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Data-driven insights into private EV-charger sharing: A multi-group analysis across London's ultra-low emission zones

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ABSTRACT

The rapid growth of electric vehicles (EVs) has heightened the need for innovative charging solutions. Charger sharing services (CSS), an emerging sharing model, leverage privately-owned chargers to supplement public infrastructure, and contribute to sustainable urban mobility. Drawing on survey data collected from 604 charger-owning households living in the ULEZ zones, we estimate a variance-based structural equation model and conduct a multi-group comparison between the Inner ULEZ and the surrounding Expanded ULEZ. Across both zones, economic, moral and social motives strongly and positively shape attitudes, and attitude in turn dominates intention to share. Secondary drivers vary spatially: knowledge about sharing services raises attitudes only inside the IULEZ, whereas perceived scarcity of public chargers suppresses sharing willingness only there. No structural paths differ significantly in magnitude between zones, indicating a robust core decision calculus with context-specific modifiers. As one of the first study to focus on this innovative sharing mobility model, this study provides nuanced data-driven insights into regional variations in private charger owners' sharing decision and offering evidence-based recommendations for policymakers and practitioners to optimize resource utilization.

1. Introduction

The transportation sector stands as one of the most significant contributors to global carbon emissions, accounting for approximately 23 % of greenhouse gas (GHG) emissions worldwide (McCollum et al., 2018; Tran et al., 2012; International Energy Agency (IEA), 2023; Tran et al., 2012). Within this, road transport (especially passenger cars and light commercial vehicles) accounts for nearly three-quarters of the total, underscoring its pivotal role in the climate challenge (IEA, 2023; IPCC, 2023). Electric vehicles (EVs) offer a substantial reduction in emissions compared to traditional engine vehicles and are increasingly viewed not only as a symbol of innovation, but also as an essential component of a sustainable transportation ecosystem (Deka et al., 2023; Li & Song, 2024; Dehkordi et al., 2024). Therefore, in the urgent quest to mitigate these emissions, the electrification of vehicles has emerged as a strategic intervention pivotal to achieving net-zero goals for most countries (Gnann et al., 2018; Li & Song, 2024). Furthermore, recent advances in bidirectional charging and vehicle-to-grid services position EVs not only as transport decarbonisation enablers but also as active grid-flexibility assets (Comi & Elnour, 2024; Shipman et al., 2021). These developments allow parked EVs to feed electricity back to the grid thereby link the mobility and energy-systems dimensions more tightly.

Like many other countries which committed to suspend sale of conventional vehicles, the UK government reported ambition in bolstering sale of ultra-low emission vehicle and completely end the sale of diesel and gasoline passenger cars and light commercial vehicles by 2035 (DfT & DESNZ, 2024; Brand et al., 2020). In London, the establishment of the Ultra-Low Emission Zone (ULEZ) is a testament to the city's commitment to cleaner air and lower emissions (LCH, 2019; Jordan, 2023). This initiative has not only improved air quality but also spurred EV adoption, demonstrating the power of policy in consumer adoption (Jordan, 2023). More recently, the London ULEZ zone further expanded from Central London to include the area inside the North Circular and South Circular roads in 2021, and then covers all London boroughs on 29 August 2023 (TfL, 2023). Given the prior trend and many other expansion examples in the rest of the world, it is foreseeable

Abbreviations: EV, Electric vehicles; IULEZ, Inner ultra-low emission zone; EULEZ, Expanded ultra-low emission zone; CSS, Charger-sharing services; SEM, Structural equation modelling; MGA, Multi-group analysis; MICOM, Measurement invariance of composite models; EM, Economic motive; SM, Social motive; MM, Moral motive; K, Knowledge; Inno, Innovativeness; EC, Environmental concern; PI, Perceived inaccessibility; A, Attitude; Inten, Intention.

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that this ULEZ expansion in London might propel the adoption of EVs, as drivers within the expanded zone are incentivized to switch to cleaner vehicles to avoid incurring charges (Morganti & Browne, 2018).

Meanwhile, despite the drivers that foster EV adoption, it is noteworthy about the barriers to EV adoption. As addressed in many consumer studies to EV adoption, range anxiety still hinders the consumers' adoption to EV (Pevec et al., 2019; Hamdare et al., 2023). Concerns about running out of power without access to a charging station contribute to hesitancy, despite advancements in EV technology and increased battery life. Furthermore, the lack of EV charging infrastructure exacerbates this range anxiety. As the number of EVs in London rises, spurred by initiatives like the ULEZ expansion, the current infrastructure struggles to meet demand (Patyal et al., 2021; Murugan & Marisamynathan, 2024). Moreover, the lack of off-road parking in over two-fifths (44 %) of UK homes, as reported by LB (Lloyds, 2023), further complicates the adoption of home EV charging solutions. This situation is expected to impact approximately ten million electric vehicles and vans by 2050, many of which are routinely parked on the street (HM, 2022). The presence of long queues at charging stations, slower charging times, alongside the difficulty in securing space for home chargers further highlight the gap between EV adoption rates and the availability of charging solutions (Xiao et al., 2020).

In this context, EV charger sharing services (CSS, see Fig. 1), also known as community EV charging (Charly et al., 2023) have emerged as a novel solution to bridge this gap. By leveraging the private chargers of existing EV owners, charger sharing can expand the effective charging network without the immediate need for substantial infrastructural investments. The sharing economy, characterized by peer-to-peer-based sharing of access to goods and services, has transformed traditional consumption patterns across a myriad of sectors (Zervas et al., 2017). For instance, platforms like Airbnb and Uber have not only changed the way of travel and stay in different cities but have also significantly influenced urban economies and local communities (Lutz & Newlands, 2018). In the context of transportation, the sharing economy has been acknowledged for its potential to reduce emissions through more efficient asset utilization and by promoting a shift away from personal vehicle ownership, such as ridesharing and car-sharing, or even the bicycle-sharing (Li et al., 2021; Lamberton & Rose, 2012; Burghard & Scherrer, 2022). By optimizing the use of existing vehicles and reducing the need for production of excess vehicles, the sharing economy contributes to a decrease in the overall carbon footprint associated with manufacturing and maintaining personal transport (Hu et al., 2021; Burghard & Scherrer, 2022). CSS extends the sharing economy's ethos to the realm of EV charging, proposing a decentralized approach to charging infrastructure (Zhang & Cao, 2025; McKenzie, 2020; Cao & Zhang, 2025). Such services have been established by several companies in the UK over the past five years, such as Co-Charger, Joosup, and Justpark. However, these initiatives are still in their nascent and receive limited attention from researchers. In simple words, this approach taps into private charging stations, thereby increasing charger availability and are expected to reduce the pressure on public charging networks and promote the widespread adoption of EVs.

Most literature to EV charging has a greater focus on infrastructure availability or consumer adoption of EV. Meanwhile, an increasing number of studies have posited EV charger sharing services (help private EV charger owners to 'rent out' their chargers and earn 'rental fees') as another possibility – by enhancing the efficiency of the 'hidden' (privately-owned) charging network, or act as a potential solution to address charging issues in areas with limited public EV chargers, it can support the increasing demand to EV charging, and wider adoption of EVs (Chen et al., 2022). For instance, research by Cao et al. (2025) position charger sharing as a promising solutions for the contemporary lack of public charging facilities and explored the characteristics that shape people's intention to share their private chargers. In addition, research by Wang et al. (2023) proposed their model of sharing charging piles to discover the benefit allocation of sharing private EV chargers. Beyond the individual benefits, Yang et al. (2024) have also emphasized the potential impact of charger sharing in soothing pressure of public charging facilities.

However, while these studies pointing out the potential benefits of CSS in individual and social levels, there is insufficient knowledge about consumer adoption. Specifically, understanding consumer adoption is a critical component of advancing any innovative technology or service (Straub, 2009).

Furthermore, private charger owners represent the supply side of CSS, and their willingness to participate directly influences the availability and scalability of the service. Given the centrality of private charger owners in enabling this sharing economy model, understanding their intention to share their chargers is a necessary starting point for advancing CSS adoption. Hence, this paper specifically examines factors influencing consumer (charger-owner) attitudes toward adopting CSS. This perspective is critical because supply-side adoption will largely determine the early-phase viability and scalability of CSS.

The recent expansion of London's ULEZ provides a unique opportunity to investigate whether the factors influencing charger sharing intention differ between owners in the expanded ULEZ (EULEZ) and those in the inner ULEZ (IULEZ). This differentiation is also crucial in facilitating adoption of CSS services in London context, because the

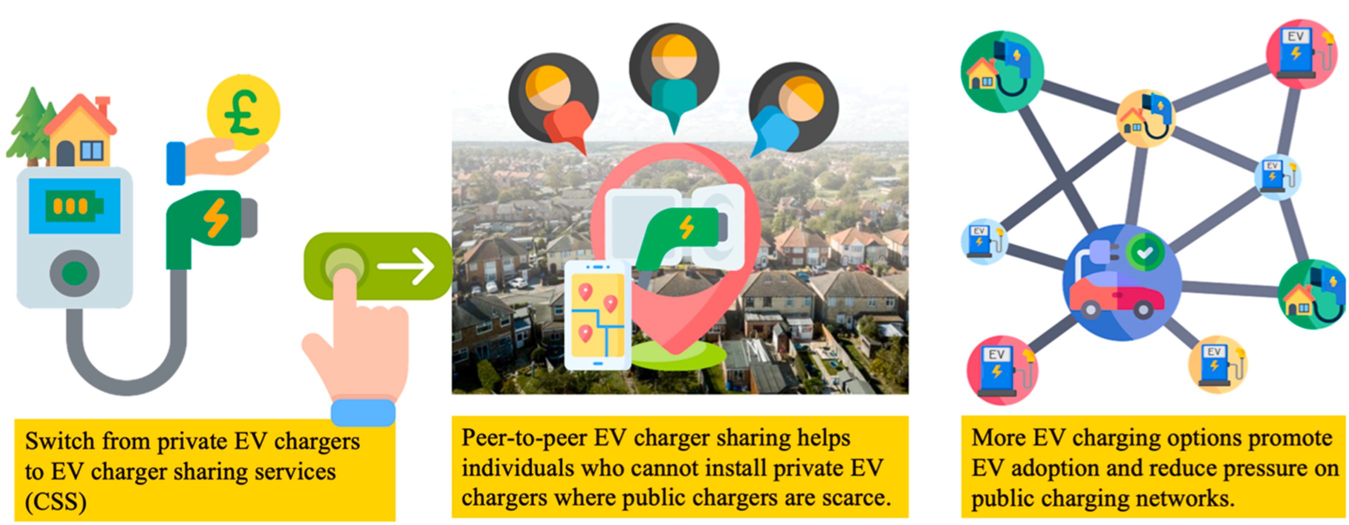

Fig. 1. EV charger sharing services (CSS). Source: Created by the authors.

residents in these two zones may exhibit distinct characteristics such as policy exposure and readiness, and familiarity with EV-related technologies. For instance, residents of the IULEZ may have had longer exposure to ULEZ policies, potentially resulting in greater awareness of EV infrastructure and adoption incentives. In contrast, the EULEZ, being a more recently regulated area, may face different challenges, such as lower EV adoption rates or less established charging networks. Exploring these differences allows us to offer data-driven insights into the tailored strategies required to promote CSS adoption, and correspondingly sustainable urban mobility.

In summary, this research aims to 1): explore the factors affecting EV charger owners' decision to share their home chargers in London and 2): investigate whether these factors have different impacts on charger owners that lives in the expanded ULEZ (EULEZ) and those who lives the inner ULEZ (IULEZ). By addressing these objectives, this research provides actionable insights for facilitating CSS adoption of London charger owners as a potential complementary tool to EV charging challenges in areas with limited public infrastructure.

The remainder of the paper will provide an in-depth & data-driven exploration of the theoretical underpinnings of EV adoption and charger sharing, review the existing literature on EV usage and charging infrastructure challenges, and present a comprehensive methodology for assessing charger owners' attitudes toward CSS. The subsequent sections will delve into data analysis, discussion of the findings, and the formulation of industrial and policy recommendations that resonate with the study's outcomes. Finally, the paper will conclude with reflections on the limitations of the current research and suggest avenues for future studies.

2. Literature review

Shared mobility services (e.g., ride-hailing, bike-sharing, etc.) have become an increasingly key area of research within urban transportation, particularly as cities grapple with the challenges of congestions and infrastructure constraints (McKenzie, 2020). To understand the consumer decision-making in adopting these services, researchers have employed various consumer psychology models such as the Technology Adoption Model, or Unified Theory of Acceptance and Use of Technology (Chopdar, 2023). Beyond that, other researchers went forward and investigate the core of sharing in the sense of an altruistic and pro-social behaviour and came up with their own theoretical framework and models (Bucher et al., 2016).

Despite these valuable contributions, current research on electric-vehicle charger sharing remains limited in both scope and analytical depth. At the time when this study was conducted, most studies have focused on technical optimisation (e.g., scheduling, network efficiency) or macro-level benefits (e.g., easing pressure on public infrastructure) (Yang et al., 2024; Wang et al., 2023; Chen et al., 2022). About recently, few new publications have examined the behavioural mechanisms that drive charger owners' willingness to participate (please see appendix D for more comprehensive synthesis). Even where sharing motives are discussed, such work tends to remain descriptive, with limited efforts paid to systematically testing psychological constructs and spatial heterogeneity. This oversight is particularly critical as the adoption of electric vehicles continues to grow, and the demand for accessible and efficient charging infrastructure becomes increasingly urgent, where CSS could potentially complement to such challenges as outlined in previous research (Wang et al., 2023). To address the identified gaps, the present study develops and validates a behavioural model grounded in the Theory of Planned Behaviour, integrating economic, social, and moral motives, as well as knowledge, innovativeness, and perceived inaccessibility. In doing so, it extends prior CSS research from a technical-system perspective to an empirically tested framework, thereby offering new insights for the design of participatory charging policies.

2.1. Attitude and behavioural intention

In the domain of consumer psychology, the Theory of Reasoned Actions (TRA) and Theory of Planned Behaviour (TPB) are one of the fundamental frameworks developed that shaped understanding of the predictive mechanism behind consumer behaviour (Ajzen, 1985; Fishbein & Ajzen, 1977). Unlike the other technology acceptance models that have a specific focus (e.g., usability, perceived ease of use), TPB and TRA provides relatively higher flexibility and adaptability in exploring the non-technological-centred antecedents. Both models emphasize the role of an individual's attitude towards behaviour, the subjective norms surrounding them, and the perceived behavioural control (in TPB only) which together determine the behavioural intentions that leading to actual behaviour (Ajzen, 1991, 1985).

Attitude is defined as the predisposition that reflects an individual's favourable or unfavourable evaluation of a particular behaviour. It has been previously and increasingly adopted in the field of energy studies to investigate the factors that affect consumer decision-making. For instance, research by Sahoo et al. (2022) examined how personal positive and negative motives, social motive, and buying involvement shaped consumers' attitude towards adoption of EVs. Besides, various other antecedents were also explored for their roles in forming consumer attitudes, such as low-carbon awareness, social and economic appeal in multiple contexts (e.g., solar panel adoption, Airbnb, etc.) (Tajeddini et al., 2021; Srivastava et al., 2023). On the other hand, behavioural intention refers to an individual readiness to perform a specific behaviour and is always framed as a direct precursor to actual behaviour as posited in the aforementioned theories (Ajzen, 1991; Fishbein & Ajzen, 1977). Extensive research has demonstrated that favourable attitude would significantly predict stronger intentions towards adopting a product or service (Deka et al., 2023; Yamashiro & Mori, 2023). Therefore, based on the theoretical underpinnings of the TPB and empirical evidence, we formulate the hypothesis as:

H1: *Attitude to private charger sharing significantly and positively affect intention towards private charger sharing.*

2.2. Economic, social and moral motivations in sharing behaviour

Past research to sharing behaviour have formed hypothesis based on a common economic theme: people engage in sharing behaviour if the perceived benefits exceed the perceived costs (Olatokun & Nwafor, 2012). Multiple research projects have revealed the importance of monetary or economic motive in driving consumer adoption of collaborative consumption, with a primary goal of 'save or gain money' (Bucher et al., 2016; Magno, 2021). This aligns with the premise that individuals are more likely to participate in sharing economy models when financial benefits outweigh perceived risks or inconveniences. This trend reflects a shift in consumer values to a more utilitarian view of goods and the underlying decision-making mechanisms (Kathan et al., 2016; Lamberton & Rose, 2012). For instance, research by Bocker & Meelen (2017) stated that economic motivation is predominantly impactful comparing to other motivations in sharing of the expensive assets for the providers (shares), such as accommodation (e.g., Airbnb). Therefore, in the context of CSS, where private EV chargers represent a valuable and costly resource, economic incentives are expected to play a similarly significant role in shaping sharing intentions:

H2: *Consumers' economic motive positively and significantly affect attitude towards private charger sharing.*

Meanwhile, status symbols, as in previous research, play a critical role in shaping social interactions and fostering a sense of community belonging (Bocker & Meelen, 2017). For example, owning certain items in specific culture is seen not just as a matter of personal taste or economic capability, but also as a way to signal one's social status and affiliation, such as luxury items (Bąk et al., 2022). Moreover, social motive also refers to the desire of forming new social ties and to find company in a community (Sahoo et al., 2022; Kaushal & Prashar, 2022).

For instance, research by Bucher et al. (2016) found social motive plays a crucial in predicting internet-mediated sharing behaviour including contexts such as online file sharing and knowledge sharing. Like many other sharing services, CSS, as introduced previously, provides the opportunities to create social relationships among users in the regional community (Yang & Mao, 2019; Bąk et al., 2022). Furthermore, given the different charging infrastructure readiness, we anticipate the social motive for consumers who live outside the IULEZ (hereinafter the EULEZ) is a more important antecedent forming the owners' attitude in adopting CSS. Therefore, we propose:

H3a *Consumers' social motive positively and significantly affect attitude towards private charger sharing.*

H3b *Impact of consumers' social motive on attitude towards private charger sharing significantly differs between IULEZ and EULEZ groups.*

Despite the social and economic gains, as a pro-social behaviour that offers convenience to others, sharing was researchers for its moral motive in past studies (Belk, 2014; Bucher et al., 2016). For instance, previous sharing services were often framed as a sustainable practice which encapsulates ecological and ethical considerations of users, as well as environmental protection messages (Kaushal & Prashar, 2022). Credited to the way of framing, consumers who are more environmentally and ethically conscious find it appealing and are more likely to form a positive attitude (Bocker & Meelen, 2017). By integrating these altruistic factors, previous studies found the moral motive is positively connected to attitude towards adoption of many sharing services (Kaushal & Prashar, 2022; Bucher et al., 2016). Additionally, given the reduced energy consumption in queueing and driving to a public charging point, it is also inspirational that if environmental concern is perceived crucial which contribute to attitude indirectly via the moral motive (Wang et al., 2020). Hence, we propose the following three hypothesis:

H4a *Consumers' moral motive positively and significantly affect attitude towards private charger sharing.*

H4b *Environmental concern has an indirect positive impact on attitudes toward adopting CSS, mediated by moral motivation.*

2.3. Other factors based on related literature

Meanwhile, past research also indicated unfamiliarity to innovations is a huge barrier to overcome for majority of consumers who had limited knowledge and experiences to a new product or services (Prieto et al., 2019; Yamashiro & Mori, 2023). Informed consumers (those with experience using similar services) are more likely to embrace novel sharing models when they understand the benefits and operational mechanisms (Yamashiro & Mori, 2023). Research by Parkins et al. (2018) indicated that perceived knowledge related to a specific target positively and significantly influence the adoption intentions, which research by Prieto et al. (2019) presented equivalent results in the context of sharing services adoption. Therefore, we propose:

H5 *Consumers' knowledge of sharing services positively and significantly affects attitude towards private charger sharing.*

On the contrary, there are also some consumers who tend to make decisions without sufficient information and market adoption, also known as the innovators or early-adopters. That is, individuals with a higher degree of personal innovativeness tend to form their decision more based on the advantages of innovative technology rather than the perceived risks or other drawbacks (Leicht et al., 2018). They act as catalysts for the diffusion and promotion of innovation in the public (Rogers, 2003). For instance, research by Wang et al. (2020) found individual innovativeness significantly influence the adoption of ride-sharing services. Hence, we propose the hypothesis:

H6 *Consumers' innovativeness positively and significantly affects attitude towards private charger sharing.*

Lastly, considering CSS as a temporary aid to the insufficient public charging infrastructure, we recognize the potential of CSS to fill the gaps where public options are lacking, especially for the residents in EULEZ. According to past research, consumers vary in their willingness to share scarce resources, especially under conditions where access to these resources is perceived as limited or uncertain Cannon et al. (2019). Therefore, while perceived inaccessibility of charging stations has been researched as one of the major barriers to mass adoption of EV (He et al., 2022; Renaud-Blondeau et al., 2023), we propose the perceived inaccessibility of public charging stations may also shapes the attitudes of potential users towards supplementing solutions like CSS. More specifically, consumers who experience or perceive difficulties in accessing public charging stations are more likely to develop a more favourable attitude towards sharing their private chargers. Hence, we propose the following hypothesis:

H7: *Consumers' perceived inaccessibility of public charging facility significantly affects attitude towards private charger sharing.*

Following the literature review, we summarized the hypothesis and produced a visual conceptual framework to investigate the determinants of consumers' attitude and intention to adopt CSS (Fig. 2).

3. Method

This study employed a quantitative survey-based design to examine factors influencing charger owners' attitudes and intentions toward participating in CSS. The methodological approach follows the logic of variance-based structural equation modelling (PLS-SEM), enabling simultaneous estimation of multiple latent constructs and relationships.

3.1. Data collection and measure

The present case study draws on survey data gathered in London as part of a wider research programme on electric-vehicle (EV) charging practices. A structured questionnaire was designed and hosted on Qualtrics. Prior to the main rollout we conducted a pilot with 239 respondents, assessing wording clarity, estimated completion time and construct validity by means of a confirmatory factor analysis; feedback led to minor re-wording of four items, conversion of two matrix tables into single-choice questions and the removal of one redundant innovativeness item. Departmental low-risk ethical approval was secured (approval number:app64) before any fieldwork commenced.

Sampling targeted private home-charger owners registered with the Prolific platform, regardless of their previous EV ownership. The questionnaire survey consists of three sections. It started with socio-demographic questions (e.g., age, sex, employment status), and follows with questions accessing their travel behaviour. Lastly, the study asks for participants' motivational drivers (i.e. economic, social and moral motivations) and intention to participate in CSS as a host. Details of these constructs, the corresponding items, and their sources are documented in Table 1. Following the approach adopted in previous research, all items listed in Table 1 were measured with 5-point Likert scales in our questionnaire, from 1 (strongly disagree) to 5 (strongly agree).

Notably, prior to the motivational drivers and intention to share section, we shown all participants a designed brief message to introduce the concept of CSS: *Charger Sharing Services (CSS) let private EV charger owners to 'rent out' their chargers to other EV users, often arranged through an app or website (just like Uber and Airbnb). All responses were collected at the individual level.* The measurement scales were adapted from extant literature on sharing services, including research that focused on ride-sharing and vehicle-sharing platforms.

3.2. Sample

Given the nascent stage of diffusion of CSS in London, the study adopted a simple random sampling strategy to maximize the flexibility and broadness of data collected. A pilot study to 239 participants was conducted first to test the questionnaire in terms of time required for completion and measurement item validity. SPSS AMOS was used a

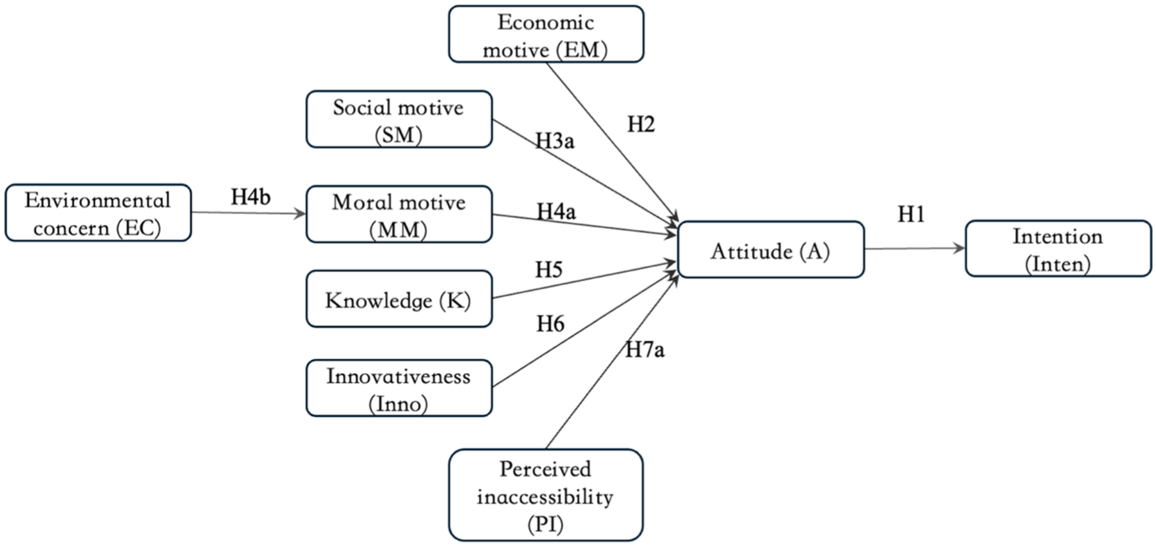

Fig. 2. Conceptual framework.

confirmatory factor analysis examining the quality of adapted measurement items. To ensure eligibility, filter questions were used at the beginning of the questionnaire: 1. Participants need to be aged above 18 years; 2. residence in London, and; 3. ownership of a private household EV charger regardless of EV ownership. These immediate screening questions ensured eligibility and secured informed consent. Main data collection then took place in May 2024 through the online recruitment portal Prolific with the same eligibility criteria. The main data collection received 780 responses, 23 turned down the consent after viewing the research information, 122 were excluded automatically as they declared no private EV charger ownership, and 31 responses were excluded due to missing value.

Respondents were then divided into two geographic groups via their post-code, subsequently mapped against the official Transport for London Ultra-Low Emission Zone (ULEZ) boundaries: those residing within the Inner ULEZ (IULEZ, $n = 348$) and those outside the IULEZ but inside the Expanded ULEZ (EULEZ, $n = 256$). Fig. 3 above shows the expanded and original ULEZ zones. These data formed the input for the PLS-SEM (partial least square structural equation modelling) analysis that follows. Table 2 summarises socio-demographic characteristics. The sample comprises 349 males, 246 females and nine respondents who identified as "other" or preferred not to disclose gender. Mean age is 35.9 years (SD = 11.0). Educational attainment is high (median = bachelor's degree). Most respondents are employed full-time ($n = 473$); 75 work part-time, 28 are students, 22 are unemployed and six are retired. Vehicle ownership is common: 67.9 % own one vehicle and 31.3 % own two or more. Consistent with the study focus, private home-charger ownership was prevalent (95 % exactly one unit; 5 % multiple). In sum for the sample, age distribution aligns with London working-age norms, while education and full-time employment are higher than citywide averages.

3.3. Data analysis

The data analysis proceeded in two stage, namely item & model checks followed by main data analysis (please see appendix E for a data analysis flowchart). SmartPLS 4 (v. 4.1.1) was used for the whole data analysis process.

For item and model quality checks, we first calculate internal consistency, indicator loadings and validity statistics. All reflective items loaded ≥ 0.65 (Table 3) and Cronbach's α; composite reliability ranged from 0.85 to 0.94 and average variance extracted (AVE) was ≥ 0.50 for every construct, thus meeting Hair et al.'s (2017) thresholds. Discriminant validity was confirmed (HTMT_max = 0.83, 95 % CIs < 1) and inner VIFs were < 3.3, which was confirmed using Fornell and Larcker criterion (Fornell & Larcker, 1981). Afterwards, although model fit indices is not a compulsory element for PLS-SEM, our data shows that the model explains substantial variance (R^2_Att = 0.71; R^2_Inten = 0.73) and exhibits acceptable fit (SRMR = 0.053), which is satisfactory. Finally, measurement invariance was assessed with the measurement invariance of composite models (MICOM) procedure (Henseler et al., 2015; Fornell & Larcker, 1981). Configural and compositional invariance were satisfied, while equality of composite means/variances failed, signalling partial invariance holds and safe to proceed for multi-group analysis (MGA).

Second, for the main data analysis, path coefficients and indirect effects were estimated by bias-corrected bootstrapping with 5 000 resamples. Predictive relevance was gauged via blindfolding ($d = 10$), yielding large Q^2 values for Attitude (0.592) and Intention (0.527) but negligible Q^2 for Monetary Motive (0.003). MGA and permutation tests (5 000 permutations) were applied to compare structural paths; no path-coefficient differences reached the 0.05 significance level, though the Knowledge – Attitude link approached significance ($p \approx 0.085$).

4. Results

4.1. Full-sample structural model

The variance-based structural model for the pooled sample of 604 charger owners explains substantial portions of the target constructs ($R^2 = 0.71$ for Attitude; $R^2 = 0.73$ for Intention) and attains satisfactory fit (SRMR = 0.053). Table 4 summarises the bootstrapped direct paths, their bias-corrected confidence intervals and effect-size statistics.

Attitude is by far the strongest predictor of sharing intention, providing clear evidence for H1. Moral motive, economic motive and social motive all exert positive influences on attitude, supporting H2, H3a and H4a in the aggregated sample. Knowledge of sharing services and consumer innovativeness register weaker yet significant paths to attitude. Perceived inaccessibility of public chargers is negative but not significant, so H7 receives no support in the full sample. In addition, the mediating role of attitude is confirmed: economic, social and moral motives each transmit a substantial indirect effect to intention, while knowledge and innovativeness provide smaller but still significant mediated contributions; perceived inaccessibility shows no such indirect influence. The environmental pathway is marginal. Environmental concern has a small positive link to moral motive ($\beta = 0.093$, $p = 0.040$),

Table 1
Constructs and scales.

Constructs	Items	Studies
Economic motive (EM)	EM1: I think EV charger sharing is a good way to supplement my income. EM2: Earning extra money is an important factor for me to share my private EV charger. EM3: I will use EV charger sharing because it helps me pay my bills.	Magno, 2021; Bucher et al., 2016; Kaushal & Prashar, 2022; Lamberton & Rose, 2012
Social motive (SM)	SM1: Using charger sharing would allow me to get in touch with people who share my interests. SM2: Using charger sharing would allow me to get in touch with people who think like me. SM3: Sharing is a good way to meet new people.	Bucher et al., 2016; Bąk et al., 2022; Lamberton & Rose, 2012; Sahoo et al., 2022
Moral motive (MM)	MM1: I share because I feel a moral obligation to help others. MM2: EV charger sharing makes me think that I am doing something meaningful. MM3: Sharing my charger with those who need it is a decent choice.	Bąk et al., 2022; Magno, 2021
Knowledge (K)	K1: I have used charger sharing or other services before. K2: I know how it works for private charger sharing. K3: I am familiar with sharing services based on my experience.	Yamashiro & Mori, 2023; Prieto et al., 2019; Lamberton & Rose, 2012
Innovativeness (Inno)	Inno1: I usually experience the new stuff before other people know it exists. Inno2: I wish I was an early adopter of new products and services. Inno3: If I hear about new products or services, I look for ways to try it out.	Wang et al., 2020; Leicht et al., 2018
Environmental concern (EC)	EC1: When humans interfere with nature it often has disastrous consequences. EC2: We are approaching the limit of the number of people the earth can support. EC3: If things continue their present course, we will soon experience a major ecological catastrophe.	Magno, 2021; Moeller & Wittkowski, 2010
Perceived inaccessibility (PI)	PI1: There are too few charging stations. PI2: Charging stations around my home are hard to find. PI3: Charging stations around my workplace are hard to find.	Renaud-Blondeau et al., 2023; He et al., 2022
Attitude (A)	A1: For me, sharing my charger would be good. A2: Sharing my charger would be enjoyable. A3: Sharing my charger would be pleasant.	Sahoo et al., 2022; Yamashiro & Mori, 2023; Deka et al., 2023
Intention (Inten)	Inten1: I plan to share my charger with others in the future. Inten2: If the circumstances allow it, I will share in the future. Inten3: I intend to share my charger in the future.	Sahoo et al., 2022; Deka et al., 2023

but its indirect contribution to attitude remains trivial (indirect $\beta = 0.030$, $p = 0.047$) and does not propagate to intention, offering no evidence for H4b at the pooled level.

Taken together, the full-sample analysis corroborates a motivational hierarchy in which pragmatic, moral and social incentives shape attitudes to share private EV chargers. Knowledge and innovativeness play supporting roles, whereas environmental concern shows a small association with moral motive, yielding only a marginal indirect effect on Attitude and no carry-over to Intention. Perceived inaccessibility of public chargers is negative but not significant for Attitude, and does not transmit an indirect effect to Intention. Thus, conditional on stronger proximal motives (moral, economic, social), both variables play a limited role in the pooled model.

4.2. Multi-group analysis (IULEZ vs EULEZ)

Before comparing structural paths, the MICOM three-step procedure established configural and compositional invariance across the two geographic subsamples, while equality of composite means and variances failed for four constructs. Therefore, the model satisfies partial but sufficient invariance for path-coefficient comparison between groups (see appendix C for MICOM outputs) (Ngah et al., 2023; Henseler et al., 2016). Table 5 presents the group-specific direct and indirect effects, their bootstrapped significance levels and the permutation test of path differences.

Across both contexts the motivational logic observed in the pooled sample remains largely intact. Attitude continues to dominate charger-sharing intention, with virtually identical coefficients in the Inner ULEZ ($\beta = 0.857$, $p < 0.001$) and the surrounding Expanded ULEZ ($\beta = 0.848$, $p < 0.001$). Economic, social and moral motives also retain strong, positive effects on attitude in each zone, and permutation tests reveal no statistically significant differences between the coefficients (all $|\Delta\beta| \leq 0.030$, $p > 0.10$). Consequently, there is no evidence H3b could be supported.

Consumers' knowledge of sharing services enhances attitude only within the Inner ULEZ whereas the effect is negligible in the outer zone. The same asymmetry carries through to the indirect path Knowledge – Intention, which is significant in the Inner ULEZ but absent outside. Given these evidence, H5 is partially supported. Similarly, innovativeness remains a weak and non-significant driver of attitude in both subsamples, therefore H6 is partially supported. Furthermore, perceived inaccessibility of public charging points exhibits a significant negative effect on attitude among Inner-zone residents, but not for those living farther out.

Although the path-difference test for pooled model is non-significant, the approach of differentiating IULEZ and EULEZ leads to a new understanding for perceived inaccessibility. Specifically, it is significantly negative inside the Inner ULEZ ($\beta = -0.120$, $p < 0.05$) but not outside ($\beta = -0.023$, n.s.), indicating a context-specific suppression of sharing attitudes under dense, contested kerb-side infrastructure. The corresponding indirect influence on intention (PI – ATT – INTEN) is also negative and significant only inside the Inner ULEZ, reinforcing this interpretation. Furthermore, the environmental pathway remains weak in both contexts echoing our full-sample model: it predicts moral motive modestly inside the core and not at all outside; the mediated link to attitude is non-significant everywhere, confirming the rejection of H4b.

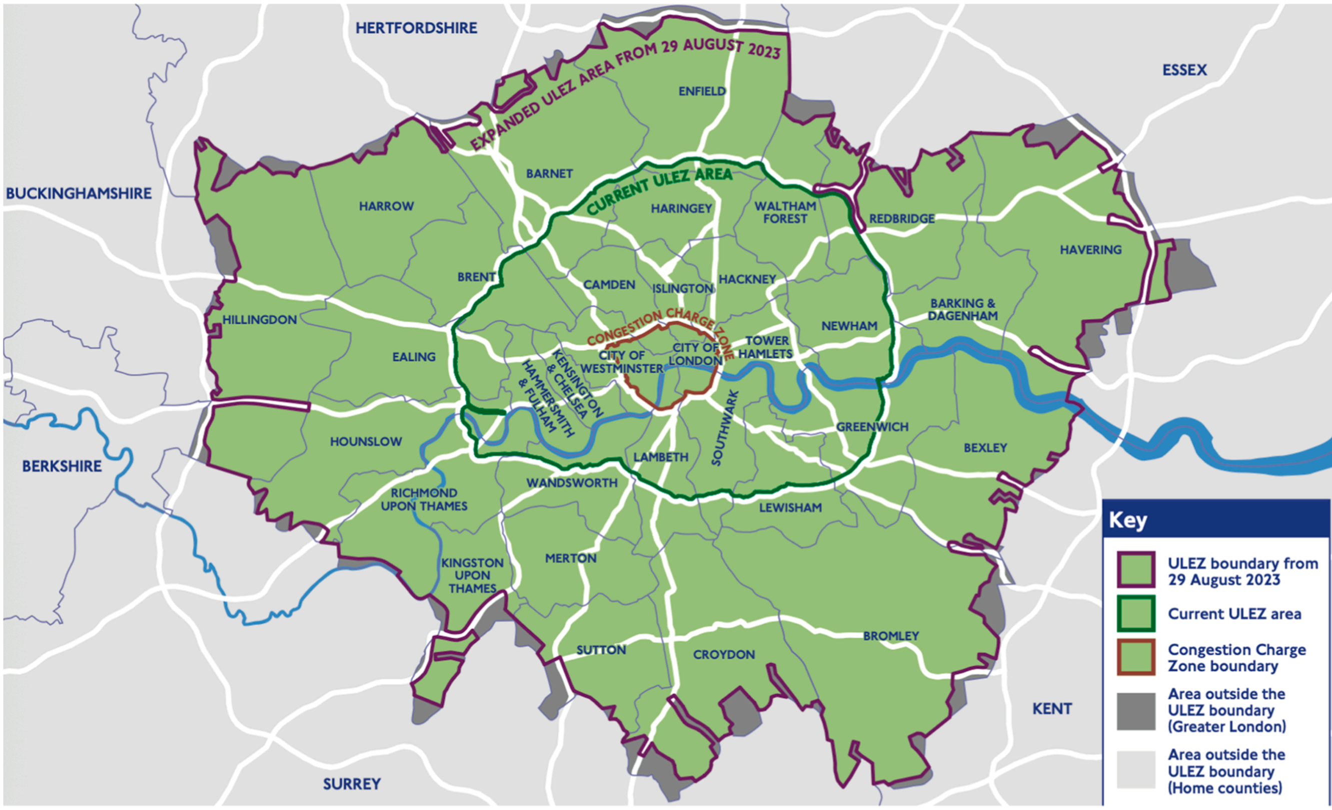

Fig. 3. Original and expanded ULEZ zones. Source: TFL (2023).

5. Discussion

This study enriches research on EV infrastructure by situating CSS within London's ULEZ geography and testing a TPB-based model at scale. In the pooled sample, attitude is the dominant conduit to intention, while the model explains substantial variance in attitude (R^2_Att = 0.71). Economic, social and moral motives each contribute to attitude, confirming multi-motivation accounts of collaborative consumption (Bucher et al., 2016; Kaushal & Prashar, 2022; Sahoo et al., 2022) while extending them to an energy-mobility context where platform participation depends on privately owned infrastructure.

Notably, moral motive emerges as the strongest single driver of attitude across both inner and outer ULEZ zones, echoing prior findings that ethical and sustainability appeals underpin pro-social sharing behaviour (Belk, 2014; Bocker & Meelen, 2017). Although the EULEZ zone scores higher for moral motive, the between-zone difference is not statistically significant, therefore it is not recommended to conclude the effectiveness of zone-specific interventions surrounding moral motive. A practical implication is to pair moral messaging with light, targeted financial incentives leveraging both the strongest psychological driver and pragmatic benefits.

Knowledge of sharing services strengthens attitude and intention only within the Inner ULEZ, and the indirect path to intention is likewise present only in the inner zone. This pattern aligns with the situational activation of knowledge under constraint—information is more behaviourally potent when consumers face tangible barriers (Parkins et al., 2018; Prieto et al., 2019; Rogers, 2003). Outside the core, awareness alone appears insufficient without pressure from parking or kerb-side access. These results qualify claims that knowledge is a universal pre-condition for sharing with CSS (Yamashiro & Mori, 2023).

Conversely, innovativeness, although marginally significant in the pooled model, loses explanatory power once the sample is disaggregated. This challenges work that treats innovativeness as a general predictor of sharing uptake (see, for example, Leicht et al., 2018; Wang et al., 2020), suggesting that curiosity and novelty-seeking do not translate into action absent a concrete environmental trigger (e.g., tariff clarity). By highlighting this interaction between individual traits and spatial context, our findings shows that contextual drivers matter more than dispositional traits for CSS participation.

In the full sample, general environmental concern contributes little once moral, economic and social motives are included, with only a small indirect pathway via moral motive. This pattern is consistent with research showing that participation in sharing schemes is typically driven more by practical and baseline moral incentives than by abstract pro-environmental tendency (Bocker & Meelen, 2017; Hamari et al., 2015). We interpret this as a proximity effect: moral framing ("help others / do the right thing") is closer to the sharing act than a broad ecological attitude, and thus dominates the decision calculus in our context. Another possible explanation is that CSS is still in its nascent stage, where limited effort has been paid for marketing (as well as its environmental benefits). For policy, the implication is not that CSS lacks sustainability value, but that sustainability appeals should be delivered through concrete moral frames and operational safeguards, rather than through general environmental messaging alone. In the IULEZ, reducing the practical costs of sharing (privacy controls, reservation windows, liability cover, transparent pricing) can mitigate the protective response and unlock participation; in the EULEZ, linking moral narratives to local air-quality/health benefits, coupled with light incentives, is likely to be more effective than appeals to environmental concern per se.

The most striking result is that perceived inaccessibility of public chargers reduces willingness to share among inner-zone residents, contrary to a simple "greater need, greater sharing" logic suggested by many recent publications into perceived accessibility (e.g., He et al., 2022; Renaud-Blondeau et al., 2023). A plausible mechanism is a self-protective response: where kerb-side charging infrastructure is crowded, owners prioritise privacy, access control and scheduling reliability over monetary gains—consistent with resource-scarcity and risk-management accounts (Cannon et al., 2019; Shah et al., 2021).

Table 2
Sample characteristics.

Characteristics	Categories	IULEZ (%)	EULEZ (%)	Full sample (%)
Age (in years)	18–25	12.5	18.4	15.9
	26–35	38.3	43.7	41.4
	36–45	26.6	23.0	24.5
	46–55	14.8	9.2	11.6
	56 and above	7.8	5.7	6.6
Gender	Male	59.4	56.6	57.8
	Female	39.1	42.0	40.7
	Others	1.2	0.9	1
	Prefer not to say	0.4	0.6	0.5
Type of EV owned	HEV	27.7	37.1	33.1
	PHEV	34.4	31.0	32.5
	BEV	37.9	31.9	34.4
Number of private EV charger at home	One	96.1	94.3	95.0
	More than one	3.9	5.7	5.0
Education	No formal qualifications	0.4	0	0.2
	GCSE or equivalent	2.7	6.3	4.8
	A-levels (high school)	12.9	19.8	16.9
	Bachelor's degree	52.0	46.3	48.7
	Master's degree	25.4	24.7	25.0
	Doctoral or professional degree	5.9	2.3	3.8
	Others	0.8	0.6	0.7
Frequency of using public EV charger (weekly)	Never	23.8	13.5	17.9
	Once	50.0	57.2	54.1
	More than once	26.2	29.3	28.0
Tenure	Owner-occupied	68.4	52.3	59.1
	Privately rented	24.6	37.6	32.1
	Socially rented	3.9	6.0	5.1
	Shared ownership	2.0	3.7	3.0
	Others	1.2	0.3	0.7
Trip purposes	Commuting	41.0	30.2	34.8
	Shopping	13.7	13.5	13.6
	Leisure	37.9	49.1	44.4
	Business purposes	5.9	6.3	6.1
	Others	1.6	0.9	1.2

Outside the core, scarcity perceptions have no measurable effect, indicating that participation depends not only on infrastructure levels but also on other factors that were not included in this study (e.g., property norms, neighbourhood expectations). Such evidence, once explored by future qualitative works, can provide behavioural explanations for why CSS may underperform in the places with constrained public supply.

Overall, this study addresses three specific gaps highlighted in the literature review. First, it provides large-scale, supply-side behavioural evidence on charger-owner participation in CSS (an area previously dominated by infrastructure or system-level studies), by showing that attitude strongly transmits to intention and that moral, economic and social motives are the principal antecedents. Second, it offers a spatially explicit test of whether these drivers vary across London's Inner vs. Expanded ULEZ. Specifically, after establishing partial measurement invariance, no path differences are supported, indicating broadly stable mechanisms across zones. Third, it clarifies the role of environmental concern and perceived infrastructure scarcity once proximal motives are controlled: environmental concern contributes only marginally via moral motive, while perceived inaccessibility reduces sharing attitude in the Inner ULEZ but not outside.

6. Policy implications

The results point to a sequenced policy mix: keep expanding public infrastructure, use finely targeted incentives to tap economic and moral motives, and back these with localised knowledge programmes. The discussion below follows the original structure (Sections 6.1–6.3) but updates the recommendations to reflect the refined PLS-SEM and multi-group findings.

Table 3
Measurement model.

Construct	Cronbach's Alpha	Composite Reliability	AVE	Item codes	Loadings (λ)
Environmental concern (EC)	0.758	0.855	0.533	EC1	0.665
				EC2	0.874
				EC3	0.628
Economic motive (EM)	0.886	0.929	0.663	EM1	0.824
				EM2	0.830
				EM3	0.895
Social motive (SM)	0.901	0.931	0.771	SM1	0.895
				SM2	0.922
				SM3	0.748
Moral motive (MM)	0.882	0.927	0.809	MM1	0.810
				MM2	0.897
				MM3	0.835
Knowledge (K)	0.888	0.931	0.819	K1	0.783
				K2	0.824
				K3	0.966
Innovativeness (Inno)	0.849	0.909	0.768	Inno1	0.809
				Inno2	0.791
				Inno3	0.826
Perceived inaccessibility (PI)	0.747	0.750	0.501	PI1	0.647
				PI2	0.766
				PI3	0.705
Attitude (A)	0.914	0.946	0.854	A1	0.831
				A2	0.903
				A3	0.935
Intention to share (Inten)	0.947	0.966	0.905	Inten1	0.931
				Inten2	0.908
				Inten3	0.940

Table 4
PLS-SEM results.

Paths	Path coefficient	BCa-CI (5–95 %)	Standard deviation	f^2
Direct effects				
EM -> Att	0.316***	[0.267, 0.369]	0.032	0.224
SM -> Att	0.234***	[0.161, 0.309]	0.037	0.076
MM -> Att	0.326***	[0.258, 0.391]	0.040	0.143
EC -> MM	0.093*	[−0.038, 0.144]	0.042	0.009
K -> Att	0.113***	[0.062, 0.155]	0.028	0.032
INNO -> Att	0.065*	[0.020, 0.115]	0.029	0.011
PI -> Att	−0.077 ns	[−0.129, 0.020]	0.048	0.020
Att -> Inten	0.853***	[0.829, 0.874]	0.014	2.680
Indirect effects				
EM -> Inten	0.270***	[0.227, 0.317]	0.027	
SM -> Inten	0.200***	[0.148, 0.253]	0.032	
MM -> Inten	0.278***	[0.220, 0.334]	0.035	
EC -> Att	0.030*	[−0.007, 0.049]	0.014	
K -> Inten	0.096***	[0.052, 0.132]	0.024	
INNO -> Inten	0.056*	[0.017, 0.098]	0.025	
PI -> Inten	−0.066ns	[−0.109, 0.017]	0.041	

Note: *** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level; ns not significant.

6.1. As the 'downstream' of EV adoption

This research examines the factors influencing the adoption of CSS and explores their potential to mitigate the challenges of EV adoption. CSS is particularly useful during the transitional period when public infrastructure is not yet well developed and in areas where it is not feasible to install individual EV chargers. Given the impact of economic motive, we propose introduction of financial incentives for individuals who participate in CSS is potentially beneficial in overcoming reluctance to share private chargers. Drawing from the findings of Deka et al.

Table 5
SEM multi group analysis (direct effect).

Paths	EULEZ group ($n = 256$)	IULEZ group ($n = 348$)	Difference (EULEZ - IULEZ)
Direct effects			
EM -> ATT	0.332***	0.314***	0.018 ^{ns}
SM -> ATT	0.244***	0.231***	0.013 ^{ns}
MM -> ATT	0.343***	0.313***	0.030 ^{ns}
EC -> MM	0.085 ^{ns}	0.126*	−0.040 ^{ns}
K -> ATT	0.064 ^{ns}	0.162***	−0.098 ^{ns}
INNO -> ATT	0.048 ^{ns}	0.097^{ns}	−0.018 ^{ns}
PI -> ATT	−0.023 ^{ns}	−0.120*	0.097 ^{ns}
ATT-> INTEN	0.848***	0.857***	−0.009 ^{ns}
Indirect effects			
EM -> INTEN	0.282***	0.269***	0.013 ^{ns}
SM -> INTEN	0.207***	0.198***	0.009 ^{ns}
MM -> INTEN	0.291***	0.268***	0.023 ^{ns}
EC -> ATT	0.029 ^{ns}	0.039 ^{ns}	−0.010 ^{ns}
K ->INTEN	0.054 ^{ns}	0.138***	−0.084 ^{ns}
INNO ->INTEN	0.041 ^{ns}	0.057 ^{ns}	−0.016 ^{ns}

Note: *** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level; ^{ns} not significant.

(2023), incentives such as tax rebates, subsidies for energy costs, or direct payments can make participation in CSS more attractive. Policymakers might consider programs that reward users based on the amount of power shared or the frequency of charger availability to the public. Such financial benefits can help offset potential concerns about wear and tear or increased electricity bills due to sharing. Moreover, it is also crucial to keep promoting EV adoption with financial incentives for purchase to boost the electrification process and reduce the environmental footprint.

Similarly, Innovativeness proved insignificant once geography was accounted for, suggesting that costly “early-adopter exclusives” in the EULEZ are unlikely to add traction. Instead, platforms might spotlight moral dividends (lower local emissions, community benefit) which scored strongly across both zones. Marketing and knowledge campaigns should frame CSS as a seamless add-on to factory-supplied smart chargers, echoing Brand et al.’s (2020) advice that ease-of-use messaging shifts consumer perceptions more than novelty appeals.

6.2. Community collaboration and framing

Furthermore, social motives play a crucial role in the adoption of sharing services like CSS. The government and local authorities can capitalize on this by promoting community-based initiatives that emphasize the social benefits of CSS. This could include community reward programs that recognize and incentivize individuals and neighbourhoods that actively participate in CSS. For example, communities could be given financial incentives based on their level of engagement with CSS, fostering a sense of community achievement. Adding to that, following the findings about the importance of moral motive in consumer decision-making, it is also viable to integrate CSS into broader local sustainability programs, and frame it as a sustainable and ethical service. Such initiatives encourage a collective action spirit, making CSS adoption a community goal and sustainability move rather than an individual challenge. Similarly, knowledge gaps differ spatially: awareness is already behaviourally potent in the Inner ULEZ but inert outside. Hence, workshops (Tran et al., 2012) should concentrate on inner-borough estates, clarifying tariff setting, liability cover and smart-lock operation. Online explainers can still target the outer zone, but resources there should stress practical sign-up steps more than conceptual benefits.

6.3. Public charging facility as the core focus

Furthermore, our results suggest that the public attitude towards sharing their own EV chargers can be improved with the increasing number of public chargers (i.e. impact of perceived inaccessibility of public chargers to attitude towards sharing private chargers) . On the one hand, it emphasize that we may have missed some other factors that affect charger owners’ sharing intention. As raised in previous studies to other sharing economy models, it is crucial, especially for ones that requires entry to private property, to investigate on the safety and concerns and means to protect the providers (sharers) (Cannon et al., 2019; Shah et al., 2021). Therefore, it is noteworthy for policymakers and sharing platforms to research about the whole spectrum of factors that may affect sharing intention.

On the other hand, it also suggests the role of CSS within future development of public charging infrastructure. That is, although the investigated motivational factors can significantly lead to a positive sharing intention, the development of public charging facilities should be prioritized to further boost the owners’ sharing intention. In addition, recent modelling work suggests that the aggregated energy potential of parked EVs could itself become a grid resource, capable of supporting local electricity demand through data-driven forecasting and integration (Comi et al., 2024; Comi & Elnour, 2025). In this light, CSS platforms could one day interlink with such grid-support schemes, aligning private-charger sharing with broader energy-system optimisation. Governments should prioritize investments in public charging infrastructure that not only meet the current demand but are scalable and adaptable to future needs. Such strategic planning will ensure that charger owners are more likely to share, and CSS to becomes an integral part of a sustainable and efficient urban mobility ecosystem.

7. Conclusion and the road ahead

This study, while providing valuable data-driven insights into the factors influencing the adoption of Charger Sharing Services (CSS), is subject to several limitations. First, our research was designed to cover the attitude and intention to share only, which ignored the decision-making of using the charging facility shared by others. As another crucial part of any sharing services, it is imperative to understand the decision-making of the users as well, which may be motivated by distinctive factors, such as privacy concerns. Hence, future research could also investigate the user perspective upon the increased awareness and users’ adoption of CSS. Furthermore, given the specific geographical focus of this research, our findings may have limited generalizability, future research could explore other cities facing similar challenges and compare the transferability of our findings.

Lastly, as noted in previous research to other sharing economy models, the authors feel obliged to note about the potential drawbacks in CSS and potential mass adoption. Despite the social (as raised in previous research to CSS) and individual level of benefits (as examined in this study), there are certain drawbacks as sharing services grows (Frenken & Schor, 2019). For instance, ride-sharing was promoted with the primary goal of reducing car ownership and urban congestion, yet studies have shown it can lead to increased vehicle miles travelled and greater congestion in some cities (Schaller, 2018). In addition, while CSS aims to optimize the use of existing charging infrastructure, mass adoption could unintentionally create new inefficiencies, such as conflicts over charger availability or increased local traffic near shared charging locations (Frenken and Schor, 2019). Thereby, we advocate that future researchers focus on exploring these potential challenges to ensure the long-term feasibility of CSS, as a complement solution for charging challenges.

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CRediT authorship contribution statement

Yanghui Cao: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Maria Kamargianni:** Writing – review & editing, Supervision. **Yuerong Zhang:** Writing – original draft, Visualization, Methodology, Funding acquisition, Data curation, Conceptualization.

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.

Appendix A. Results of hypothesis testing

Proposed hypotheses	Result
H1: Attitude to private charger sharing significantly and positively affect intention towards private charger sharing.	Supported
H2: Consumers' economic motive positively and significantly affect attitude towards private charger sharing.	Supported
H3a: Consumers' social motive positively and significantly affect attitude towards private charger sharing.	Supported
H3b: Impact of consumers' social motive on attitude towards private charger sharing significantly differ between IULEZ and EULEZ groups.	Not supported
H4a: Consumers' moral motive positively and significantly affect attitude towards private charger sharing.	Supported
H4b: Environmental concern has an indirect positive impact on attitudes toward adopting CSS, mediated by moral motivation.	Not supported
H5: Consumers' knowledge to sharing services positively and significantly affect attitude towards private charger sharing.	Partially supported
H6: Consumers' innovativeness positively and significantly affect attitude towards private charger sharing.	Partially supported
H7: Consumers' perceived inaccessibility of public charging facility significantly affect attitude towards private charger sharing.	Partially supported

Appendix B. Fornell-Larcker criterion

	ATT	EM	EC	INNO	INTEN	K	MM	PI	SM
ATT	0.924								
EM	0.664	0.902							
EC	0.101	0.189	0.814						
INNO	0.392	0.257	0.113	0.877					
INTEN	0.853	0.694	0.119	0.329	0.951				
K	0.45	0.254	−0.051	0.403	0.413	0.905			
MM	0.75	0.56	0.093	0.359	0.709	0.374	0.9		
PI	−0.122	0.02	0.176	0.029	−0.124	−0.122	−0.091	0.624	
SM	0.716	0.521	0.052	0.362	0.653	0.424	0.744	−0.039	0.878

Appendix C. MICOM output

To justify the multi-group comparisons, we followed the three-step Measurement Invariance of Composite Models (MICOM) procedure recommended by Henseler et al. (2016).

The first step of MICOM involves testing the configural invariance of data, which should be met for this research as the data was treated identically throughout the data analysis for both groups. The second step uses 5 000 permutations to test whether each composite in the two groups is created from its indicators in the same way. All permutation p-values exceeded 0.05 (max = 0.28), so compositional invariance is established for every construct, permitting path-coefficient comparisons. The third step is split into Step 3a (means) and Step 3b (variances). Four composites (Environmental Concern, Knowledge, Moral Motive and Perceived Inaccessibility) showed significant differences. Because at least one construct fails Step 3, partial invariance holds. This level of invariance is sufficient for comparing structural paths with Henseler-MGA and permutation tests, but latent-mean differences are not interpreted.

Step 2. Compositional invariance

	Original correlation	Correlation permutation mean	Permutation p values
ATT	1	1	0.265
EC	0.95	0.872	0.556
EM	1	1	0.975
Inno	0.999	0.999	0.407
K	0.999	0.999	0.343
MM	1	1	0.774
PI	−0.05	0.485	0.112
SM	1	1	0.879
INTEN	1	1	0.893

Step 3a and 3b Mean and variance

	Original difference	Confidence interval	Permutation p value
Step 3a			
ATT	−0.13	[−0.159, 0.162]	0.112
EC	0.177	[−0.161, 0.166]	0.034
EM	−0.083	[−0.157, 0.163]	0.328
Inno	−0.073	[−0.158, 0.157]	0.367
K	−0.268	[−0.16, 0.165]	0.001
MM	−0.088	[−0.161, 0.157]	0.287
PI	−0.044	[−0.159, 0.158]	0.586
SM	−0.104	[−0.163, 0.165]	0.21
INTEN	−0.151	[−0.162, 0.161]	0.069
Step 3b			
ATT	0.134	[−0.195, 0.188]	0.167
EC	−0.025	[−0.28, 0.237]	0.855
EM	0.24	[−0.256, 0.234]	0.055
Inno	0.058	[−0.236, 0.219]	0.613
K	−0.109	[−0.157, 0.15]	0.164
MM	0.214	[−0.204, 0.197]	0.036
PI	0.259	[−0.257, 0.242]	0.041
SM	0.072	[−0.195, 0.187]	0.465
INTEN	0.19	[−0.211, 0.191]	0.064

Appendix D. CSS literature synthesis

Study	Study focus	Research method	Key findings
Plenter et al., 2018	Whether there is sufficient supply (willing peer-providers) of private chargers and platform service design	New Service Development process with provider assessment step; survey potential peer-providers to profile willingness and	A pool of prospective hosts exists and that integrating provider assessment into NSD helps shape platform features/policies.
Akbari & Dean, 2025	Gauges California EV households' awareness, interest, and concerns about P2P residential charger sharing.	Cross-sectional survey of California EV households focusing on motivation, concerns and various socio-demographic characteristics.	A meaningful minority express willingness to participate, with interest tempered by practical and trust/risk considerations typical of P2P models.
Shi et al., 2025	Community residents' support for private charging pile sharing and how it complements public charging in urban China (didn't differentiate host and chargees).	Questionnaire survey to the proposed factors that may affect charger sharing uptake among respondents. Ordered probit model used to test the impact of factors.	PCPS aligns with convenient daily slow charging, while public sites address faster, emergency/occasional demand. Findings are used to argue policy measures that boost neighbourhood PCPS acceptance.
Xingjun et al., 2024	One of the most related: whether the privacy paradox affects willingness to share private charging piles and how "reasons for/against," attitudes, and social cues shape intention to participate.	Behavioural reasoning theory framework tested on a survey of 1005 potential private charger owners in Chongqing; modelling with mediation and moderation, plus multi-group analysis by gender, age, education, income.	Both desire to share and privacy concerns are significant. Reasons for sharing and attitudes mediate the desire -intention path; reasons against sharing mediate the privacy concerns - intention path. Herd mentality moderates only the reasons against sharing - intention link.
Chen et al., 2022	Strategies to relieve the potential of charging-capacity shortages by letting private "idle" home chargers be shared alongside public stations in a coordinated scheduling framework.	A hierarchical EV-charging scheduling model: the upper level sets EV charging times; the lower level assigns charging locations across public stations and shared private piles.	Simulation evidence shows the approach can improve utilization of private piles, reduce peak-period strain at public stations, and maintain grid operating quality.
Yang et al., 2024	The system-level impact of sharing private home charging posts on access to charging and the load borne by public infrastructure in Beijing.	Micro-simulation calibrated with trajectory data from 76,000+ private EVs, and scenarios compare networks with vs. without charger sharing to quantify changes in charging access and usage.	In the baseline scenario with PHCPS enabled, the model estimates a 6.32 % increase in the share of parking events with accessible charging and a 33.37 % decrease in the average electricity delivered by public posts on a working day
Wang et al., 2023	How to fairly allocate benefits among participants in shared private charging pile projects so cooperation is sustained.	Proposes an improved Shapley value approach that adjusts payoffs using risk, input, and service-quality factors via a cloud-gravity-center correction; demonstrates with a worked example.	The modified Shapley scheme yields more reasonable(fair) allocations and enhances multi-party cooperation compared with the classical Shapley split in the example analysis.
Cai et al., 2025	Governance and incentives for the pile owners–property companies–EV users to support sustainable urban transport in China.	Tripartite evolutionary game integrating prospect theory (risk/loss perception), analysed with system-dynamics simulations over 15 policy/market factors	Increasing loss awareness and reducing risk preference promotes proactive strategies. Having owners contribute a portion of management fees and applying dynamic government incentives markedly increases property-company engagement.
Charly et al., 2023	Where to place "community" EV charge (not strictly peer-to-peer) points in Dublin so they actually serve users—distinguishing shared-residential, en-route, and charging types.	GIS-based multi-criteria siting using an open-source workflow (QGIS/OSM), with catchment analysis for 5-minute walk/cycle accessibility	Identifies 770 priority sites for initial rollout and 3080 additional sites for later phases; the approach is transferable to similar cities and helps planners target locations by user type and short-access catchments.
Murugan & Marisamynathan, 2024	(Related but not charger sharing) Drivers for Indian householders to adopt home EV charging (paired with rooftop PV) and which policies best support adoption.	Questionnaire survey ($n = 850$, Ahmedabad) analysed with a two-stage PLS-SEM and Artificial Neural Network pipeline to estimate constructs, rank drivers, and compare policy bundles.	Strong motivators are home-charging convenience, reduced range anxiety, lower charging cost, flexibility, and no waiting. Willingness to adopt rooftop PV positively relates to adopting home charging.

Studies included:

Plenter, F., Chasin, F., von Hoffen, M., Betzing, J.H., Matzner, M. and Becker, J., 2018. Assessment of peer-provider potentials to share private electric vehicle charging stations. Transportation Research Part D: Transport and Environment, 64, pp.178–191.

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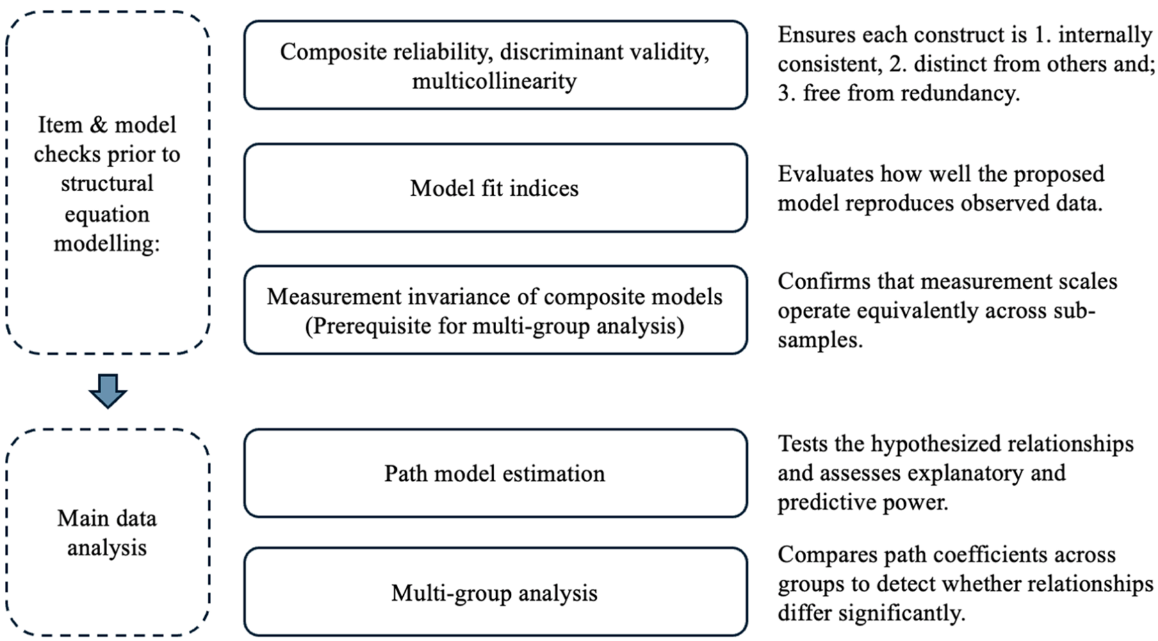
Appendix E. Data analysis flowchart



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