Policy Pract. 124, 388–395. https://doi.org/10.1016/j.tra.2019.04.009.

Bedir, A., Crisostomo, N., Allen, J., Wood, E., Rames, C., 2018. California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025. Future Infrastructure Needs for Reaching the State's Zero- Emission-Vehicle Emission-Vehicle Deployment Goals [WWW Document]. Calif. Energy Comm. URL https://www.energy.ca.gov/publications/2018/california-plug-electric-vehicle-infrastructure-projections-2017-2025-future.

Burroughs, N., Kolich, K., Byers, T., Nordstrom, V., 2021. Electric Vehicle Charging Survey : insights into EV owners' charging habits, and use of public EV charging [WWW Document]. URL ers-guides/Electric-Vehicle-Charging-Survey.pdf.

California Air Resources Board, 2019. Electric Vehicle Supply Equipment (EVSE) Standards Standardized Regulatory Impact Assessment (SRIA).[WWW Document]. URL https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/evse2019/appc.pdf?_ga=2.154747707.2021840979.1679129318-139232426.1678880367.

Chakraborty, D., Bunch, D.S., Lee, J.H., Tal, G., 2019. Demand drivers for charging infrastructure-charging behavior of plug-in electric vehicle commuters. Transp. Res. Part D Transp. Environ. 76, 255–272. https://doi.org/10.1016/j.trd.2019.09.015.

CMA, 2021. Summary: Building a comprehensive and competitive electric vehicle charging sector that works for all drivers [WWW Document]. URL https://www.gov.uk/government/publications/electric-vehicle-charging-market-study-final-report/final-report.

Coffman, M., Bernstein, P., Wee, S., 2017. Electric vehicles revisited: a review of factors that affect adoption. Transp. Rev. 37, 79–93. https://doi.org/10.1080/01441647.2016.1217282.

Cox, E., Pidgeon, N., Spence, E., 2022. But They Told Us It Was Safe! Carbon Dioxide Removal, Fracking, and Ripple Effects in Risk Perceptions. Risk Anal. 42, 1472–1487. https://doi.org/10.1111/risa.13717.

Das, H.S., Rahman, M.M., Li, S., Tan, C.W., 2020. Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. Renew. Sustain. Energy Rev. 120 https://doi.org/10.1016/j.rser.2019.109618.

Delmonte, E., Kinnear, N., Jenkins, B., Skippon, S., 2020. What do consumers think of smart charging? Perceptions among actual and potential plug-in electric vehicle adopters in the United Kingdom. Energy Res. Soc. Sci. 60, 101318 https://doi.org/10.1016/j.erss.2019.101318.

Transport Scotland, 2021. Electric Vehicle Charging Infrastructure Report.[WWW Document]. URL https://rctcbc.moderngov.co.uk/documents/s28854/Appendix%201a.pdf?LLL=0.

Department for Transport, 2022b. Electric Vehicle Charging Research Survey with electric vehicle drivers, [WWW Document]. URL https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1078871/dft-ev-driver-survey-summary-report.pdf.

Department for Transport, 2022a. Public Electric Vehicle Charging Infrastructure Deliberative and quantitative research without access to off-street parking. [WWW Document]. URL https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1061865/public-ev-charging-infrastructure-research-report.pdf.

Dodson, T., Slater, S., 2019. Electric Vehicle Charging Behaviour Study. [WWW Document] URL. http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/04/20190329-NG-EV-CHARGING-BEHAVIOUR-STUDY-FINAL-REPORT-V1-EXTERNAL.pdf%0Ahttps://www.smarternetworks.org/project/nia_ngso0021/documents.

Ensslen, A., Gnann, T., Jochem, P., Plötz, P., Dütschke, E., Fichtner, W., 2020. Can product service systems support electric vehicle adoption? Transp. Res. Part A Policy Pract. 137, 343–359. https://doi.org/10.1016/j.tra.2018.04.028.

European Environment Agency, 2022. Electric vehicles and the energy sector - impacts on Europe's future emissions [WWW Document].URL https://www.eea.europa.eu/publications/electric-vehicles-and-the-energy.

Funke, S.Á., Sprei, F., Gnann, T., Plötz, P., 2019. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. Transp. Res. Part D Transp. Environ. 77, 224–242. https://doi.org/10.1016/j.trd.2019.10.024.

Ge, Y., MacKenzie, D., 2022. Charging behavior modeling of battery electric vehicle drivers on long-distance trips. Transp. Res. Part D Transp. Environ. 113, 103490 https://doi.org/10.1016/j.trd.2022.103490.

Ge, Y., MacKenzie, D., Keith, D.R., 2018. Gas anxiety and the charging choices of plug-in hybrid electric vehicle drivers. Transp. Res. Part D Transp. Environ. 64, 111–121. https://doi.org/10.1016/j.trd.2017.08.021.

Gellrich, M., Block, A., Leikert-Böhm, N., 2022. Spatial and temporal patterns of electric vehicle charging station utilization: a nationwide case study of Switzerland. Environ. Res. Infrastruct. Sustain. 2, 021003 https://doi.org/10.1088/2634-4505/ac6a09.

Gómez Vilchez, J.J., Jochem, P., 2020. Powertrain technologies and their impact on greenhouse gas emissions in key car markets. Transp. Res. Part D Transp. Environ. 80, 102214 https://doi.org/10.1016/j.trd.2019.102214.

Greene, D.L., Kontou, E., Borlaug, B., Brooker, A., Muratori, M., 2020. Public charging infrastructure for plug-in electric vehicles: What is it worth? Transp. Res. Part D Transp. Environ. 78, 102182 https://doi.org/10.1016/j.trd.2019.11.011.

Gutjar, M., Kowald, M., 2023. The configuration of charging stations : What do potential users want ? Travel Behav. Soc. 32, 100579 https://doi.org/10.1016/j.tbs.2023.100579.

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., Figenbaum, E., Jakobsson, N., Jochem, P., Kinnear, N., Turrentine, T., Witkamp, B., Plötz, P., Pontes, J., Refa, N., Sprei, F., Turrentine, T., Witkamp, B., 2018. A review of consumer preferences of and interactions with electric vehicle charging infrastructure. Transp. Res. Part D Transp. Environ. 62, 508–523. https://doi.org/10.1016/j.trd.2018.04.002.

Helmus, J.R., Wolbertus, R., 2023. Cooperative behaviour at public electric vehicle charging stations. Travel Behav. Soc. 32, 100572 https://doi.org/10.1016/j.tbs.2023.100572.

Hink, C., 2021. Improving Drivers' Confidence in Public EV Charging.[WWW Document]. URL https://www.evaengland.org.uk/wp-content/uploads/2021/04/EVA-England-Consumer-Charging-Survey-Report.pdf.

Hopkins, E., Potoglou, D., Orford, S., Cipcigan, L., 2023. Can the equitable roll out of electric vehicle charging infrastructure be achieved? Renew. Sustain. Energy Rev. 182, 113398 https://doi.org/10.1016/j.rser.2023.113398.

Jochem, P., Gnann, T., Anderson, J.E., Bergfeld, M., Plötz, P., 2022. Where should electric vehicle users without home charging charge their vehicle? Transp. Res. Part D Transp. Environ. 113, 1–4. https://doi.org/10.1016/j.trd.2022.103526.

Kchaou-Boujelben, M., 2021. Charging station location problem: A comprehensive review on models and solution approaches. Transp. Res. Part C Emerg. Technol. 132, 103376 https://doi.org/10.1016/j.trc.2021.103376.

Kester, J., Noel, L., Zarazua de Rubens, G., Sovacool, B.K., 2018. Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the Nordic region. Renew. Sustain. Energy Rev. 94, 719–731. https://doi.org/10.1016/j.rser.2018.05.067.

Kim, S., Yang, D., Rasouli, S., Timmermans, H., 2017. Heterogeneous hazard model of PEV users charging intervals: Analysis of four year charging transactions data. Transp. Res. Part C Emerg. Technol. 82, 248–260. https://doi.org/10.1016/j.trc.2017.06.022.

LaMonaca, S., Ryan, L., 2022. The state of play in electric vehicle charging services – A review of infrastructure provision, players, and policies. Renew. Sustain. Energy Rev. 154, 111733 https://doi.org/10.1016/j.rser.2021.111733.

Langbroek, J.H.M., Franklin, J.P., Susilo, Y.O., 2017. When do you charge your electric vehicle? A stated adaptation approach. Energy Policy 108, 565–573. https://doi.org/10.1016/j.enpol.2017.06.023.

Latinopoulos, C., Sivakumar, A., Polak, J.W., 2017. Response of electric vehicle drivers to dynamic pricing of parking and charging services: Risky choice in early reservations. Transp. Res. Part C Emerg. Technol. 80, 175–189. https://doi.org/10.1016/j.trc.2017.04.008.

Lee, J.H., Chakraborty, D., Hardman, S.J., Tal, G., 2020. Exploring electric vehicle charging patterns: Mixed usage of charging infrastructure. Transp. Res. Part D Transp. Environ. 79, 102249 https://doi.org/10.1016/j.trd.2020.102249.

Li, H., Yu, L., Chen, Y., Tu, H., Zhang, J., 2023. Uncertainty of available range in explaining the charging choice behavior of BEV users. Transp. Res. Part A Policy Pract. 170 https://doi.org/10.1016/j.tra.2023.103624.

Liao, F., Molin, E., van Wee, B., 2017. Consumer preferences for electric vehicles: a literature review. Transp. Rev. 37, 252–275. https://doi.org/10.1080/01441647.2016.1230794.

Limmer, S., 2019. Dynamic pricing for electric vehicle charging—a literature review. Energies 12. https://doi.org/10.3390/en12183574.

Limmer, S., Rodemann, T., 2019. Peak load reduction through dynamic pricing for electric vehicle charging. Int. J. Electr. Power Energy Syst. 113, 117–128. https://doi.org/10.1016/j.ijepes.2019.05.031.

Liu, J., Santos, G., 2015. Decarbonizing the Road Transport Sector: Break-even Point and Consequent Potential Consumers' Behavior for the U.S. Case. Int. J. Sustain. Transp. 9, 159–175. https://doi.org/10.1080/15568318.2012.749962.

Ma, S.C., Yi, B.W., Fan, Y., 2022. Research on the valley-filling pricing for EV charging considering renewable power generation. Energy Econ. 106, 105781 https://doi.org/10.1016/j.eneco.2021.105781.

Märtz, A., Langenmayr, U., Ried, S., Seddig, K., Jochem, P., 2022. Charging Behavior of Electric Vehicles: Temporal Clustering Based on Real-World Data. Energies 15, 1–26. https://doi.org/10.3390/en15186575.

Metais, M.O., Jouini, O., Perez, Y., Berrada, J., Suomalainen, E., 2022. Too much or not enough? Planning electric vehicle charging infrastructure: A review of modeling options. Renew. Sustain. Energy Rev. 153, 111719 https://doi.org/10.1016/j.rser.2021.111719.

Moon, H.B., Park, S.Y., Jeong, C., Lee, J., 2018. Forecasting electricity demand of electric vehicles by analyzing consumers' charging patterns. Transp. Res. Part D Transp. Environ. 62, 64–79. https://doi.org/10.1016/j.trd.2018.02.009.

Nienhueser, I.A., Qiu, Y., 2016. Economic and environmental impacts of providing renewable energy for electric vehicle charging – A choice experiment study. Appl. Energy 180, 256–268. https://doi.org/10.1016/j.apenergy.2016.07.121.

Pan, L., Yao, E., MacKenzie, D., 2019. Modeling EV charging choice considering risk attitudes and attribute non-attendance. Transp. Res. Part C Emerg. Technol. 102, 60–72. https://doi.org/10.1016/j.trc.2019.03.007.

Philipsen, R., Schmidt, T., Van Heek, J., Ziefle, M., 2016. Fast-charging station here, please! User criteria for electric vehicle fast-charging locations. Transp. Res. Part F Traffic Psychol. Behav. 40, 119–129. https://doi.org/10.1016/j.trf.2016.04.013.

Potoglou, D., Whittle, C., Tsouros, I., Whitmarsh, L., 2020. Consumer intentions for alternative fuelled and autonomous vehicles: A segmentation analysis across six countries. Transp. Res. Part D Transp. Environ. 79, 102243 https://doi.org/10.1016/j.trd.2020.102243.

Rajendran, G., Vaithilingam, C.A., Misron, N., Naidu, K., Ahmed, M.R., 2021. A comprehensive review on system architecture and international standards for electric vehicle charging stations. J. Energy Storage 42, 103099. https://doi.org/10.1016/j.est.2021.103099.

Sachan, S., Deb, S., Singh, S.N., 2020. Different charging infrastructures along with smart charging strategies for electric vehicles. Sustain. Cities Soc. 60, 102238 https://doi.org/10.1016/j.scs.2020.102238.

Santos, G., Davies, H., 2020. Incentives for quick penetration of electric vehicles in five European countries: Perceptions from experts and stakeholders. Transp. Res. Part A Policy Pract. 137, 326–342. https://doi.org/10.1016/j.tra.2018.10.034.

IEA, International Energy Agency, 2019. Global EV Outlook 2019, OECD iea.org. [WWW Document]. URL https://www.iea.org/publications/reports/globalevoutlook2019/.

Sheldon, T.L., DeShazo, J.R., Carson, R.T., 2019. Demand for Green Refueling Infrastructure. Environ. Resour. Econ. 74, 131–157. https://doi.org/10.1007/s10640-018-00312-9.

Song, R., Potoglou, D., 2020. Are existing battery electric vehicles adoption studies able to inform policy? A review for policymakers. Sustain. 12 https://doi.org/10.3390/su12166494.

Sun, X.H., Yamamoto, T., Morikawa, T., 2016. Fast-charging station choice behavior among battery electric vehicle users. Transp. Res. Part D Transp. Environ. 46, 26–39. https://doi.org/10.1016/j.trd.2016.03.008.

Sun, X.H., Yamamoto, T., Takahashi, K., Morikawa, T., 2018. Home charge timing choice behaviors of plug-in hybrid electric vehicle users under a dynamic electricity pricing scheme. Transportation (Amst). 45, 1849–1869. https://doi.org/10.1007/s11116-018-9948-6.

ten Have, S.Y., Gkiotsalitis, K., Geurs, K.T., 2020. Investigating the future of ultrafast charging: A choice experiment in The Netherlands. World Electr. Veh. J. 11, 1–22. https://doi.org/10.3390/wevj11040070.

Teoh, T., 2021. Electric vehicle charging strategies for Urban freight transport: concept and typology. Transp. Rev. 1–24. https://doi.org/10.1080/01441647.2021.1950233.

Visaria, A.A., Jensen, A.F., Thorhauge, M., Mabit, S.E., 2022. User preferences for EV charging, pricing schemes, and charging infrastructure. Transp. Res. Part A Policy Pract. 165, 120–143. https://doi.org/10.1016/j.tra.2022.08.013.

Wang, Y., Yao, E., Pan, L., 2021. Electric vehicle drivers' charging behavior analysis considering heterogeneity and satisfaction. J. Clean. Prod. 286, 124982 https://doi.org/10.1016/j.jclepro.2020.124982.

Wen, Y., MacKenzie, D., Keith, D.R., 2016. Modeling the charging choices of battery electric vehicle drivers by using stated preference data. Transp. Res. Rec. 2572, 47–55. https://doi.org/10.3141/2572-06.

Wolff, S., Madlener, R., 2019. Charged up? Preferences for Electric Vehicle Charging and Implications for Charging Infrastructure Planning. SSRN Electron. J. 10.2139/ssrn.3491629.

Wolbertus, R., van den Hoed, R., 2019. Electric vehicle fast charging needs in cities and along corridors. World Electr. Veh. J. 10, 1–13. https://doi.org/10.3390/wevj10020045.

Woo, J.R., Choi, H., Ahn, J., 2017. Well-to-wheel analysis of greenhouse gas emissions for electric vehicles based on electricity generation mix: A global perspective. Transp. Res. Part D Transp. Environ. 51, 340–350. https://doi.org/10.1016/j.trd.2017.01.005.

Wood, E., Rames, C., Muratori, M., Raghavan, S., Melaina, M., 2017. National Plug-In Electric Vehicle Infrastructure Analysis, National Renewable Energy Laboratory.

Xu, M., Meng, Q., Liu, K., Yamamoto, T., 2017. Joint charging mode and location choice model for battery electric vehicle users. Transp. Res. Part B Methodol. 103, 68–86. https://doi.org/10.1016/j.trb.2017.03.004.

Yu, H., MacKenzie, D., 2016. Modeling charging choices of small-battery plug-in hybrid electric vehicle drivers by using instrumented vehicle data. Transp. Res. Rec. 2572, 56–65. https://doi.org/10.3141/2572-07.

Zhang, Q., Li, H., Zhu, L., Campana, P.E., Lu, H., Wallin, F., Sun, Q., 2018. Factors influencing the economics of public charging infrastructures for EV – A review. Renew. Sustain. Energy Rev. 94, 500–509. https://doi.org/10.1016/j.rser.2018.06.022.

Zhang, Y., Luo, X., Qiu, Y., Fu, Y., 2022. Understanding the generation mechanism of BEV drivers' charging demand: An exploration of the relationship between charging choice and complexity of trip chaining patterns. Transp. Res. Part A Policy Pract. 158, 110–126. https://doi.org/10.1016/j.tra.2022.02.007.