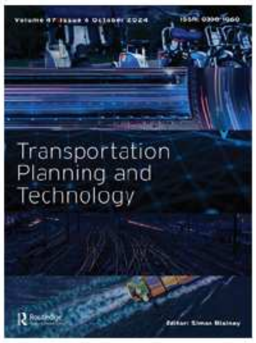

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Electric vehicle public charging choices: a qualitative investigation

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ABSTRACT

Understanding how potential and existing electric vehicle users choose public charging is critical for the development of public-charging infrastructure. This study employs a qualitative approach guided by stated choice tasks to examine the decision-making processes regarding public charging. Through 20 interviews of existing and potential EV users in the UK, thematic analysis of responses pointed towards three areas: the choice context, attribute non-attendance and payment method. Participants sought detailed information about the circumstances under which they had to charge their vehicles. Attribute non-attendance meant that some participants paid more attention to specific attributes than others (e.g. location, price). Responses around the payment method pointed towards differences in relation to personal attitudes. This evidence suggests that charging choices are context-dependent, choices may be guided by specific attributes and individual attitudes play a role in these choices. These are also important considerations when designing a large-scale survey involving choice experiments and public charging.

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Electric vehicles; public-charging choices; stated preference discrete choice experiment; cognitive interviews; choice experiment face validity

1. Introduction

A significant volume of literature has thus far focused on the demand for electric vehicles (see, Song and Potoglou 2020) including the effectiveness of subsidies and incentives to encourage electric vehicle (EV) uptake (Cavallaro et al. 2018; Kwon, Son, and Jang 2018; Langbroek, Franklin, and Susilo 2016; Santos and Davies 2020). However, an increasing discourse in the literature and the public-policy and decision-making domains revolves around the availability and coverage of charging points to satisfy demand on behalf of EV users (Hopkins et al. 2023). Public charging, in particular, is important in providing confidence to the users and accelerating demand, especially for EV owners without access to off-road private parking space equipped with an EV charger (Potoglou, Song, and Santos 2023).

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EV public-charging stations can be located in a variety of locations such as destinations (e.g. supermarkets, shopping centres and transport hubs such as airports and train stations), en route (e.g. highways), residential streets and charging hubs (HM Government 2022), enabling EV users to charge their vehicles away from their own driveways and workplace parking spaces. Lack of public-charging infrastructure not only hinders the widespread adoption of electric vehicles (Miele et al. 2020) but also triggers 'range anxiety' among EV users (Pevec et al. 2020). Government initiatives aim at further investing in charging infrastructure. For example, the UK Government has announced plans to expand the number of public-charging points tenfold by 2030 (GOV.UK 2022).

Understanding choices for public charging is important for several reasons as it involves complex cross-sectoral interrelations such as energy and transport infrastructure and traveller/consumer behaviour. For example, understanding choices for public charging would have a significant effect on infrastructure planning by providing an appropriate evidence base for decision-making (Wolff and Madlener 2019). Knowledge around public-charging choices increases the satisfaction of existing EV users with the upcoming public-charging infrastructure (Wang, Yao, and Pan 2021). Most importantly, evidence from public-charging choices will enhance consumer confidence to adopt EVs (Ma, Yi, and Fan 2022) as it would also help address issues around range anxiety of EV users by providing appropriate information on where to strategically locate public-charging points (Potoglou, Song, and Santos 2023).

Research on EV charging choices has focused on either modelling actual charging choices of EV users (Lee et al. 2020) or hypothetical choices using stated preference discrete choice experiments (SPDCE) (Gutjar and Kowald 2023), which were employed to investigate the significance of various factors and derive monetary valuations (e.g. willingness to pay). While quantitative analyses and related models provide significant insights, they do often under-report (or assume) the underlying decision-making process on why individuals make specific choices. Most importantly, surveys involving SPDCE need to be thoroughly tested to ensure face and construct validity of the generated choice tasks, in order to enhance the robustness of the study findings and conclusions.

Qualitative methods, especially prior to large-scale surveys, can provide an insight into the cognitive processes and decision-making rationale (Payne et al. 1992) of both EV and non-EV users as well as help enhance the validity of subsequent quantitative analyses (Murphy, Hollinghurst, and Salisbury 2018). Although these techniques have been commonly applied in choice experiments in health and other areas (e.g. Haggar et al. 2022), they are less common in transport studies, particularly concerning vehicle type and public-charging infrastructure choices. Thus, the aim of this study is to fill this gap and gain a detailed insight into public-charging choices. Specifically, this study aims to: (a) understand how existing and potential EV users make public-charging choices and, most importantly, understand the underlying reasons for arriving at those choices; and (b) examine the trade-offs they make when evaluating different characteristics (attributes) of public charging through a qualitative analysis of a choice experiment.

This study offers valuable contributions across several dimensions. Methodologically, using an SPDCE as the basis to conduct cognitive interviews provides a deeper insight into individuals' cognitive processes and decision-making rationale regarding public-charging choices. This approach also ensures the internal validation of subsequent large-scale survey questionnaires. Empirically, this study can enhance our understanding of the features of public-charging points that are important to both EV and non-EV users. Practically, the findings of this study provide policy-relevant evidence base aimed at enhancing the public-charging network and helping public-charging service operators towards improving the quality and competitiveness of their services.

The remainder of this paper is organised as follows. Section 2 offers a detailed discussion of the methodology employed, and Section 3 presents the findings of this study. Sections 4 and 5 discuss the findings and provide concluding remarks including recommendations for further exploration of EV public-charging choices, respectively.

2. Methods

As shown in Figure 1, this study comprised three phases: (a) study design phase, which included the design of a public-charging choice experiment, which was informed by a critical assessment of the literature on public-charging choices (Potoglou, Song, and Santos 2023) and the cognitive-interview protocol; (b) data collection including the recruitment of EV and non-EV user participants and the cognitive interviews and (c) transcription and thematic analysis of the collected interview data.

2.1. Definition of the charging scenario and alternatives

As shown in Figure 2, the charging scenario involved the EV user being away from their home and with their vehicle at 20% state of charge (SOC) in need to be recharged at 80%. Participants were presented with two unlabelled charging options, which were described by their location, price and other attributes discussed in Section 2.2.

The scenario controlled for four external factors:

(1) *The EV had to be recharged almost immediately*. Prior evidence has consistently shown that the willingness of EV drivers to charge their vehicles decreases dramatically when their EVs are at a sufficient level of charge (e.g. Wang, Yao, and Pan

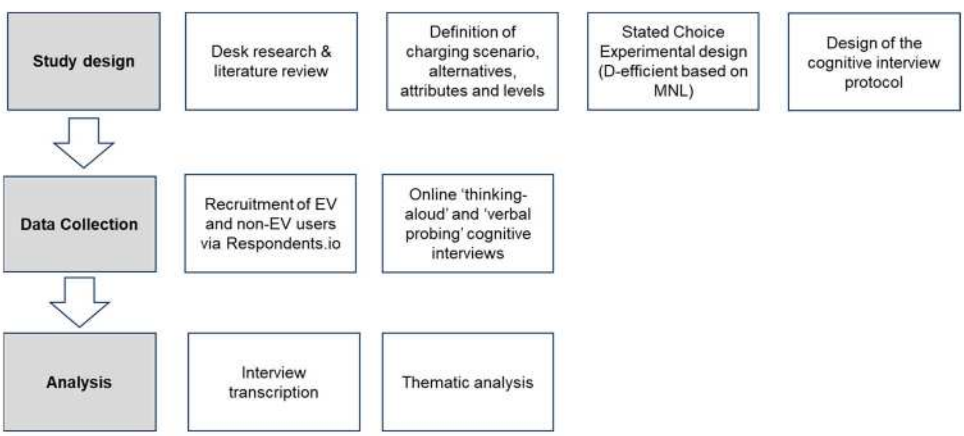

Figure 1. Study design, data collection and analysis steps.

Imagine, that you are away from your home but within the area you normally spend time during the day and your electric car is at 20% of its charging level and needs recharging.

You wish to charge your vehicle at an 80% charging level, and you have two options available within the range of your current charging level (20%).

We will present you with a total of 5 cards.

In turn, each card will present you with two charging options (points) with different characteristics including the type of the location (e.g., on-street, at the surface car park, multi-storey car park, or underground car park), whether fast charging, charging cost, amenities within walking distance from the charging point, etc.

Please: carefully read each card and indicate which charging point you would choose to charge your electric car to the 80% charging level or you can choose neither options if they are not what you want.

Note: fast charging can charge an EV in several minutes to 30 minutes, while public slow charging usually takes 1-4 hours, depending on the charging power.

Figure 2. The public-charging scenario.

2021). This hypothesis was initially adopted to avoid situations where participants would think it was not critical to make a charging choice.

(2) *The EV driver was away from their home but within the area they normally lived*. The main reason for introducing this factor was to frame the decision-making of users on public charging and around their daily travels, rather than home charging, less frequent activities or long-distance travel.
(3) *The initial SOC of the vehicle was 20% and needed to reach 80% charge at the end of the charging session*. Most non-EV owners are more inclined to charge when SOC drops below 15%, a level at which most EVs display a 'low battery' warning (Pevec et al. 2020). Maintaining a fixed charging demand from 20% to 80% was important to maintain the simplicity of the choice scenario, as it prevented participants from both commencing and ending charging at different SOCs.
(4) *The scenario took place 'during the day'*. This factor was introduced because prior evidence showed that potential and existing EV users were more likely to charge at home overnight and only use public-charging infrastructure during the day (Moon et al. 2018).

2.2. Attributes, attribute levels, and choice tasks

The attributes and levels of the alternatives were derived from a synthesis of public-charging choice studies (Potoglou, Song, and Santos 2023). Overall, seven attributes were identified as most relevant for the choice experiment: charging location, availability of fast charging, charging price, waiting time, distance from the charging point to the destination, payment method, and amenities. The attribute levels for each of these attributes are presented in Table 1.

Charging locations can vary depending on the study setting and geographic differences across countries. For example, charging points can be located at supermarkets, shopping

Table 1. Attributes and levels in the public-charging choice experiment

	Levels				
Attributes	1	2	3	4	5
Location	On street	Surface-level car park	Multi-storey car park	Underground car park	
Fast charging	✓	X			
Cost (p/kWh)	Current price (45)	10% more than current price (50)	20% more than current price (54)	30% more than current price (59)	40% more than current price (63)
Distance from charging point to your destination (m)	100	250	500	1,000	
Waiting time for an available charging point (minutes)	Available right away	2	5	10	
Method of payment	Card or contactless payment	Card or contactless payment or via supplier's app	Card or contactless payment or via universal app	Payment taken automatically	
Amenities	None	Waiting room	Small shop or café	Shopping mall	

centres, near residential estates, motorways, schools, and gyms (Wolff and Madlener 2019). This study introduced four charging locations aimed at avoiding too specific assumptions about charging locations: (i) on the street; (ii) surface car park; (iii) multi-storey car park; and (iv) underground car park.

Fast charging is often favoured over slow charging due to time savings (e.g. Dorcec et al. 2019). Instead of using charging time as an attribute, this study adopted 'charging speed' to indicate whether a charging point offered fast charging (or not). This definition reduced the potential complexity of introducing charging power and corresponding charging times.

Previous studies have reported a strong negative association between *charging prices* and public-charging choices (e.g. Pan, Yao, and MacKenzie 2019). The charging price in this study was introduced as the cost to charge the vehicle from 20% to 80% of its battery level. Based on the charging price at public-charging points in the UK (e.g. BP Pulse), the base level was chosen at 45 p/kWh with another four levels defined as 10% increments from the base: 50, 54, 59, and 63 p/kWh. The base and the first two of these levels corresponded to price variations for slow charging, while the last three levels (see, Table 2) corresponded to fast charging.

Table 2. Characteristics of participants in the interviews.

Non-EV users					EV users				
#	Gender	Age	Education	Car type	#	Gender	Age	Education	Car type
1	Male	27	Postgraduate	ICEV	11	Male	29	Postgraduate	BEV
2	Female	26	Postgraduate	ICEV	12	Male	46	Postgraduate	PHEV
3	Female	32	Postgraduate	ICEV	13	Female	28	Postgraduate	BEV
4	Male	30	Postgraduate	ICEV	14	Male	32	Postgraduate	PHEV
5	Male	31	Undergraduate	N/A	15	Female	40	Some college, no degree	BEV
6	Male	42	Undergraduate	ICEV	16	Male	29	Postgraduate	BEV
7	Female	29	Postgraduate	ICEV	17	Female	48	Some college, no degree	BEV
8	Male	44	Undergraduate	ICEV	18	Male	31	Some college, no degree	PHEV
9	Male	28	Undergraduate	ICEV	19	Female	29	Undergraduate	PHEV
10	Female	40	Postgraduate	ICEV	20	Male	32	Undergraduate	PHEV

Time and distance have been used to evaluate the accessibility to public-charging points (ten Have, Gkiotsalitis, and Geurs 2020). For example, Latinopoulos, Sivakumar, and Polak (2017) used a range of walking times from a charging point to a destination (e.g. a 4- to 20-min walk from the destination) to present the accessibility of public-charging points. Generally, potential and existing EV users would prefer higher accessibility to public-charging stations. For example, ten Have, Gkiotsalitis, and Geurs (2020) found that having to make a time-based detour (e.g. 5 min) made the charging point less appealing to use. A study of private EV users in Japan showed that they preferred to make a 1,750-m detour on weekdays and up to 750-m detours on weekends in order to use fast charging (Sun, Yamamoto, and Morikawa 2016). Based on the above studies, accessibility from/to a charging point was defined as the *distance from the destination* and included four levels: 100, 250, 500, and 1000 m.

Previous studies have also considered *availability of charging points* as a potential correlate of public-charging choices (see, Wolff and Madlener 2019). Low availability would entice users to detour to the next available charging point, wait longer at the current charging station or postpone charging their vehicle. Charging point availability has been introduced as queueing/waiting time to measure the availability of public-charging points and it has been found to have a negative effect on public-charging choices (Wang, Yao, and Pan 2021). In this study, waiting time was defined as 'the time EV users would have to wait for a charging point to become available' and included four levels: 0 min (no wait), 2, 5, and 10 min.

The *payment method* can significantly impact the user experience (Ricardo Energy & Environment 2022). However, this attribute has not been frequently included in previous public-charging studies. This study introduced various payment methods that have also been offered by public-charging infrastructure providers in the UK (e.g. BP Pulse) and included: card payment, contactless payment, and payment via the supplier's app. In general, mobile applications offered by charging operators allow EV users to view live charging information and charging history of their vehicle, download value-added tax (VAT) receipts, and bill users monthly via credit/debit cards.

In addition to existing payment methods, this study further included a 'universal app' option that would enable users to pay for public charging via a single mobile application. Another level presented technology that allowed automatic payments once the EV is connected to the charger, as new EVs will have in-built authentication data. Overall, the payment method attribute included four levels: 'card or contactless payment', 'card or contactless payment or via supplier's app', 'card or contactless payment or via a universal app', and 'card-free with payment taken automatically' once the EV is connected to the charger.

Amenities near public-charging points are also important for public-charging preferences. For example, ten Have, Gkiotsalitis, and Geurs (2020) examined users' responses to different amenity scenarios around public-charging stations, such as waiting rooms, shopping malls, small shops or cafés, or places without facilities. The authors reported that having a slow charging point near a shopping area increased its attractiveness. The authors also found that in the absence of any other facilities, the propensity to choose fast and slow charging points was higher than ultrafast charging. This study also included the same levels mentioned in the literature: 'no facilities', 'waiting room',

Description	Option A	Option B
Distance from charging point to your destination (metres)	1000	100
Rapid charging	✓	×
Cost (p/kWh)	20% more than current price	20% more than current price
Method of payment	Card or contactless payment	Payment taken automatically
Amenities	Small shop or café	Waiting room
Waiting time for an available charging point (minutes)	2	5
Location	Multi-storey car park 	Underground car park 
I would choose option:	☐	☐

Figure 3. An example choice task.

'small shop or café', and 'shopping mall within walking distance' (ten Have, Gkiotsalitis, and Geurs 2020).

Sixty choice tasks each including two unlabelled charging alternatives and an 'opt-out' option were generated through a D-efficient experimental design based on the multinomial logit model with zero priors (see, Figure 3 for an example) using the software NGENE (ChoiceMetrics 2021). The choice tasks were further grouped into 12 blocks, with each respondent presented with 5 choice tasks. To control for possible ordering bias, three versions of the choice tasks were generated, featuring different attribute orders within each block.

2.3. Recruitment of participants

This qualitative study involved 20 participants; 10 EV (battery electric, hybrid and plug-in hybrid) and 10 non-EV users including those planning to purchase a car. All participants were over 18 years of age, held a full driving license, lived in the UK and were recruited via 'Respondents.io', a market research agency. As shown in Table 2, the participants were almost equally split between males and females in both the EV and non-EV user groups and included a diverse range in terms of age and education qualifications. A sample of 20 participants was sufficient to gain insights on how participants approached the choice task and made choices based on the alternative options and the attributes presented to them.

Table 3. Probing techniques and example questions.

Cognitive probe technique	Example Question
Comprehension	• What does the 'distance' mean to you? Do you have any picture in your mind?
Paraphrasing	• Could you please briefly describe to us what is the context of the choice task?
Specific probe	• Do you see there is any difference between supplier's app and the universal app?
General probe	• Why did you choose that option? Was that easy or hard to choose/answer?
	• I noticed that you hesitated - tell me what you were thinking

2.4. Cognitive interviews

The cognitive-interview materials comprised a set of slides including the scenario description (Figure 2), the attributes and their levels (Table 1) and five choice tasks – i.e. different configurations of attribute levels of the example shown in Figure 3. The cognitive interviews involved a combination of 'thinking aloud' and 'verbal probing'. The former involves providing instructions to participants via an interviewer who requires training and allows open-ended responses (Ericsson and Simon 1993). Verbal probing encourages the interviewer to seek additional details thus helping to control the interview (Willis 2011).

As shown in Figure 2, participants were firstly introduced to a charging scenario at the destination of their trip during the day. This step was followed by a detailed explanation of the attributes and levels involved in the experiment and a presentation of five choice cards, which were variants of Figure 3 in terms of the levels shown. For each card, participants were prompted to make a choice between the two unlabelled options on each card or opt out. During the presentation of each choice card, a series of probing questions were used to collect details on comprehension, paraphrasing, specific probe and general probe. Examples of probing questions against the aforementioned techniques are shown in Table 3. The interview protocol is shown in the Appendix.

Interviews were conducted between 5 and 16 December 2022 online via Zoom, a video conferencing software that supports screen sharing. The consent form was sent along with the invitation on the 'Respondents.io' platform. A signed consent form was obtained prior to the formal interview, followed by a question at the start of the interview asking for verbal consent to ensure that the respondent was willing to participate in the study. Prior to conducting the interviews, an Ethics Approval was obtained by the Ethics Committee within the School of Geography and Planning at Cardiff University.

2.5. Thematic analysis of cognitive interviews

All interviews were recorded and transcribed verbatim. Also, detailed notes were taken to record participants' observations of the materials and choices, their thoughts, and impressions. Transcriptions were then combined with the notes following Braun and Clarke's (2006) methodology to provide the basis for thematic analysis.

Drawing from Beatty and Willis (2007), the collected responses were used to construct a 'theme sheet' with one column for participant names and one row for themes/codes – i.e. points that were consistently mentioned during the cognitive interviews. The theme sheet was divided into three sections covering the introductory text, attributes and attribute levels, and the choice cards in the SPDCE. The themes/codes referred to each section were populated in the corresponding cell for each participant in the theme table. While thematic analysis has been previously used to analyse qualitative interviews in transport research (e.g. Liu, Nikitas, and Parkinson 2020), this is the first time this approach has been employed to confirm the construct validity of an SPDCE choice task. From an empirical perspective, most importantly, this approach helped uncover nuanced aspects of public-charging choices using the choice tasks as the departure point of the discussion.

3. Findings

The thematic analysis of the cognitive-interview data revealed three key themes regarding participants' public-charging choices: (1) the choice context and its cognitive challenges, (2) attribute non-attendance, and (3) the definition of the 'payment methods' attribute and its varying interpretations by respondents. As shown in Figure 4, each of the three themes further comprised several subthemes.

3.1 Choice context

Most participants were ultimately able to make choices based on the charging scenarios presented to them. Fifteen participants, including nine non-EV users and six EV users, expressed concerns about the lack of clarity in the choice context. As shown in Figure 5, five subthemes and further codes related to the charging context were identified: (1) charging destination; (2) time for travel; (3) travel purpose; (4) vehicle information; and (5) charging station information.

3.1.1. Destination

The scenario was based on the premise of being 'away from your home but within the area you normally spend time'. Likewise, the inclusion of the factor 'the distance from charging point to your destination' in the choice task was meant to depict a destination

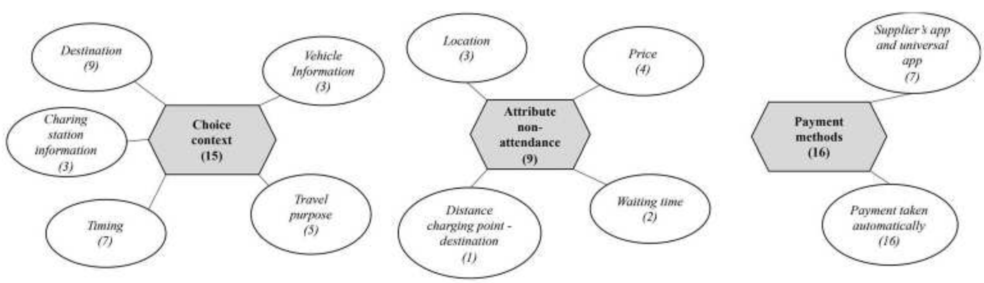

Figure 4. Themes and subthemes identified by thematic analysis. Note: Figures in parentheses indicate the number of participants who mentioned the theme.

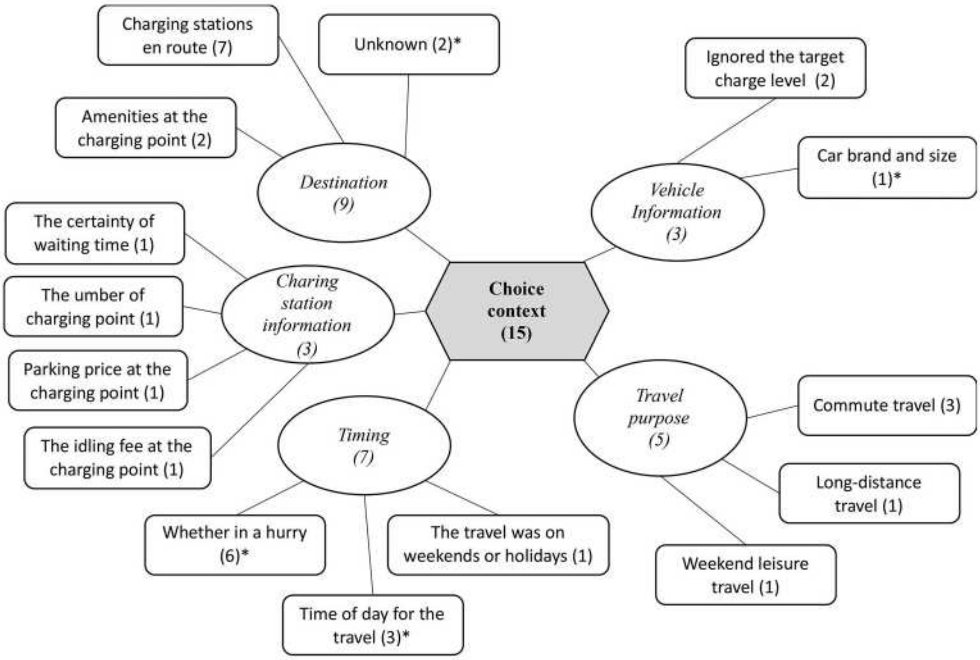

Figure 5. Subthemes within the 'choice context' theme. Note: Figures in parentheses indicate the number of participants who mentioned the theme. * A participant was unable to make a choice for the reasons listed.

charging scenario. However, five non-EV and four EV users experienced challenges in pinpointing their destination. Two non-EV users wished the destination to be more specific:

> [It] says distance from charging point to your destination. What is my destination in this context? Where I'm living, for example, or where I'm working, that kind of thing? (#6)

Seven participants, three non-EV users and four EV users, perceived the destination as charging stations en route. For example, they considered charging stations on their way home or during a long journey to another destination:

> It feels as if I was almost to the end of a long journey, where I thought, alright, I can sort of top up to charge my car, it'll get me to my destination, but then I need to return back.(#4)

A non-EV and an EV user would rather choose a destination that combined amenities available at the charging point. They imagined scenarios of entertainment or errands while waiting for their vehicle to charge. This may also reflect their perceptions of the importance of amenities when charging electric vehicles:

> [The amenities are] probably more things nearby. For example, yesterday, I needed to charge, and I needed to do food shopping. So for me, having that there is great, because I've got an hour at lunchtime, and I can do both things. (#16)

3.1.2. Timing

Despite the scenario specified that the charging session would occur 'during the day', six non-EV users and an EV user wished to know when they travelled. Respondents stated that the time of day and day of the week would influence their public-charging decisions because of their time schedule. As a result, five non-EV users and an EV user also emphasised the importance of knowing their 'time budget'. For example, they enquired whether the trip would take place on a weekend or a holiday because charging preferences would be different for them. A participant, for example, stated that they needed to charge quickly on weekdays to keep up with work but would prefer slow charging on weekends or holidays. Overall, this group of participants would use fast charging when time was limited but were content with more affordable, slower charging their schedule was more flexible:

> If it was only going to take an hour, I could spend an hour but that would be dependent on how much of my journey have I got left. Is it worthwhile for me to spend an hour of my day at a slower charger or am I just going to have to suck it up and pay the extra 40% because I'm in a hurry? (#15)

Finally, the time of day at which charging occurs greatly influenced the public-charging decisions for three non-EV user female participants because of safety concerns:

> If it was daytime I would definitely go for option A just because I wouldn't be so concerned about hanging around for a bit longer. (#3)

3.1.3. Travel purpose

Since the purpose of the travel was not explicitly stated in the scenario, three non-EV users and two EV users assumed different travel purposes. For example, three participants thought it was a commute travel, one participant believed it was a long-distance travel, and another participant interpreted the scenario as leisure travel over the weekend:

> In that scenario, I'm coming to the office. (#13)

> It feels as if I was almost to the end of a long journey, … I'm almost at the end of my journey. I'm just going to add on a bit more, I'll get to them to my journey, but then I need to return back where I'm going. (#4)

> I think about this, it's mostly a weekend trip. And not exactly a trip. I'm just going out for a ride. Or maybe getting some grocery or something. Like a casual journey. (#11)

An EV user also highlighted that different trip purposes sometimes can lead to completely different public-charging choices:

> So, it's different for me when I'm coming into the office versus if I was doing a long journey to go somewhere or like a leisure visit. (#13)

3.1.4. Vehicle information

Participants asked for further details about the vehicle including the target charge level and the vehicle's model/size. Even though the charging scenario assumed an initial SOC at 20% and a target charge level of 80%, a non-EV and an EV users missed this information. Instead of waiting for the vehicle to reach the 80% charge level, they expressed an intention to quickly charge the vehicle with enough power for the next trip. In this case, they did not mind choosing the more expensive fast-charging option because it would not be too expensive to charge the vehicle for a short period of time:

> I don't need to do the whole 80% charge I think here. I imagine if the price is significantly lower than I could, I could go with a with a 40% more. But if the if it was really if it was as expensive as petrol, then I will definitely shop around for the cheapest option, especially now. (#10)

The model/size of the vehicle would also raise as a potential factor of particiapnts' choice of public charging. A non-EV user was unable to make a choice because they felt that smaller EVs were better suited for street parking, while an owner of a larger or luxury models might prefer larger spaces and locations, such as underground car parks:

> I think it would depend [on] what car I'm driving. If it was a small electric car, like I've seen recently, like the Honda II, … I probably parked that on the street, because that's super easy to park, it's small. But if I was in a Porsche Taycan, and I'd be in the underground car parks, I'd be parking that in a much bigger, bigger spot, and I would want to park down the street. (#7)

3.1.5. Charging station information

Three participants, a non-EV user and two EV users, wished to know more about charging points such as waiting times, number of charging points, parking prices, and idling fees (i.e. fees incurred to minimise the amount of idling time at a charging station after a vehicle has finished charging), as they felt that these factors would be crucial in their decision to charge. Although the choice task included the 'time waiting for available charging point' attribute, an EV user was still concerned about the uncertainty of waiting times based on their own experience of public charging:

> I keep coming back to the waiting time for an available charging point. As well, it's just never ending, never a way of knowing how long it's going to be doing. (#12)

A non-EV user was also concerned about the limited number of available charging points at the public-charging station. The participant emphasised the importance of knowing the number of charging points prior to deciding where to charge their EV. In general, stations with more charging points are seen as more convenient as users can plan ahead:

> So now number of charging points that you get? Because if I'm driving a car, and I'm thinking where should I park … this one spot only has two charging points. That's always busy. But the other one has 10 charging points. So they've got more, even before I go there and see the waiting time I can sort of plan about that. (#10)

Another EV user emphasised the importance of parking cost at charging points and would rather prefer locations with lower charges:

> The underground carpark I'm thinking here, if it was in Leeds, I would be paying to park in there as soon as I drove in, and they're really expensive in comparison to on street parking. (#13)

At the same time, the participant felt that if public-charging stations charged for idling they would also impact their choice of public charging, especially if fast charging was available:

So this the issue that I've mentioned before about sort of rapid charger finishes in half an hour, and you've got to go back and move are you paying idling fees? (#13)

3.2. Attribute non-attendance

Some participants' choices were driven by specific factors. For example, charging location, price, waiting time, and the distance from the charging point to their destination. This is known as 'attribute non-attendance' and occurs when participants do not consider or pay attention to all attributes when making their choices (Hensher 2006). This is common in real-life decision-making processes where individuals may not always thoroughly assess or consider each and every attribute, especially when faced with a complex set of options. However, attribute non-attendance should be accounted for in a study to satisfy the presumption of choice experiments and the Random Utility Theory supporting them. Figure 6 summarises the subthemes and codes of the attribute non-attendance theme in this study.

Three female, non-EV users prioritised their choices based on charging location. Two of them paid particular attention to the different types of car parks, and strongly felt that they avoid charging at a multi-storey car park due to safety concerns:

It's mainly the location. Being like when I earlier was talking about multi storey car parks, like you don't know who's arranging … you don't know how to get help a lot the time or if anyone will hear you if you shout out, which is a bit scary. (#3)

Another non-EV user placed higher importance on vehicle security and would rather prefer spacious car parks over narrow streets to avoid possible damage to their car:

On the street here that looks like a really narrow street with loads of cars parked on the left and right hand side … it looks really tight if somebody else was to park … maybe scratch my

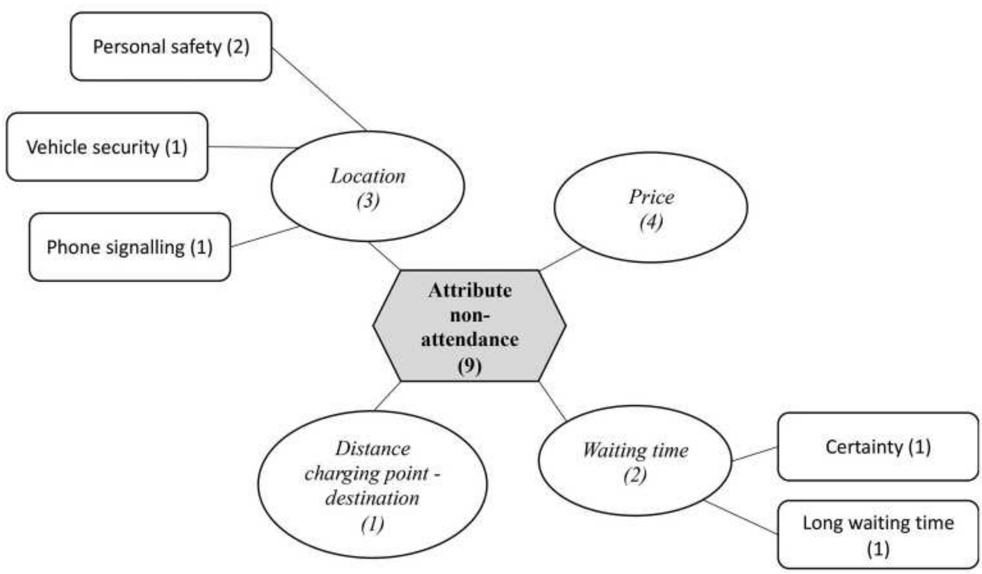

Figure 6. Subthemes of the 'attribute non-attendance' theme. Note: Figures in parentheses indicate the number of participants who mentioned the theme.

> car or, or damage it and then just drive away. In car park like this seems to be there's more space, there's a little bit more security. (#10)

Also, a non-EV user discussed considered phone signalling issues; they highlighted the importance of charging at an above-ground car park that would provide better signal reception:

> Multi-story car park, great. So you're above ground level so you've got signal so that then would influence if you need amenities because obviously if you're an underground carpark if you sat there waiting, well you can't even do anything like check your phone or anything like that. (#2)

Four participants (a non-EV user and three EV users) paid very close attention to charging prices. They consistently chose options with the lowest price:

> I would select Option A because of the cost majorly though it doesn't have rapid charging and I'll have to wait for a really long time. But it costs 40% less. (#11)

Two EV users were highly concerned about waiting times. One of them expressed frustration about the unpredictable waiting times for an available charging point, highlighting the lack of information on the duration of the wait.

> I keep coming back to the waiting time for an available charging point. As well, it's just never ending, never a way of knowing how long it's going to be doing. (#12)

The other EV user prioritised minimising waiting times and preferred options showing immediate availability of charging points regardless of other attributes:

> I would choose option A because it's available right away, although I don't like it's in an underground car park and there isn't rapid charging. (#17)

Finally, an EV user primarily focused on the distance between the charging point and their destination and chose the option showing the shortest distance to their final destination across all five choices presented to them.

3.3. Interpretation of the payment method

Another finding from the cognitive interviews was that participants had different interpretations of payment methods. In particular, it was difficult for them to distinguish across 'supplier's app', 'universal app', and 'payment taken automatically'. Figure 7 presents the subthemes and further codes regarding the understanding of payment methods.

3.3.1. The understandings of 'supplier's app' and 'universal app'

Seven participants expressed different understandings of 'supplier's app' and 'universal app'. Three participants (a non-EV user and two EV users) interpreted these payment methods being analogous to paying for parking fees. For example, a participant said: 'a supplier's app is like a specific app for parking, such as RingGo[1]' (#6) and due to 'different cities, different companies, different locations have different methods and different apps' (#10) therefore 'they can have several different apps' (#20). Regarding a universal app, an EV user thought of 'it like a universal parking app'.

On the other hand, a non-EV user perceived the 'supplier's app' and the 'universal app' payment options as being analogous loyalty card. According to this participant, a

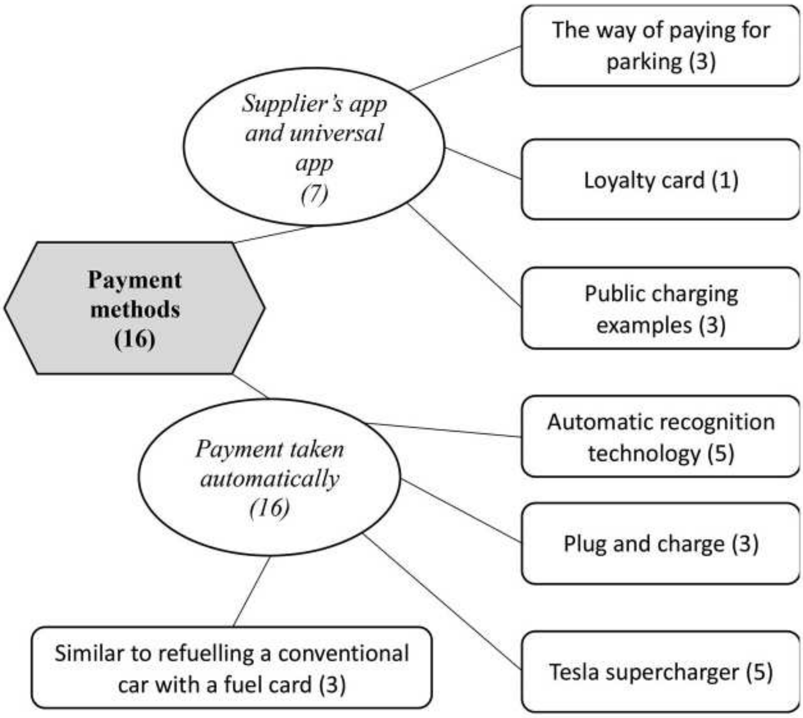

Figure 7. Various interpretations of 'payment methods'. Note: Figures in parentheses indicate the number of participants who mentioned the theme.

membership card for each shop was similar to the 'supplier's app', while a 'universal app' would be similar to an app that 'stores all of your different loyalty cards on one universal third party app' (#7).

Only three participants (a non-EV user and two EV users) specifically linked these payment methods with public-charging examples. They perceived the supplier's app as being like 'network or charges' (#8), such as 'pod point' (#15, #19) and 'BP pulse charging station' (#18) or 'the brand of car' (#8) such as 'Tesla charging points' (#19). In relation to the universal app, an EV user said this could refer to 'third-party organisations that have agreements with many other charging companies such as BP Pulse' (#18), while a participant mentioned the 'ChargePlace Scotland' (#15), which is a national EV charging information network developed by the Scottish Government.

Finally, nine participants (including two non-EV users and seven EV users) expressed their views on using these apps for payment. A non-EV user was indifferent to between using the 'supplier's app' and the 'universal app'. Four of them (a non-EV user and three EV users) were in favour of the use of a 'universal app' because it was more convenient than to use a 'supplier's app', as their phone may need to download many different apps. By contrast, four EV users indicated that they did not like the idea of using apps at all because of the inconvenience in having to download apps, registering, and potential risks when using apps, such as draining battery or no signal on the phone.

3.3.2. The understandings of 'payment taken automatically'

As for the understanding of automatic payment method, three non-EV users understood them as similar to traditional car refuelling methods by recalling their own refuelling experiences, such as pay at the 'pump source' (#2), 'put your card details in and you put the amount of petrol and it takes the money out there' (#1), or use the 'fuel card' (#6) where the car driver can track purchases on an app and make payments at the end of the month, or prepay a pre-deposited account.

Six participants (three non-EV users and three EV users) linked automatic payment to the automatic recognition technology. A non-EV user envisioned this technology recognising EVs, where the driver would simply drive the car away at the end of the charge and the bill would be paid automatically via an app. Some participants felt this was analogous to the technology used in the London Congestion Charging and interpreted as charging would begin when the user drove their EV into a specific zone. Whereas some participants imagined EVs could be recognised through the 'car license plate' (#3, #11, #16, #20), 'a barcode or a QR code' on the window or windscreen (#11), or 'an account' that the EV charging station can obtain details of the vehicle and then automatically charge the EV (#9).

On the other hand, an EV user understood that billing would start when the charger is plugged in, and the bill would be automatically generated and paid when the charger is unplugged. Five participants (two non-EV users and three EV users; one being a Tesla owner) associated this automatic payment method with a 'Tesla Supercharger'; although two non-EV users did not know how these chargers worked.

In addition to stating their different understandings of 'automatic payment technology', seven participants further exhibited attitudes towards this technology; four (a non-EV user and three EV users) were in favour because they found it inconvenient to carry a card and there was 'no need to interact with people', while the other three (a non-EV user and two EV users) said 'it is scary' and would not trust it.

4. Discussion

This is the first qualitative study to facilitate data collection employing think aloud and verbal probing techniques in the context of eliciting preferences for public-charging choices. Thematical analysis of the interview data uncovered the challenges and nuances faced by potential and existing EV users in choosing public-charging stations. The study delved into the reasons and interpretation of EV and non-EV user choices as these were elicited through stated choice tasks. Charging-point configurations had their basis on a discrete choice experiment and formed different alternatives described by their location (on street, surface level, multi-storey, and underground parking), charging price per kWh, payment method, etc. The interviews sought views from EV and non-EV users.

The primary insight gained from the cognitive interviews of the EV public-charging choice interviews was that participants needed more contextual details including the travel destination, timing of day, travel purpose. Also, participants requested specific details regarding the vehicle (e.g. target charge level and car brand or size), and information about the public-charging point (e.g. certainty of waiting time, number of charging points, parking price, idling fee). This evidence is in line with previous empirical studies reporting on the importance of charging-context related factors, which were found to significantly impact upon public-charging choices (Potoglou, Song, and Santos 2023). However, the complexity of these factors has generally resulted in various context-specific stated choice experiments. For example, some studies focused on public-charging choices en route (e.g. Li et al. 2023), charging at the destination of a trip (e.g. Wang, Yao, and Pan 2021), or have included different travel purposes, such as commutting to work (Chakraborty et al. 2019) and long-distance travel (Ge and MacKenzie 2022).

Another important observation from the cognitive interviews was that attribute non-attendance is likely to exist in public-charging stated choice experiments. Several participants expressed their choices by concentrating on specific factors such as the charging location, price, waiting time, and distance from the charging point to their destination. Through the analysis of the participants' interpretations regarding these specific factors, this study showed that their tendency may be related to attitudes including risk aversion (Pan, Yao, and MacKenzie 2019), cost minimisation (Ge, MacKenzie, and Keith 2018), and concerns around charging service availability and quality (Wang, Yao, and Pan 2021). For example, risk aversion might affect the choice of public-charging location – e.g. on-street vs. surface car parks vs. multi-storey car parks. Participants linked their preferences for these locations with varying levels of safety risks including personal safety and vehicle security, as well as concerns about potential mobile- phone signal loss. This finding was in line with previous parking-choice studies such as Soto, Márquez, and Macea (2018) who found that individual risk aversion towards personal and vehicle security was significantly associated with the choice of a parking location.

Terminology-related challenges regarding the payment methods were also identified in the cognitive interviews in this study. Participants expressed various understandings of 'supplier's app', 'universal app' and 'payment taken automatically', suggesting that a clear explanation of terminology would be necessary. Also, individuals held contrasting views on new technologies, and particularly when considering privacy issues. Such attitudes have been extensively explored in previous studies focusing on the choice of 'charge or not' and have been further classified into risk-seeking and risk-averse attitudes (Pan, Yao, and MacKenzie 2019). Also, pro-technology attitudes may result in positive preferences towards specific payment methods some of which may emerge because of technological advancements and may be introduced in the future.

5. Conclusion

This study contributes to an emerging body of knowledge pertaining the planning, allocation, design, quality, functionality, and demand for public-charging points for EVs. Improving our understanding of these processes and the demand-related features for public-charging points will have significant implications for the future. For example, the effective transition and functioning of future decarbonised, electricity-powered transport systems (Kim, Lim, and Lee 2024), which are aimed at improving local air quality (Isik, Dodder, and Kaplan 2021) and health-related outcomes (Mousavinezhad et al. 2024) would require public-charging infrastructure, which aligns with user needs and demand. The findings of this study provide robust, new evidence on charging point demand from a series of qualitative interviews, which were guided by different configurations of charging points within the urban context.

The interview data and the findings of the study are of methodological, empirical, and practical value. Methodologically, the findings showed that the use of choice experiments in the context of charging-point location choice is prone to 'attribute non-attendance' – i.e. the risk of respondents focusing on specific features (characteristics) of the charging-point options (e.g. location, price, waiting) rather than trading-off between them (Hensher 2006). Also, relevant choice experiments would require more details about the contextual background upon which respondents would be asked to make a choice (e.g. three female non-EV users tended to value charging location attributes more as they had strong safety concerns about different locations). Future experiments involving charging-point choices need to ensure that enough contextual detail is provided prior to asking respondents to complete a task as decision-makers tend to choose various selection strategies to adapt the task or context (Leong and Hensher 2012). Thus, appropriate time and resources should be allocated to cognitively test the experiment and analyse the interview data through thematic analysis to prevent these issues; this study provides a guide on how to do so.

Empirically, this paper contributes to an emerging body of literature on public-charging choices and points towards significant factors that are likely to drive the success of charging point allocation and demand. For example, location, price, walking distance from the destination to the charging point, and waiting time are key factors that all are likely to influence people's preferences for public charging. EV and non-EV users were observed to have different preferences. For example, non-EV users tended to pay more attention to charging locations, considering personal safety and vehicle security and phone signal when making charging choices, while EV users tended to value waiting time and the distance from the charging point to their final destinations. Finally, this study shows that effective communication regarding the availability of different payment methods is key and that acceptance of these methods might differ according to EV and non-EV user attitudes and perceptions. A follow-up quantitative survey would help to further uncover likely associations across public-charging choices, charging-point features, and individual attitudes and perceptions. For example, attitudes related to risk aversion, cost minimising, concerns about charging service reliability, and respondents' attraction to/familiarity with technology should be further explored in large-scale quantitative survey campaigns.

Last but not least, the practical implications of this study involve insights for policy makers and public-charging service providers in ensuring the safety, interoperability, transparent pricing information, and convenient access to public-charging points. Providers should also aim to improve the attractiveness of public-charging points and align these to consumer needs. For example, this study finds that it is important to ensure the availability of a diverse range of payment methods, which would also work for individuals less 'technology proficient', the elderly, and the disabled.

Note

1. RingGo is a UK-based cashless phone parking provider to local authorities and private operators. Users can pay parking fees by phone with the RingGo app.

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Author contributions

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

Data access statement

Due to ethical concerns, supporting data cannot be made available.

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Appendix. Cognitive-interview protocol

Inception

- Thank you for your willingness to participate and be interviewed in this study.
- I am … [NAME], and am [AFFILIATION].
- Do you consent to this meeting being recorded and me to view the recording?
- Paul and I, also, will be taking notes during the interview, if that's alright.
- Do you have any questions before we begin?
- I will start sharing my screen. Can you see the title of this research? So the title of the research is investigating public-charging preferences of potential and existing electric vehicle users. Basically, it means that we are interested in what factors are important for them to make choices for public-charging stations.
- We will do a survey to explore people's preferences towards public charging, but before the survey, we need to test whether the factors/attributes and choices we will show you later in a choice card are clear or not. This is exactly the aim of today's cognitive interview. We hope you can think and say aloud whatever comes in your mind while reading about the materials.

Part 1: Basic questions

- The first part of the interview is some of the basic questions that participants will see in the first part of the survey. Could you please answer these questions one by one? Another thing is, if you find anything confusing or misleading, you can just mention it while you are reading through these questions (see, Table 1).

Introduction to the choice experiment

Show an example of choice experiment with the introductory text and a choice card which contains attributes and attribute levels.

- To give participants a basic understanding of these terms

Part 2: First think-aloud

Show respondents attributes and levels:

- In this part, I am mostly interested in knowing what is going through your mind to make sure that attributes and attribute levels are clear, useful and not ambiguous or misleading. Again, you can say anything comes through your mind while reading the table. Please know there are no wrong answers.
- Great, how did you find that?
- But you found those the sentences on the screen are easy enough to understand or are there any difficult one?
- Can we tell the difference between Card or contactless payment or via supplier's app and Card payment or via universal app?

Part 3: Choice card – introductory text

Now, we will move to the second part of the survey. The choice cards. This part starts with an introduction. Again, you can say anything comes through your mind while reading it.

- Could you please read that and once you get to the end I'll just ask you one or two questions about it?
- Great, how did you find that?
- But you found those the sentences on the screen are easy enough to understand or are there any difficult one?

Part 3: Choice card – making choices

This part includes five (5) choice cards. Could you please read them and then make a choice? Again, you can say anything comes through your mind while reading them and please give us the reason of why you make that choice.

When the participant pauses

- What is going through your mind?
- What you're looking at on the screen?

Probe questions	Question part: (a) How easy or difficult was this question to answer? Why? (b) Why did you choose the option for this question? Attributes and attribute level part: (a) Did you find anything unclear about the attributes and attribute levels? Or was there anything that you found difficult to understand? (b) When you saw the 'the distance from the charging point to the destination' attribute, what did you perceive the 'distance' mean? Where was the 'destination' for you? (c) Are 'supplier's app' and 'universal app' the same? What do they mean for 'supplier's app' and 'universal app'? Choice card section: (a) Did you find anything unclear, or did you feel anything difficult to understand? (b) I'd like to ask you, in your own words, how would you describe the introductory text/task? (c) Why did you choose that option? Others: (i) (Optional) Could you tell me a bit more about that? (ii) (Optional) You said 'xxx', perhaps you could elaborate on that for me?
Closing	• Thank you for taking time to answer these questions. Your participation is extremely valuable for our research. • Any questions do you have? • Your input will be very helpful. I do appreciate your time and help. Thank you very much and have a good day.