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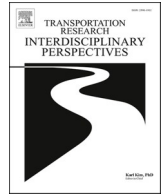
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Residents' preferences regarding shared mobility in car-free zones: the case of delft's inner city

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ABSTRACT

Growing car dependence intensifies congestion and reduces urban liveability. In response, many cities are introducing car-free zones supported by shared mobility to promote sustainable and accessible transport. However, residents' preferences for shared modes in actively transitioning car-free contexts remain underexplored. This study examines these preferences in the inner city of Delft, a medium-sized Dutch city transforming toward a car-free area under the "Mobility Plan 2040."

A stated choice experiment examines how travel cost, walking time, socio-demographic characteristics, and trip purposes influence the adoption of four shared electric modes, (e-) bikes, scooters, cargo bikes, and cars, while an "opt-out" option captured avoidance behaviour. A Mixed Logit model estimated the Value of Time and quantified preference heterogeneity.

Travel cost and walking time are the most significant determinants. The estimated VoT (€0.20 per minute) highlights the importance of reducing access distances. Socio-demographic variation was significant: younger, digitally literate residents prefer micromobility, while those aged 50+ are more likely to opt out. Gender, income, education, and trip purpose further shape preferences, with commuting trips showing lower adoption due to time and reliability constraints.

Rather than forecasting demand, we use the experiment as a behavioural diagnostic of an urban transition in progress: the 64% of choices selecting the opt-out indicate that the offered shared modes were frequently not acceptable substitutes for the recalled trip—most strongly when that trip was car-based—highlighting that car-free strategies must combine service design (pricing, fleet proximity) with car-ownership targeted measures for the groups least ready to substitute.

1. Introduction

Global urbanization and growing car dependence continue to intensify traffic congestion, air pollution, and reduced urban liveability (UN-Habitat, 2020; van Arem et al., 2022; Geržinić et al., 2024). A core illustration of this inefficiency is the disproportionate share of urban space devoted to private vehicles—most of which remain unused for over 90% of the time—creating structural barriers to sustainable spatial development (Kim, 2018). These challenges underscore the need for a fundamental shift in mobility patterns and the reallocation of urban space away from private car use.

Addressing car dependency has therefore become a central challenge for policymakers, demanding carefully tailored solutions. These

strategies must simultaneously enhance urban mobility while effectively mitigating traffic congestion (Tate et al., 2025). Transportation and land use planning are inherently interdependent: transport decisions shape patterns of land development, while existing land use strongly influences travel demand and activity (Litman, 2025). Changes in travel behaviour induced by land use management strategies can simultaneously address urban challenges and support a wide range of planning objectives (Litman, 2025). At the same time, emerging transport technologies, such as shared micromobility services and electric mobility, offer potential alternatives to private car ownership, though their long-term implications for travel demand, urban form, and parking requirements remain uncertain (Shaheen et al., 2020).

In response, cities are increasingly pursuing two complementary

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pathways:

- (1) the implementation of car-free, car-reduced, or car-independent areas to reclaim public space and promote sustainable mobility (Nieuwenhuijsen, 2020; van Arem et al., 2022; Aumann et al., 2023; Brownrigg –Gleeson et al., 2025), and
- (2) the expansion of shared mobility systems (e-bikes, e-scooters, shared cars, cargo bikes) as flexible, low-carbon mobility alternatives (van Marsbergen et al., 2022; van Arem et al., 2022; Zhou et al., 2023; Geržinić et al., 2025; Torabi Kachousangi et al., 2025).

Although existing studies examine either the impacts of car-free zones or the role of shared mobility in urban areas, there is limited research on how shared mobility functions within newly implemented car-free environments. This gap is particularly relevant for policy-makers, as it highlights the need to consider shared mobility alongside conventional modes such as walking, cycling, and public transport. Integrating shared mobility into car-free planning may therefore enhance accessibility and support a more comprehensive transition toward sustainable urban environments.

The Dutch planning context is particularly conducive to such transitions. Dense historical city centres, a strong cycling culture, and national policy shifts toward mobility hubs and car-free areas create favourable conditions for reducing car dependency (Torabi Kachousangi et al., 2025). While previous studies demonstrate the potential of car-free strategies to improve environmental quality and urban liveability (Nieuwenhuijsen, 2020; Geurs & Münzel, 2022; van Arem et al., 2022; Aumann et al., 2023) and highlight the role of shared mobility in supporting modal shift (van Marsbergen et al., 2022; van Arem et al., 2022; Zhou et al., 2023), they also reveal societal resistance (Požani et al., 2018; Chun et al., 2019). Achieving a successful transition therefore requires not only infrastructural changes but also a deeper understanding of residents' behavioural responses and preferences. Research on mobility transitions shows that behavioural factors strongly influence attitudes toward shared mobility and reduced-car environments (Selzer & Lanzendorf, 2022; Torabi Kachousangi et al., 2025).

Existing literature on car-reduced and car-independent neighbourhoods in Europe (e.g., Aumann et al., 2023; Sprei et al., 2020; Basu & Ferreira, 2020) primarily explores environmental improvements, changes in space allocation, or public support for car-free planning. However, little is known about the behavioural mechanisms driving individual adoption—or rejection—of shared mobility within actively transitioning car-free contexts. Conventional choice models often investigate mode substitution (e.g., from private car to cycling or shared modes) but rarely incorporate non-participation or avoidance behaviour, where individuals choose not to travel at all under new mobility conditions. Furthermore, the social dimension of shared mobility remains underexamined: recent studies show that despite policy support, shared modes are not equally appealing across demographic groups, reflecting concerns related to comfort, identity, safety, or social norms (Geržinić et al., 2025; Selzer & Lanzendorf, 2022).

This omission creates a critical gap: residents who avoid shared mobility—even when high-quality infrastructure is available and policies are supportive—remain largely invisible in planning practice. Understanding the determinants of this opt-out behaviour, alongside socio-demographic variability in shared mode preferences, is essential for designing inclusive car-free mobility transitions.

This study is grounded in the behavioural-economic framework of Random Utility Maximisation (RUM) theory, which assumes that individuals choose the alternative that provides the highest perceived utility among a discrete set of options. In this context, residents evaluate shared mobility alternatives based on observable service attributes, such as travel cost and walking access time, as well as their own socio-demographic and trip-related characteristics. This theoretical perspective also motivates the use of a Mixed Logit model, which allows for

preference heterogeneity across individuals and avoids the restrictive substitution patterns of simpler choice models. In addition, the study draws on the shared mobility acceptance literature, which suggests that behavioural, social, and contextual factors shape both the attractiveness of shared modes and the likelihood of rejecting them altogether. Accordingly, the opt-out alternative is interpreted as reflecting insufficient perceived utility of the offered shared modes for the recalled trip under the stated conditions.

This study responds to this gap by examining how residents evaluate shared electric mobility as one element within a broader car-free transition package in Delft's inner city. Rather than treating shared mobility as a stand-alone solution, we use a stated choice experiment to diagnose when shared modes are perceived as acceptable substitutes for a recently made trip and when they are not, given key service attributes (price and access distance) and heterogeneous resident characteristics. Crucially, the experiment includes an opt-out alternative to capture cases where none of the offered shared modes is considered a viable substitute for the recalled trip under the stated conditions. This allows us to identify potential accessibility and acceptance barriers that remain largely invisible when analyses assume universal mode substitution. We estimate Mixed Logit models to account for preference heterogeneity and to derive policy-relevant measures (e.g., sensitivity to distance access) that can inform the design of inclusive car-free transition strategies. We treat the stated choice experiment not as an end but as a behavioural diagnostic instrument for an urban transition in progress. The opt-out alternative is read through the lens of transition research: it identifies residents for whom the emerging car-free mobility system does not yet provide an acceptable option, making visible the social unevenness of the transition rather than merely estimating substitution elasticities. Modal choice is thus one component of a broader transformation—alongside the reallocation of public space, land-use change, and governance—and our contribution is specifically to its behavioural-acceptance dimension.

The findings provide planners and policymakers with evidence on how shared mobility can support the transition toward car-free, liveable urban environments. By identifying which resident groups are inclined to adopt shared modes—and why—the study offers actionable insights for designing accessible, inclusive, and socially equitable private car-free mobility systems.

2. Research background

This section provides a literature review that establishes the conceptual and empirical foundations of the study. It focuses on two core strategies central to our research, the creation of car-free areas and the role of shared mobility in modal shift and clarifies how these strands of literature inform the study's research gap and analytical approach.

2.1. Car-free areas: unlocking sustainable urban mobility

Sustainability principles have gained prominence in urban and transport planning, aiming to reduce car dependence (Buehler et al., 2017). The persistent reliance on privately owned, fossil fuel-powered vehicles remain a primary challenge to sustainable urban mobility in European cities, contributing significantly to greenhouse gas emissions, poor air quality and severe congestion (Ceccato et al., 2024). This car-centric paradigm also results in substantial spatial inefficiencies, evidenced by the vast amounts of public land dedicated to regulated parking and traffic infrastructure, thereby limiting opportunities for more sustainable urban uses (van Arem et al., 2022; European Parking Association, 2024).

In response, urban planning is shifting from a private car-dominated model toward one that greatly limits or eliminates private car use, fundamentally aiming to address environmental degradation, public health challenges, and social inequities (Gundlach et al., 2018; Aumann et al., 2023). These interventions take multiple forms, including pedestrian-only areas, low-traffic zones, car-free areas, car-independent

neighbourhoods (Erturan & Aksel, 2024), as well as what the literature describes as car-lite or low-car(bon) developments, private-car-restricted and mobility-served neighbourhoods, and areas governed by low or maximum parking requirements (Basu & Ferreira, 2020; Sprei et al., 2020). Removing car-oriented infrastructure in these contexts frees considerable urban space, enabling the expansion of public areas and green spaces for pedestrian use (Nieuwenhuijsen and Khreis 2016). Consequently, these environments reclaim urban space for diverse residents to move safely and comfortably, without the barriers posed by motorized traffic (Erturan & Aksel, 2024). Concepts like the 15-Minute City prioritise integrated land use, walkable urban density, and the fundamental redistribution of urban space away from private motorised transport to favor active and public transport modes (Christidis et al., 2024; Wang et al., 2024; Brownrigg-Gleeson et al., 2025).

The successful creation of genuinely private car-free zones requires a rigorous combination of prohibitive (push) and facilitative (pull) measures. Push measures—such as Urban Vehicle Access Regulations (UVARs) (Ogunkunbi & Meszaros, 2022), including Low Emission Zones (LEZs) (Fransen et al., 2023)—play a critical role in reducing the presence of pollutant vehicles and initiating shifts in travel behaviour (Ceccato et al., 2024). However, these interventions primarily function as preparatory steps for the broader objective of reallocating street space. Effective implementation relies particularly on strong pull factors: substantial investments in high-quality public transport, dedicated cycling and walking infrastructure, and the expansion of shared mobility systems. While push policies constrain car use, pull measures enable sustainable mobility choices in everyday life. Reviews of complex interventions show that integrating both approaches is most effective in achieving the modal shift required for a car-free urban fabric.

Empirical evidence confirms the transformative potential of car-free planning: neighborhoods explicitly designed for car independency exhibit structurally lower levels of car ownership and usage, with residents showing a higher propensity to adopt non-motorised and collective transport options (Aumann et al., 2023). However, the successful implementation of this transition is highly contingent on key social and governance factors. This includes effectively managing behavioural change, ensuring spatial and social accessibility for all user groups, and establishing inclusive governance to maintain public acceptance of radical spatial changes (Torabi Kachousangi et al., 2025). Importantly, public acceptability has been identified as a critical condition for the successful adoption of access regulations and alternatives to private car use (Ogunkunbi & Mészáros, 2022).

Despite the clear benefits and growing global implementation of these low-car and car-free models, research remains fragmented. There is limited empirical evidence on how such complete spatial strategies systematically influence mobility behaviours, accessibility outcomes, and modal shift across varied urban contexts. This gap underscores the need for studies that rigorously analyse the effectiveness of dedicated car-free zones within the wider transition towards a sustainable urban mobility system.

2.2. The role of shared mobility in modal shift

Reducing the number of vehicles on the road and promoting shared mobility options are essential for achieving sustainable transportation goals (Zhou et al., 2023). Shared mobility refers to various shared services such as (electric) carsharing, bike-sharing or any other shared means of transport (Shaheen et al., 2016), utilised on an 'as-needed' basis (Machado et al., 2018; Shaheen et al., 2017). These services serve as primary modes of transport and provide crucial first/last-mile connectivity at public transport stops (Geržinič et al., 2025; Humm, 2020; Stam et al., 2021). However, the effective integration of these services with public transport systems remains complex, as it involves challenges related to physical infrastructure, institutional coordination, and digital systems (Brown & Van Oort, 2026). Smart mobility options operate independently of private car ownership and offer substantial, yet still

largely untapped, potential to supplement or even replace car-based travel while requiring significantly less space (van Arem et al., 2022; Zhou et al., 2023; van Marsbergen et al., 2022). Shared mobility services such as (electric)- bike sharing, scooter sharing, cargo bike sharing, and carsharing hold promise for reducing car dependency. However, empirical evidence also highlights that the substitution dynamics are not uniformly beneficial; for example, e-scooters frequently replace walking or public transport rather than private car trips in several European cities, raising concerns about their overall sustainability. Indeed, some cities have scaled down or discontinued public e-scooter programs due to safety, clutter, and limited environmental benefits.

Despite these concerns, recent studies still report meaningful substitution potential under favourable spatial, regulatory, and pricing conditions. For instance, micromobility modes such as e-bikes and e-scooters can replace approximately 30% of short car trips in dense urban centres (Fitt et al., 2019). Conventional shared bikes are particularly suitable for trips between 1 and 1.6 km and have been shown to substitute for car use and public transport (Reggiani et al., 2023; Boor, 2019; Shen et al., 2018; Abduljabbar et al., 2021). Moreover, e-scooters demonstrate substitution effects for short-distance car trips when supported by appropriate infrastructure and integrated pricing strategies (Torabi Kachousangi et al., 2022; Torabi Kachousangi et al., 2025; Van Kuijk et al., 2022; Masoud et al., 2019; Hollingsworth et al., 2019; PBOT, 2019). Taken together, these findings suggest that while unintended mode shifts may undermine sustainability outcomes, shared micromobility can still contribute to reducing car dependency when aligned with targeted local mobility policies.

Shared cargo bikes offer a sustainable alternative for transporting goods and toddlers (Becker & Rudolf, 2018; Fishman et al., 2013; Zademach & Musch, 2016), with studies showing substitution for up to 46% of car trips (Becker & Rudolf, 2018).

The availability and convenience of carsharing services encourage the transition from private car ownership (Liao et al., 2020; Nijland et al., 2015). Frequent carsharing use substantially reduces reliance on private cars, with each shared car potentially replacing up to 16 privately owned cars (Schreier et al., 2021). Introducing shared electric vehicles further enhances sustainability benefits and promotes a shift toward active transportation (Martin & Shaheen, 2016; Liao & Correia, 2022).

However, societal values highly affect shared mobility perception and acceptance, making it challenging to shift from privately owned cars to shared alternatives (Geurs & Münzel, 2022; Pojani et al., 2018; Chun et al., 2019). For instance, shared mobility is sometimes perceived as an option for lower socioeconomic groups, while vehicle ownership is associated with higher status (Pojani et al., 2018; Chun et al., 2019). Moreover, adoption and usage are highly influenced by socioeconomic characteristics, trip characteristics, and contextual variables (Torabi Kachousangi et al., 2022; Van Kuijk et al., 2022). To ensure an equitable and inclusive mobility transition, it is particularly critical to address the needs and limitations of the ageing population. Therefore, to effectively design inclusive strategies, it is essential to understand how actual and perceived mobility limitations shape individual choices, especially the decision to opt out of a trip entirely.

3. Research methodology

We have developed a stated choice experiment to address residents' intentions to use shared mobility services and the potential to reduce private car use by introducing car-free areas and shared mobilities in inner cities. This experiment aims to reveal residents' preferences for these services. The city centre of Delft, which serves as an example of a car-free zone, has been selected as the case study for this research.

3.1. Case study: delft inner-city (in The Netherlands)

Delft is a small, medium-sized historic city with around 103,500

inhabitants in the Netherlands. Delft will continue to develop in the coming decades, and the municipality is ambitious to add 15,000 homes and 10,000 jobs by 2040. This city's growth by about 30% by 2040 will negatively affect its accessibility and mobility if suitable measures are not taken.

The historic downtown was designed for pedestrians. However, cars gradually took over the streets. With the implementation of low-traffic programs in the 1990 s, car traffic started reducing in the inner city. This positive development creates more space for public activities. The Delft Mobility Program 2040 and Environmental Vision Delft 2040 aim to improve accessibility and increase sustainability in Delft by accelerating the mobility transition from private cars to more public transport modes and making an utterly car-free city centre in 2040 (Gemeente Delft, 2021a,b) (Fig. 1).

These reports have mentioned that the disappearing parking spaces should be compensated for by introducing mobility hubs and appropriate transport and facilities. Offering shared mobility (shared cars and shared bicycles) in public spaces (mobility hubs) offers opportunities to reduce car ownership and use sustainable transport modes, making the transport network more sustainable (Gemeente Delft., 2021a, b).

We have selected Delft city centre as our case study because it has already taken significant steps towards becoming a low-car or even car-free city centre. The existing policies in Delft, such as the Delft Mobility Program 2040 and the Environmental Vision Delft 2040, actively promote the transition from private car usage to shared modalities and public transport. Furthermore, the availability of shared mobility options, such as shared cars and bicycles, makes Delft a potentially good candidate to study the impact and feasibility of a car-free and shared mobility-focused urban environment.

Survey overview

To identify the factors influencing these attitudes and to capture both

current and potential future-mode choice behaviour, an online survey was conducted consisting of two main components. The first part collected background information, including socio-demographic characteristics and general travel behaviour of Delft's inner-city residents. The second part contained the stated choice experiment, which forms the analytical basis of this study. This survey (English and Dutch versions) was advertised on Delft Municipality's social media pages (Facebook and Instagram) between November 14 and December 7, 2022, and was only accessible to inner-city residents. As recruitment relied on municipal social media, the sample should be interpreted as a convenience sample that may overrepresent digitally engaged residents; accordingly, we frame the findings as behavioural diagnostics within this context rather than population-representative forecasts. This focus was intentional, as the Delft Mobility Plan 2040 specifically targets the city centre. The survey began with a brief explanation of the study's purpose and context, including an introduction to shared mobility in Delft's inner-city, the rationale for the municipality's interest in residents' travel preferences, and information on how the survey results would be used to support future mobility planning.

Part 1: Background information (Revealed Preferences)

This survey aims to capture the level of familiarity of residents with shared modes, car dependency, and socioeconomic characteristics. Firstly, they were asked about their shared experience modes and willingness to use them instead of private cars. Then, respondents were asked to consider their recent max 20 km distance trip from Delft inner-city and specify the means of transport used and other information regarding trip purposes, destination, and travel companions. Finally, some general questions about gender, age, family status, education level, income, driver's license possession and owning cars were raised. According to the literature review, all these factors could influence mode choice.

Part 2: Stated choice experiment

A stated choice experiment was performed in this study to examine the substitution potential of shared modes for private cars. Twelve choice sets were generated based on four potential alternatives for private cars: 1) shared (e) bike, 2) shared (e) scooter, 3) shared (e) cargo bike, 4) shared (e) car, and 5) opt-out, and two attributes; 1) travel cost and 2) walking time to shared modes. These modes were selected because past studies (e.g. Torabi kachousangi et al. 2022; 2025; Nijland et al., 2015) have identified shared bikes, scooters, and cars as potential alternatives for private cars in the Netherlands. While cargo bikes are becoming increasingly popular in the Netherlands, the potential of shared cargo bikes has not yet been extensively studied (Rickmers, 2022). Our study aims to investigate the potential of all these shared modes in the city center, exploring their viability for reducing car dependency and enhancing urban mobility. This makes them suitable options for exploring the transition towards sustainable urban transport systems. Moreover, the inclusion of a "opt-out" option allows the model to capture both the participation and mode choice decisions, accounting for possible reluctance toward shared mobility. This option also makes the choice process more realistic by enabling individuals to opt out of shared modes altogether.

Regarding attributes, travel cost and walking time to reach shared modes are essential factors influencing modal choice based on literature. These are considered with two corresponding attribute levels in our SP experiment. The travel cost attribute levels were based on the pricing structures of major shared mobility operators active in the Dutch market, including Felyx and Check for shared e-scooters, Donkey Republic for shared e-bikes, Cargoroo for shared cargo bikes, and Greenwheels and MyWheels for shared car-sharing services. These sources reflect the prevailing per-minute tariffs in the Netherlands during 2022, providing realistic and policy-relevant ranges for the stated choice experiment.

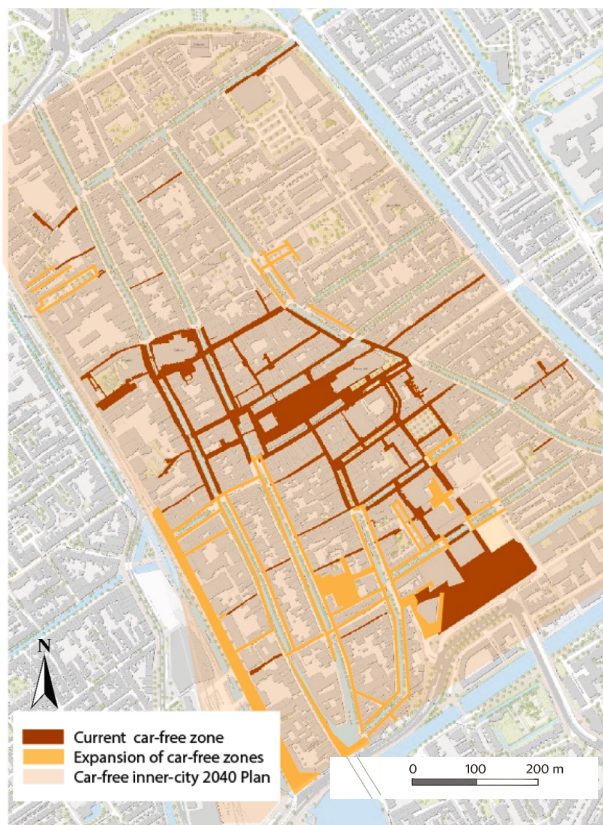


Fig. 1. Current and proposed car-free zone in the Delft inner city (. Source: Gemeente Delft, 2021; edited by the author)

Besides, walking time, denoted as the maximum distance to reach the first shared mode, has been estimated to range between 2 min and 10 min, as shown in Table 1. The selection of alternatives and attributes are all based on the importance mentioned in literature.

To design the choice sets, an efficient design was generated using Ngene software. Unlike orthogonal designs, efficient designs require prior information on parameter estimates; therefore, two pilot studies based on orthogonal design were conducted to obtain preliminary coefficient priors. Using these priors, the final efficient design was constructed for the main survey, comprising five alternatives, two attributes (travel cost and walking time), and two attribute levels, resulting in 12 choice sets in total. A sample is shown in Fig. 2.

To minimise cognitive burden and survey fatigue while maintaining statistical validity, the design was blocked into two groups of six choice sets. Each respondent was randomly assigned to one block and thus evaluated only six choice sets, which is consistent with standard practices in stated choice experiments (Hensher et al., 2015). This approach balances efficiency and respondent engagement, ensuring high-quality responses without compromising the design's robustness.

Participants were instructed to recall their most recent trip (within 20 km of Delft's inner city) and to indicate, for that specific trip, whether they would use one of the offered shared electric modes or none of them ("I would not travel with these shared modes"). The alternatives were deliberately restricted to shared modes because the motivating policy question—how mobility hubs and shared fleets can compensate for reduced private-car access under the Delft Mobility Plan 2040—concerns the shared offer specifically; walking and cycling are already dominant and unconstrained in the inner city. Accordingly, the opt-out denotes non-acceptance of the shared substitution for that trip and does not imply that the respondent would forgo the trip or be barred from using a private car or other non-shared mode. This framing means that respondents reconsidering an already-sustainable trip (e.g., walking or cycling) can rationally opt out, while the transformative question—substituting a car trip—is captured directly by the car-based sub-sample analysed in the descriptive analysis of opt-out behaviour (Section 4.1.4, Table 5-6).

We analysed the stated choice (SP) experiment using discrete choice models within the framework of Random Utility Maximisation (RUM) (Train, 2009). Under this framework, individuals are assumed to choose the alternative that provides the highest utility among the available options, where utility is a function of observable attributes and unobserved factors.

We selected the Mixed Logit (ML) model for our analysis as it offers greater flexibility and behavioural realism compared to the standard Multinomial Logit (MNL). Unlike the MNL, which is constrained by the Independence of Irrelevant Alternatives (IIA) assumption, the ML relaxes this assumption and allows substitution patterns to vary across alternatives (Train, 2009; McFadden & Train, 2000). This flexibility is particularly important in our context, as travel behaviour is unlikely to follow strictly proportional substitution, and individuals exhibit heterogeneous sensitivity to cost and accessibility (Hensher et al., 2015).

Moreover, the ML captures unobserved preference heterogeneity by treating key parameters as random, thereby accounting for individual differences in tastes and sensitivities that cannot be explained by

observed socio-demographic variables alone. Incorporating this heterogeneity improves both model fitness and interpretability, yielding a more accurate representation of travel behaviour.

The models were estimated in R (RStudio) using simulation-based maximum likelihood with the Apollo package (Hess & Palma, 2019), a flexible and widely used framework for discrete choice analysis. To perform numerical integration and improve simulation accuracy, we employed 1,500 Halton draws, which provide more efficient coverage of the parameter space than purely random draws. The random parameters, particularly for travel cost and walking time, were modeled using exponential distributions to ensure effects consistent with behavioural expectations, thereby capturing heterogeneity in sensitivity across individuals. 138 respondents each evaluated six choice sets, giving 828 panel observations. Mixed Logit pools information across all observations and respondents, and the random coefficients are identified from within-respondent variation across the six repeated choices; the attribute and heterogeneity estimate therefore do not rest on the non-opt-out sub-sample alone. Because the opt-out share is a share of choices (531 of 828) rather than of respondents, the four shared modes are still chosen in 297 observations distributed across the majority of respondents.

This estimation strategy combines theoretical rigor, empirical performance, and behavioural realism, making maximum likelihood the most suitable approach for our study.

4. Descriptive statistics of the empirical survey data

This section presents the descriptive statistics of the survey sample and provides an overview of current travel behaviour, distinguishing between private car use, shared mobility experience, and the socio-demographic profile of the opt-out group.

In total, 169 respondents completed the survey. 31 respondents were excluded from the data set due to travelling further than the maximum 20 km distance; the remaining 138 respondents formed the data set in this study. This equals 828 complete choices, higher than the minimum required (i.e. 528).

Descriptive statistics

Regarding the socio-demographic characteristics of the sample, Table 2 shows that it contains higher shares of old ≥ 50 years (64%), university-educated (87%), and high economic level $\geq 71,000$ euro (32%) users who are mostly household with at least two adults (57%), single (30%) and 15% have children up to 17 years old. Regardless of age, they mostly are fully physically mobile (87%), and only 12% have mobility limitations due to their age, concerning cycling and walking, respectively.

To assess sample representativeness, Table 2 compares respondents' socio-demographic characteristics with those of the Delft population. The sample includes a higher proportion of older respondents (64% aged 50 or above) and slightly more males (56%) than the city average (53%). Single-person households are underrepresented (30% vs. 59%), while highly educated individuals are overrepresented (57% vs. about 47%). Car ownership in the sample (70%) is similar to the Delft average (69%), although driving licence possession is considerably higher among respondents (93% vs. 74%). Overall, the sample is somewhat skewed toward older, highly educated, and car-oriented individuals.

Fig. 3 shows that participants travel most often for social/recreational/visitation purposes (40%) and work/education (35%), with the majority traveling alone (60%). These trips primarily target nearby cities such as Delft, Den Haag, and Rotterdam, with a common travel time of 16–30 min.

To characterise the trips respondents were asked to reconsider, Table 3 reports the original mode of the recalled trip. Car-based trips (driver or passenger) account for 37.7% of recalled trips, with active modes (bicycle, e-bike, walking) making up 48.6% and public transport 10.1%.

Table 1
Overview of attributes and attribute levels used in the SP experiment.

Attribute	Attributes levels	
Travel cost-shared (e) bike	€ 0.10/ min	€ 0.30/ min
Travel cost-shared (e) scooter	€ 0.20/ min	€ 0.40/ min
Travel cost-shared (e) cargo bike	€ 0.20/ min	€ 0.40/ min
Travel cost-shared (e) car	€ 0.50/ min	€ 0.70/ min
Walking time to access shared (e) bike	1 min	3 min
Walking time to access (e) scooter	1 min	3 min
Walking time to access shared (e) cargo bike	3 min	7 min
Walking time to access shared (e) car	7 min	10 min

Choice Set A1	 Shared (e) bike	 Shared (e) scooter	 Shared (e) cargo bike	 Shared (e) car
Cost per minute	0.10 euro	0.20 euro	0.40 euro	0.70 euro
Walking Time to shared modes	3 min	3 min	3 min	7 min

1) Shared (e) bike 2) Shared (e) scooter 3) Shared (e) cargo bike 4) Shared (e) car 5) I would not travel with these shared

Fig. 2. Example of giving a choice set to respondents in the survey.

We tested the impacts of socioeconomic indicators on car and shared mode use in Delft City Centre, following age, gender, and family status. Below, we provide an overview of our main findings.

4.1.1. Experience of using private cars and its reasons

As shown in Table 2, considering 93% of respondents have a driving license, and 70% have a private or lease car, resulting in significant weekly car use (79%) in Delft city centre, 64% by 1–3 days per week and 15% by four days per week or more. The main reasons are long trips (76%), carrying a heavy, big or numerous bag (65%), and rainy/ cold weather (34%) respectively in all age groups.

The data indicated that 57.7% of individuals over 40 used a car 1–3 days per week. Among all age groups, daily car usage (4 or more days per week) was highest among those aged 50–59 (7.2%). Factors such as adverse weather, heavy or numerous bags, and long trips were significant reasons for car use among individuals aged 40–69. Regarding gender, 43% of men drive weekly compared to 34% of women. Both men (57%) and women (41%) primarily drive for long trips and heavy bags. More than half the female population always uses cars, but 33% of the total use is for males. Without a car, 11.5% of women and 13.5% of men use trains or bikes, and 1.9% of men use shared cars. In addition, the findings showed that 85% of singles and families with teenagers use a car weekly. However, families with children under 12 use a car monthly (27.3%).

4.1.2. Experience of using shared modes and its reasons

The survey revealed that most have never used shared modes: shared cargo bike (97%), shared car (79%), shared scooter (77%), and shared bike (66%), respectively. Although 57% are not interested or unsure about using shared modes to travel to a destination outside the city centre, 44% would use them occasionally (35%) or frequently (9%), primarily single men. Families with children (64.3%), especially those under 12 (35.7%), show higher interest, whereas older adults over 50 (46.6%) are the primary opponents. On the other hand, younger users (aged 18–29) are more open to occasional use. They also declared they are willing to walk up to 5 min to access these modes (bike 27%; scooter 22%; cargo bike 18%; and car 25%). Fig. 4 shows the familiarity and experience of Delft's inner-city residents with shared mobility modes.

Shared bike: Despite 66% of residents never using shared bikes, 14% have tried once or twice. The shared bike is mainly used annually (15%), with the highest usage among those aged 25–29. However, those aged 30–39 years often used this mode four days/week or more. Looking at the family status and gender of dominant users shows that single and families with children are the primary users, with men more experienced than women. Regarding the max walking time, users under 40 prefer to walk 5 min, while those over 40 prefer a 2-minute walk to reach a shared bike. Moreover, men are willing to walk longer distances than women to reach shared bikes.

Shared scooter: Unlike shared bikes, shared scooters have been mainly used monthly (7.1%). Young individuals aged 18–29 years used

it at least once per week. Data shows that shared scooters are more attractive for singles, families with kids under 12 years old, and males, respectively. Female over 40 are more willing to walk 5 min to access shared scooters, while younger men users prefer a 2-minute walk.

Shared car: Considering 79% of residents of Delft City Centre have never used a shared car, while 9% have tried it once or twice. Interest decreases among 18–40 years old and increases for those over 40. In addition, families with teenagers and singles use shared cars weekly (28.6%) and yearly (14.6%), respectively. Most users are willing to walk up to 5 min (25%), primarily men (13.8%), with some willing to walk 10 min (23%), mainly women over 40.

Shared cargo bike: Shared cargo bike has the lowest usage, with 97% of residents having never used them. The few users are mainly single men aged 25–29 (1.4%)—no families with children reported using shared cargo bikes. Interest in accessing shared cargo bikes decreases with age, with most men willing to walk up to 5 min.

4.1.3. Observed mode shares from the survey

Table 4 presents the observed shares of travel modes based on the stated choice survey responses. The results show that most respondents (64%) selected the “opt-out” option, indicating a strong tendency to abstain from shared mobility use under the given conditions. Among shared modes, shared e-scooters (12%) and shared bikes (12%) were the most frequently chosen, while shared e-cars (10%) and particularly shared e-cargo bikes (1%) were selected far less often.

These findings suggest that while there is noticeable interest in lightweight shared mobility options, significant barriers remain, particularly related to cost, access, and convenience, that may limit their attractiveness compared to existing transport modes. The high share of opt-out choices indicates that, for many respondents and recalled trip contexts, the presented shared-mode options (given their price and access distance) were not considered acceptable substitutes.

4.1.4. Socio-demographic profile of opt-outs

Identifying the socio-demographic characteristics of individuals who opt out of shared mobility is crucial for understanding resistance to the car-free transitions. Fig. 5 shows socio-demographic profile of optouts including gender, age, education, income, trip purpose, willingness to use shared modes and interaction of age with income and education.

To support interpretation of the opt-out alternative, we first examine how ‘opt-out’ selections relate to respondents’ mobility context. As the stated choice task asked respondents to substitute a specific recalled trip, a high opt-out share does not necessarily imply opposition to shared mobility in general but may reflect limited substitutability for particular trip–mode combinations.

Descriptively, opt-out choices were more frequent among respondents who reported access to a private car and among trips originally made by car, whereas respondents without car access showed a higher propensity to select at least one shared mode. This pattern suggests that the opt-out often reflects trip-specific feasibility rather than

Table 2
Sample statistics with different socioeconomic variables.

Socio-economic variable	Category	Share sample	Category	Delft population
Age	18–39	22%	15–25	20%
	40–49	12%	25–45	31%
	50–69	43%	45–65	20%
	70≤	21%	65≤	16%
Gender	Male	56%	Male	53%
	Female	42%	Female	47%
Family status	Single	30%	Single	59%
	Households with at least two adults	57%	Multi-person households	41%
	Household with 1 ≤ children the age 12 years old or younger	10%	Multi-person households without children	21%
	Household with 1 ≤ children with the age of 13 up to 17 years old	5%	Multi-person households with children	20%
Hiving children	Yes	55%	—	—
	No	44%	—	—
Number of children	12–4	23%	—	—
		77%	—	—
Education level	Less formally educated (under HAVO and VWO)	11%	Practical education level	18%
	Moderately educated (HBO / WO (Bachelor's degree)	30%	Secondary education level	35%
	Highly educated (HBO / WO Master's or doctoral degree)	57%	Theoretical education level	47%
	Less than € 42,400	21%	€26,000-€28,000	9%
Income (Total family gross annual)	Between € 42,400 and € 71,000	19%	€28,000-€32,000	27%
	Between € 71,000 or more	32%	€32,000 or more	64%
Health ability	I am fully mobile (physically able)	87%	—	—
	My mobility is limited (due to age, pregnancy, etc.)	12%	—	—
Health limitation	Walking	53%	—	—
	Cycling	59%	—	—
	Driving	24%	—	—
	Travelling by public transport	12%	—	—
Having driving license	YesNo	93%5%	YesNo	74%26%
Having car (private or lease)	YesNo	70%30%	YesNo	69%31%
Average Use of car	Daily or weeklyMonthly	79%21%	—	—
Reasons for using car	Rainy/cold weather	34%	—	—
	If I have a heavy, big and a lot of bags (s)	65%	—	—
	When I travel with people who are old and/or children	33%	—	—
	When I have a long trip	76%	—	—
	Always	7%	—	—
	Never	4%	—	—
	Other	14%	—	—

Table 2 (continued)

Socio-economic variable	Category	Share sample	Category	Delft population
Willing to use shared modes	Yes, for the most trips	8%	—	—
	Yes, occasionally	35%	—	—
	No	57%	—	—

categorical rejection of shared mobility.

Opt-out behaviour is strongly conditioned by the trip being reconsidered and by mobility resources. Table 5 shows that respondents recalling a car-based trip opted out of the shared alternatives in 74.7% of their choices, more than double the 32.1% rate among those recalling a public-transport trip; active-mode trips fell in between (62.7%). Car owners opted out far more often than non-owners (72.3% vs. 44.7%) (Table 6). These patterns indicate that a high opt-out share does not reflect categorical opposition to shared mobility but rather limited substitutability for specific trip-mode combinations—above all, the substitution of a private-car trip. This trip-conditional reading reframes the opt-out as a diagnostic of where and for whom shared modes are not yet acceptable, rather than as blanket resistance.

Age is the most decisive factor: 84% of opt-outs are aged 50 or above, strongly highlighting a generational reluctance to embrace shared modes. This age effect is reinforced by the distribution of education and income across age groups. Older cohorts, particularly those between 60–79 years, not only dominate the opt-out group but also hold higher educational qualifications, with many possessing a master's degree or above. At the same time, these age groups are disproportionately represented in the upper income brackets (€72,000–84,000 and above €84,000), underlining that disengagement is primarily concentrated among financially secure and highly educated older individuals.

Furthermore, opting out is concentrated among highly educated and financially secure individuals, suggesting reluctance is not driven by financial constraints or lack of awareness. Specifically, 52% of opt-outs hold a master's degree or above, and over one-third earn above €84,000 annually, with these older cohorts being disproportionately represented in the highest income brackets (€72,000–€84,000 and above €84,000). Regarding trip characteristics, opt-outs are slightly more likely to be male (56%). The “opt-out” decision is most common for recreational travel (42%), followed by work or education and shopping or personal care (25%).

Attitudinal data reinforce the resistance, as nearly four in five respondents (79%) reject shared mobility outright, while only 2% are willing to adopt it for all trips. Fig. 6 shows shared modes experience of opt-outs, with most reporting rare use and very few using them often.

Overall, individuals opting out are best described as older, higher income, highly educated, and firmly committed to private mobility. Their higher propensity to opt out is consistent with several plausible barriers—such as digital access, perceived comfort/safety, physical effort, and established travel routines—which cannot be fully disentangled in the present design and should be investigated further using attitudinal measures or revealed behaviour.

5. Choice modelling results

This section presents and interprets the results of the discrete choice modelling analysis and explains how the estimated parameters provide insight into residents' preferences for shared mobility in a car-free context. We first report the outcomes of the Mixed Logit (ML) model, which was estimated using the stated choice data described in Section 4. The models focus on service attributes (price and access distance), and respondent characteristics, while treating the recalled trip as the behavioural reference point rather than modelling its full set of characteristics. This reflects the study's exploratory objective: to examine

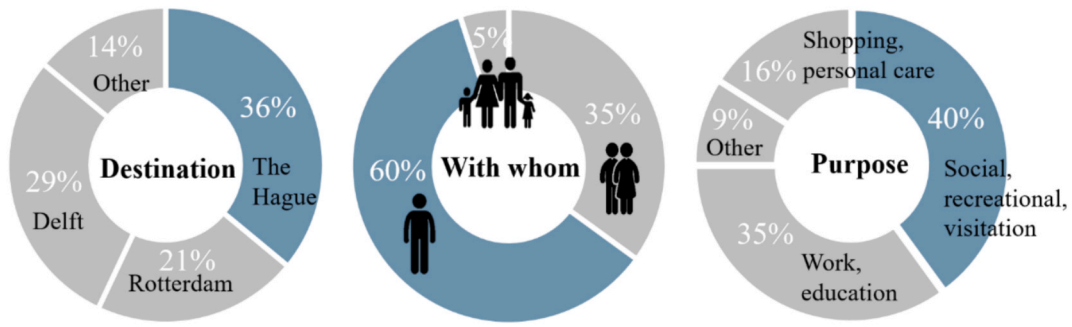


Fig. 3. Current journey characteristics of the survey respondents (n = 138).

Table 3

Original mode of the recalled trip (n = 138).

Original mode of recalled trip	Respondents	Share
Car (driver)	43	31.2%
Car (passenger/other car)	9	6.5
Bicycle	21	15.2%
E-bike	14	10.1%
Walk	32	23.2%
Other private	5	3.6%
Public transport	14	10.1%
Total	138	100%

conditional willingness to substitute a recently made trip under shared-mobility scenarios, rather than to predict mode choice for all trip types. As discussed later, trip-specific factors such as original mode and vehicle access are therefore examined descriptively to support interpretation of the opt-out alternative.

As a robustness check, car ownership was included as an additional interaction variable to capture the influence of private vehicle access on substitution behaviour. The results suggest that car ownership slightly increases the likelihood of selecting the opt-out alternative, indicating a lower propensity among car owners to consider shared mobility substitutions. However, the inclusion of this variable did not materially affect the estimated coefficients of the core attributes (travel cost and walking time) or alter the overall behavioural patterns observed in the baseline model. Furthermore, most interaction effects involving car ownership were not statistically significant, and the extended model exhibited a marginally weaker overall fit compared to the more parsimonious specification. For these reasons, the final model specification includes both the main effects, a comprehensive set of socio-demographic interactions, and trip purposes to capture observed and unobserved heterogeneity in mode choice behaviour.

We estimated a further specification adding the prior trip mode (car-based vs. non-car recalled trip) as an interaction on the opt-out

alternative, alongside car ownership. The interaction is signed as expected, a car-based recalled trip increases the opt-out propensity, consistent with the descriptive gap in Table 5, but it does not significantly improve fit (likelihood-ratio test below the $\chi^2(1) = 3.84$ threshold at 5%) and leaves the travel-cost and walking-time parameters essentially unchanged. Because prior mode is a respondent-level attribute strongly collinear with car ownership and age, it is only weakly identified in a sample of 138 respondents and costs degrees of freedom without altering the substantive findings. We therefore retain the parsimonious specification as the main model and report this as a robustness check. Notably, the reduction in the random-parameter standard deviations when trip- and ownership-related terms are added indicates that part of the unobserved heterogeneity originates in the characteristics of the trips and modes being substituted, not in person-level demographics alone, a point we treat as a substantive finding and a motivation for the trip-enriched designs recommended in the discussion and future-research section.

The model fit indicators (LL = -514.2, Adj. $\rho^2 = 0.593$, AIC = 1084.4) demonstrate that incorporating socio-demographic factors substantially enhances the explanatory power of the model. Moreover, the Mixed Logit (ML) specification significantly outperforms the

Table 4

Observed mode shares from the stated choice survey.

Alternatives	Observations (count)	Average Probability from MXL model
Shared (e) bike	100	0.120 (12%)
Shared (e) scooter sharing	103	0.124 (12%)
Shared (e) cargo bike sharing	10	0.012 (1%)
Shared (e) car sharing	84	0.101 (10%)
Opt-out	531	0.641 (64%)

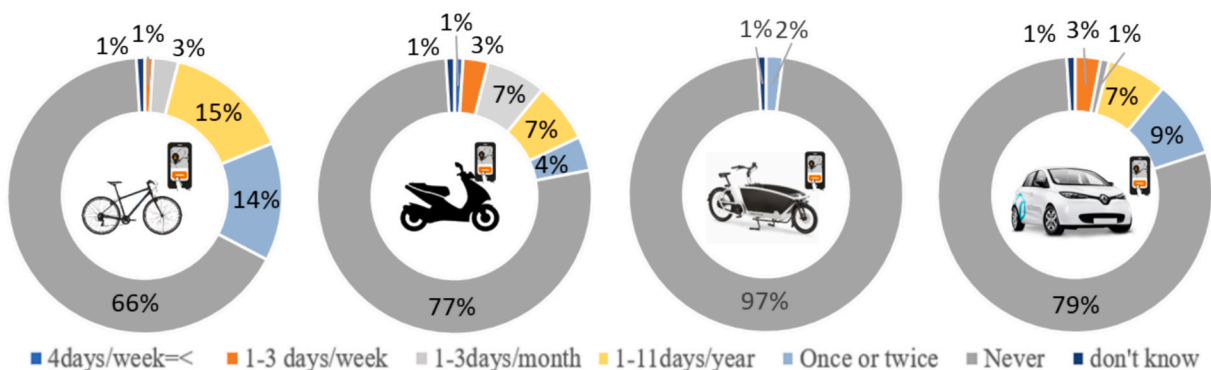


Fig. 4. Experience of using shared modes of Delft inner city residents.

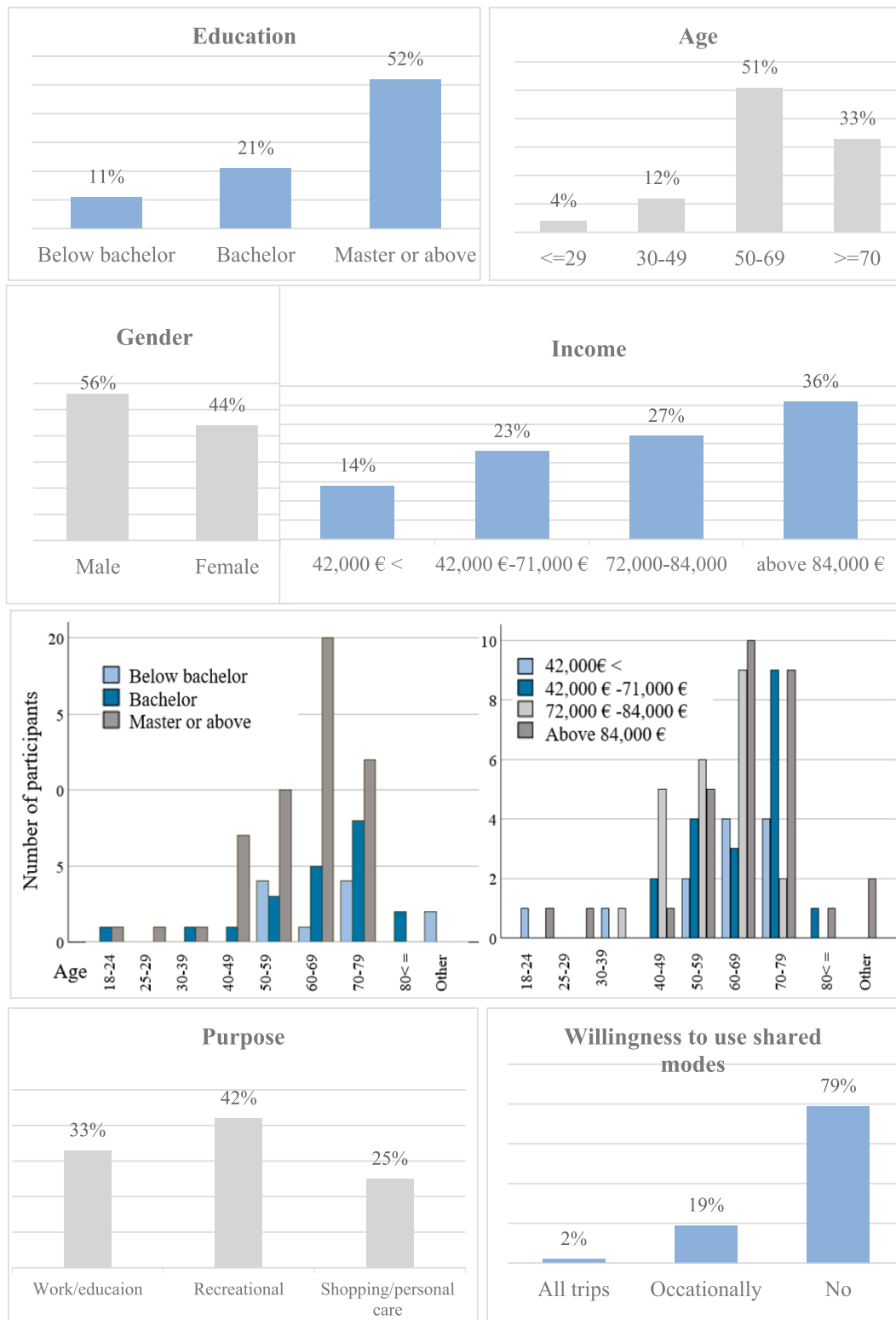


Fig. 5. Socio-demographic and behavioural patterns of opt-outs.

standard Multinomial Logit (MNL) model (LL = -898.3, Adj. $\rho^2 = 0.452$, AIC = 1461.7), underscoring the importance of accounting for taste heterogeneity. Together, these results confirm that capturing both observed and unobserved heterogeneity yields a more accurate and behaviourally realistic representation of shared-mobility choices. Table 7 presents the parameter estimates of the Multinomial Logit (MNL) model, showing the main effects of travel cost, walking time, trip

purposes, and socio-demographic factors on shared mobility mode choice.

5.1. Mixed Logit model results

In this section, we discuss the findings of Mixed Logit model, (Table 8). The inclusion of socio-economic variables and trip purposes

Table 5

Opt-out rate by the original mode of the recalled trip.

Recalled trip category	Respondents	Opt-out rate
Car-based (driver / passenger)	52	74.7%
Active / other (bike, e-bike, walk)	72	62.7%
Public transport	14	32.1%

Note: “Car-based” combines car driver (43) and car passenger (9); “Active / other” combines bicycle (21), e-bike (14), walking (32), and other private non-car, non-PT trips (5). Categories correspond to those in Table 3.

Table 6

Opt-out rate by household car ownership.

Recalled trip category	Respondents	Opt-out rate
Owns or leases a car	97	72.3%
No car	41	44.7%

substantially enriches the explanatory capacity of the model, highlighting systematic differences in mode choice preferences across age, gender, trip purpose, education and income.

The choice model results reveal several important dynamics shaping residents’ preferences for shared mobility in car-free contexts. The alternative-specific constants provide an initial indication of underlying preferences once socio-demographic heterogeneity is accounted for. Scooter sharing shows a positive and statistically significant constant (Estimate = 3.51, $t = 2.95$) suggesting a general baseline preference for this mode. In contrast, both cargo-bike sharing (Estimate = −13.41, $t = -2.34$) and car sharing (Estimate = −12.30, $t = -2.42$) show strongly negative and significant constant, indicating that these options are inherently less attractive to many respondents, even after controlling for observed heterogeneity. The negative constant for the “opt-out” alternative (Estimate = −6.24, $t = -4.63$) further suggests that socio-demographic factors reduce the baseline inclination to abstain from shared mobility, although specific groups still display strong avoidance tendencies. Mode-specific results for the shared cargo bike should be interpreted with caution, as this alternative was selected in only 10 of the 828 choice observations; the corresponding estimates therefore rest on a small cell and are reported as indicative rather than robust.

The core attributes—travel cost and walking time—play a central role in shaping mode choice. Both variables are negative and highly significant, cost (Estimate = −6.97, $t = -5.45$) and walking time (Estimate = −1.43, $t = -12.10$), confirming that monetary and physical access costs are major barriers to adoption. Accessibility is particularly critical: even a one-minute increase in walking time considerably lowers the probability of selecting a shared mode. The estimated Value of Time (VoT), approximately €0.20 per minute of walking ($\approx$ €12/h), indicates that users perceive access distance as a tangible burden, comparable to direct financial costs. Comparable studies report values of short-distance

non-business travel time between approximately €6 and €11 per hour (Wardman et al., 2016), which positions our VoT estimate toward the upper, yet still empirically plausible, end of the range. Therefore, although the estimated VoT appears relatively high, it remains consistent with evidence suggesting that users attach a non-trivial disutility to walking time when accessing shared mobility systems. However, the significant standard deviations (SD) associated with both attributes (travel cost; $\sigma = 2.18$, $t = -14.54$ and walking time; $\sigma = 0.39$, $t = 7.89$) demonstrate that sensitivities vary considerably across individuals. This suggests that policy measures such as fare adjustments or improved spatial accessibility will not affect all residents uniformly, but are likely to benefit certain user groups more than others.

$$VOT = \frac{\beta_{\text{walkingdistance}}}{\beta_{\text{travelcost}}} = \frac{-1.43}{-6.97} = 0.20 \text{ €/min}$$

5.2. Socio-demographic influences on shared mobility preferences

Incorporating socio-demographic variables into the model provides further insight into the sources of behavioural variation. Age emerges as a central determinant: older respondents are consistently less likely to adopt any of the shared mobility alternatives—scooter sharing (−1.43, $t = -6.07$), cargo bike sharing (−1.50, $t = -3.39$), and car sharing (−1.75, $t = -2.87$) — and more likely to choose the “opt-out” option (1.39, $t = 7.08$). This pattern reflects a combination of digital, physical, and attitudinal barriers that disproportionately affect older populations. Gender also contributes to differentiated preferences, with men expressing stronger preferences for scooter sharing (0.783, $t = 3.96$) and a slightly higher likelihood of opting out (0.635, $t = 3.62$), although effects for cargo bike (0.666, $t = 1.47$) and car sharing (0.984, $t = 1.69$) modes are weaker. Education introduces additional complexity: higher educational attainment increases the likelihood of selecting cargo-bike (2.020, $t = 2.09$), and carsharing (1.907, $t = 2.04$) services, while also slightly raising the probability of choosing the “opt-out” (0.420, $t = 1.84$) alternative. Income shows a similar trend, with higher-income respondents more inclined toward premium or higher-value shared services such as cargo bikes (0.477, $t = 1.80$) and car sharing (0.830, $t = 2.45$), and somewhat more prone to abstain from using shared modes altogether (0.180, $t = 1.97$).

Trip purpose further moderates these patterns. Shared modes appear less attractive for work and education trips, which likely reflects concerns about reliability and time sensitivity. For commuting purposes, respondents exhibit a greater tendency to avoid shared mobility options (0.477, $t = 2.43$), reinforcing the notion that shared modes are currently perceived as more suitable for discretionary or flexible travel than for daily structured routines.

While vehicle access is not explicitly interacted within the Mixed Logit specification due to sample size constraints, supplementary descriptive checks indicate that substitution willingness varies

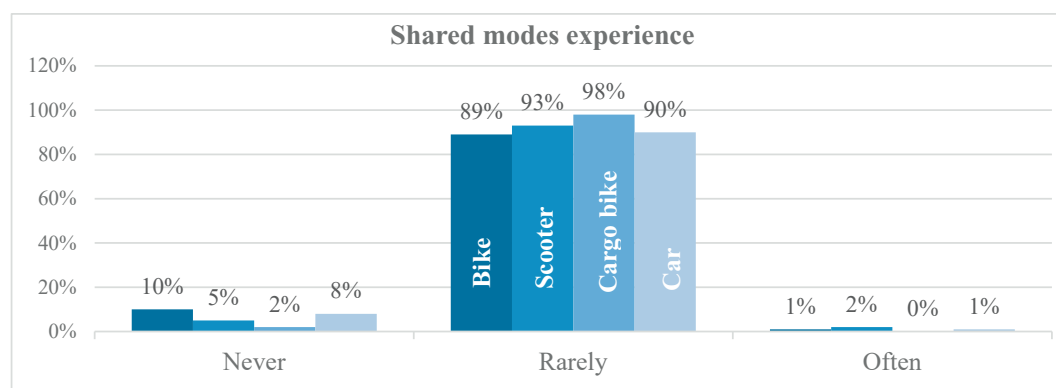
**Fig. 6.** Shared modes experience of opt-outs.

Table 7

The parameter estimates of the MNL model.

Main effects	MNL Model + Socio-demographic	
	Estimate	t-value
ASC Shared (e) bike	0	(Fixed)
ASC Shared (e) scooter	3.69 **	3.82
ASC Shared (e) cargobike	− 10.8 **	− 2.18
ASC Shared (e) car	− 2.81 **	− 2.25
ASC “opt-out”	− 4.52 **	− 5.14
Travel cost	− 0.577	0.91
Walking time	− 0.049	0.96
Socio-economic variables	Estimate	t-value
Age- Shared (e) scooter	− 0.893 **	− 4.76
Age- Shared (e) cargo bike	− 0.772 **	− 2.02
Age- Shared (e) car	− 0.013	− 0.08
Age “opt-out”	1.01 **	7.05
Male- Shared (e) scooter	0.728 **	4.42
Male- Shared (e) cargo bike	0.765 **	2.06
Male- Shared (e) car	0.425 **	2.75
Male- “opt-out”	0.415 **	3.43
Education – Shared (e) scooter	− 0.214	− 1.28
Education – Shared (e) cargo bike	1.47 *	1.78
Education – Shared (e) car	0.426 **	2.14
Education – “opt-out”	0.414 **	2.99
Income – Shared (e) scooter	− 0.206 **	− 2.44
Income – Shared (e) cargo bike	0.292	1.31
Income – Shared (e) car	0.199 **	2.22
Income – “opt-out”	0.223 **	3.28
Trip purpose for work/ education- Shared (e) scooter	− 0.81	
Trip purpose for work/ education- Shared (e) cargo bike	0.146	
Trip purpose for work/ education- Shared (e) car	− 1.01	− 1.84
Trip purpose for work/ education- “opt-out”	0.165	0.95
Trip purpose for work/ education- “opt-out”	0.365	2.60
Model fit		
Number of estimated parameters (k)		26
Number of observations (n)		828
Initial log-likelihood		− 1332.615
Final log-likelihood		− 898.336
R2		0.471
Adjusted R2		0.452
likelihood-ratio test		1255.561
AIC		1461.7
BIC		1584.4

** $p \leq 0.05$,* $p \leq 0.1$.

systematically across these dimensions. Respondents with access to a private car and those recalling car-based trips were more likely to select the opt-out, reinforcing the interpretation that substitution feasibility depends on prior mobility conditions rather than uniform resistance to shared mobility.

Overall, these results highlight that shared mobility adoption is shaped by a complex interplay of cost sensitivities, accessibility constraints, and socio-demographic characteristics. The strong heterogeneity observed across the sample underscores that mobility transitions cannot be understood solely through average effects. Instead, policy design must recognise that user groups differ markedly in their constraints, motivations, and behavioural thresholds. As cities move toward car-free or low-car strategies, understanding these differentiated patterns becomes essential for designing interventions that are both effective and equitable.

Table 8

The parameter estimates of the MXL model.

Main effects	ML Model + Socio-demographic	
	Estimate	t-value
ASC Shared (e) bike	0	(Fixed)
ASC Shared (e) scooter	3.51 **	2.95
ASC Shared (e) cargobike	− 13.41 **	− 2.34
ASC Shared (e) car	− 12.30 **	− 2.42
ASC “opt-out”	− 6.24 **	− 4.63
Random parameters		
Travel cost	− 6.97 **	− 5.45
Walking time	− 1.43 **	− 12.10
Random parameter standard deviations		
SD Travel cost	2.18 **	− 14.54
SD Walking time	0.39 **	7.89
Socio-economic variables	Estimate	t-value
Age- Shared (e) scooter	− 1.43 **	− 6.07
Age- Shared (e) cargo bike	− 1.50 **	− 3.39
Age- Shared (e) car	− 1.75 **	− 2.87
Age “opt-out”	1.39 **	
Male- Shared (e) scooter	0.783 **	3.96
Male- Shared (e) cargo bike	0.666	1.47
Male- Shared (e) car	0.984	1.69
Male “opt-out”	0.635 **	3.62
Education- Shared (e) scooter	− 0.020	− 0.09
Education- Shared (e) cargo bike	2.020 **	2.09
Education- Shared (e) car	1.907 **	2.04
Education – “opt-out”	0.420 *	1.84
Income- Shared (e) scooter	− 0.158	− 1.57
Income- Shared (e) cargo bike	0.477 *	1.80
Income- Shared (e) car	0.830 **	2.45
Income – “opt-out”	0.180 **	1.97
Trip purpose for work/ education- Shared (e) scooter	0.088	0.40
Trip purpose for work/ education- Shared (e) cargo bike	− 1.01	1.61
Trip purpose for work/ education- Shared (e) car	0.988	1.60
Trip purpose for work/ education- “opt-out”	0.477 **	2.43
Model fit		
Number of draws	1500	
Number of estimated parameters (k)	28	
Number of observations (n)		828
Initial log-likelihood		− 1324.6
LL (0) (equal shares)		− 1332.61
Final log-likelihood		− 514.19
R2		0.6142
Adjusted R2		0.5931
likelihood-ratio test		1636.84
AIC		1084.37
BIC		1216.51

** $p \leq 0.05$,* $p \leq 0.1$.

6. Conclusions, discussion and policy implications

6.1. Main conclusion

This study examined under what conditions inner-city residents in Delft consider shared electric mobility to be an acceptable substitute for a recently made trip, during an ongoing transition toward a private car-free centre. Using a stated choice experiment with an opt-out alternative and Mixed Logit models, we identify how price, access distance, and

socio-demographic heterogeneity shape acceptance of shared-mode substitution scenarios.

While core attributes like travel cost and walking time are critical (resulting in a high Value of Time for walking, €0.20 per minute), the model results confirm a strong propensity toward non-participation, particularly among certain demographic groups. Although the descriptive survey data showed that 64% of respondents opted out of shared modes, the Mixed Logit model further reveals that this tendency is statistically associated with age-related and socio-economic factors. Older (50 +), affluent, and highly educated residents exhibit a significantly higher likelihood of choosing the “opt-out”. For these older, more affluent, and more highly educated residents, opting out is not primarily financial; instead, it is closely tied to car access and use. Residents with a car in the household opted out far more often than those without (72.3% versus 44.7%; [Table 6](#)), and respondents reconsidering a car-based trip opted out in 74.7% of cases ([Table 5](#)). This suggests that, for these groups, choosing the opt-out reflects established car ownership and habitual car use—and the digital, physical, or attitudinal barriers associated with them—rather than a purely financial constraint. This pattern underscores that car-free zone policies cannot treat all residents uniformly but must address the distinct needs of car-dependent groups showing behavioural resistance. Moreover, the results demonstrate substantial preference heterogeneity across the population. Individuals differ widely in their sensitivity to both cost and walking time, suggesting that interventions such as fare reductions, improved spatial accessibility or service redesign will not have uniform effects. Socio-demographic variables, particularly age, emerge as strong determinants of shared mobility adaption. Younger residents show greater openness, likely due to digital familiarity and flexibility in travel routines, whereas older users remain hesitant. Gender, education, and income also play differentiating roles: men show stronger preferences for scooter sharing, and individuals with higher educational attainment or income are more inclined to adopt premium shared services such as cargo-bike or car sharing. Trip purpose further shapes behaviour: shared modes are notably less favoured for commuting, where time reliability is crucial.

Although this study is grounded in Delft urban context, the behavioural mechanisms it uncovers are broadly relevant to other cities pursuing car-free or low-car strategies. The socio-demographic patterns—particularly the reluctance among older, higher-income, and digitally less-engaged residents—are consistent with international research, suggesting that similar barriers will likely emerge elsewhere. The findings therefore offer a generalisable set of insights: cities should anticipate substantial demand segmentation, recognise that shared mobility is not equally attractive across demographic groups, and ensure that car-free transitions are supported by targeted interventions addressing accessibility and behavioural acceptance. In this sense, while local conditions may vary, the observed behavioural dynamics provide transferable guidance for urban mobility planners aiming to foster equitable and effective car-free environments.

6.2. Discussion on study limitation and future research directions

The study has several limitations that should be acknowledged. First, recruitment was primarily conducted through the municipality’s Facebook and Instagram channels, which likely over represent digitally connected and civically engaged residents. While these platforms are widely used, they may introduce potential selection bias and reduce external validity, particularly for residents with low digital literacy or limited online presence. Future studies should use stratified sampling or multiple recruitment channels (e.g., local community groups, offline events, random household sampling) to enhance representativeness.

Our design measured revealed recent behaviour (the original mode of the recalled trip and household mobility resources) but did not collect attitudinal constructs (perceived safety, trust, social norms), fine-grained built-environment measures, or the recalled trip’s distance

and travel time as continuous variables. This was a deliberate trade-off to keep the instrument short for a difficult-to-recruit inner-city resident sample, but it means habitual and attitudinal mechanisms are only partially observed. The systematic association we find between prior car use and opt-out is consistent with a habit or car-dependence interpretation, but disentangling habit from attitude—and quantifying the role of trip length and time—requires hybrid choice / latent-variable models and richer trip data, which we recommend for future revealed-preference work. Relatedly, because trip- and mode-related characteristics were treated as the behavioural reference point rather than modelled explicitly, part of the unobserved heterogeneity captured by the random-parameter standard deviations likely reflects variation in the trips and original modes being substituted, not person-level demography alone.

Second, the stated preference experiment offers controlled causal inference but does not fully reflect the actual market conditions or real-world availability of shared modes. Importantly, the experiment was not calibrated against the actual share of private car trips that could realistically be replaced by shared modes. Future research should incorporate revealed preference data—e.g., through smart-card logs, app-based trip histories, or before-after field trials—to validate the predictive accuracy of stated preferences.

Third, while our model accounts for heterogeneity through random coefficients, psychological constructs such as perceived safety, social influence, and trust in shared systems were not directly measured. These attributes have been shown to influence zero-ownership mobility adoption and could refine behavioural segmentation. Future research should therefore integrate attitudinal latent factors through hybrid choice modelling or structural equation approaches.

Finally, the study focuses on inner-city residents, meaning that the findings do not necessarily generalise to suburban areas or commuters traveling from outside Delft. Future work could compare spatial groups explicitly to understand whether access distance, mode reliability, and sociotechnical acceptance differ between urban neighborhoods and regional commuters.

Taken together, these limitations do not undermine the validity of the present findings, but they do highlight important avenues for extending the analysis. Incorporating revealed behaviour, psychological dimensions, and spatial heterogeneity could substantially improve the ability to forecast behavioural change under future mobility scenarios.

6.3. Policy implications

The findings of the Mixed Logit model on preference heterogeneity and the high rate of avoidance behaviour led to four targeted, scientifically grounded policy implications for cities implementing car-free zones.

1 Engage and familiarise the opt-out group for inclusion

From a policy perspective, the opt-out alternative should be interpreted cautiously. Rather than solely indicating a rejection of car-free policies or a willingness to forgo activities, it may reflect situations where the offered shared mobility options are not perceived as adequate substitutes for a specific trip, as well as a lack of interest, habitual preferences, or attitudinal resistance toward shared mobility. This distinction is critical: a high opt-out share can signal gaps in service design, coverage, or trip compatibility, but may also indicate deeper behavioural or perceptual barriers to adoption. Accordingly, the opt-out provides diagnostic insight into where shared mobility requires complementary measures, such as improved public transport, enhanced cycling infrastructure, targeted incentives, or awareness and engagement strategies.

2 Prioritize micro-accessibility to reduce access effort

Our results show that even small increases in access distance significantly reduce adoption; therefore, providing vehicles closer to

users—rather than at scattered stand-alone hubs—can lower this access effort. Policy should focus on establishing a sufficiently dense and spatially distributed network of physical pick-up and return locations within short walking time of residences, workplaces, and transit nodes. This does not aim to replace walking as an activity, but rather to ensure that when shared modes are chosen, they can be accessed without long detours or unreliable availability. Improving proximity and availability increases the utility of shared modes, particularly for users who currently avoid them due to low predictability or long access distances.

3 Target engagement using the observed opt-out gradients.

Our estimates show that older residents (50 +), car owners, and those reconsidering a car trip are markedly more likely to opt out. These gradients identify which groups any engagement or communication effort should prioritise. We note explicitly that our data do not test whether messaging changes behaviour; the content and effectiveness of such engagement (e.g., emphasising reliability and comfort for older residents) is offered as a hypothesis for attitudinal follow-up research rather than a tested finding.

4 Design for access among high-opt-out groups.

The one design implication our results support directly is reducing access effort: the large, significant walking-time disutility (VoT $\approx$ €0.20/min) implies that dense, reliable, close-proximity fleet placement—and non-digital access/booking options for groups with low digital engagement and high opt-out—would most plausibly raise acceptance. We refrain from broader inclusive-design prescriptions that the data cannot adjudicate.

By directly addressing the attitudinal and generational barriers identified in this study, cities can move beyond purely infrastructural solutions and foster genuine behavioural inclusion. Combining improved service reliability, targeted engagement, and visible environmental progress will be essential to converting potential opt-outs into active participants in an evolving, car-free urban mobility system. Future work should explicitly integrate trip characteristics and mobility holdings within larger samples, enabling stronger causal inference regarding substitution across trip types.

CRediT authorship contribution statement

Fatemeh Torabi Kachousangi: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yashar Araghi:** Writing – review & editing, Validation, Supervision, Software, Methodology, Data curation. **Sascha Hoogendoorn-Lanser:** Project administration, Conceptualization. **Niels van Oort:** Writing – review & editing, Supervision, Project administration, Conceptualization. **Serge Hoogendoorn:** Writing – review & editing, Supervision, 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.

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Data availability

Data will be made available on request.

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