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# Bike-sharing, car-sharing, e-scooters, and Uber: Who are the shared mobility users and where do they live?

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ABSTRACT

This research provides new evidence on factors associated with the use of four different shared mobility options – bike-sharing, e-scooter sharing, car-sharing, and ridehailing (Uber) – in the same urban region. Factors examined are sociodemographic characteristics, concern about climate change, access to a private car, and built environment characteristics of users' residential locations. The analyses are based on survey and GIS-measured, individual-level geospatial data from Oslo and its surrounding Viken county in Norway. Findings suggest that *bike-sharing* users are more likely to be younger, men, single, concerned about climate change, and living in denser neighborhoods with good access to public transport. *E-scooter sharing* users are more likely to be younger, men, without disabilities, and less educated, and live in denser neighborhoods. *Car-sharing* users are more likely to be living with a partner or spouse and children, not have access to a private car, and live in transit-oriented neighborhoods. *Uber* users are more likely to be younger and less educated, have higher incomes, be less worried about climate change, and live in proximity to the city center. These outcomes offer input for critical issues of urban and transport planning including compact urban form, sustainable mobility, and transport equity.

## 1. Introduction

The shared use of travel modes, in other words "shared mobility", has been developing rapidly during the last years. Shared mobility "enables users to gain short-term access to transportation modes on an as-needed basis" (Shaheen et al., 2016, p. 77). The rise of shared mobility can be attributed to two main factors. First, developments in information and communication technologies (ICT) have enabled the easy use of shared mobility options through smartphones and mobile apps (Gössling, 2018). Second, the search for environmentally friendly mobility and better accessibility has led the transport industry, including start-ups, to seek alternative, complementary mobility solutions in cities (Battarra et al., 2018). The growth of shared mobility has brought new forms of transport to cities such as ridehailing (e.g. Uber or Lyft) and the sharing of electric scooters (e-scooters). At the same time, older forms of shared mobility have been boosted, especially bike-sharing and car-sharing. Bicycles, e-scooters, cars, and rides are usually not shared between individuals, but they are actually rented via private companies or co-operatives. Shared mobility operates either through a business-to-consumer (B2C) relationship or in a peer-to-peer form typically mediated by companies (P2P).

These developments in shared mobility and the increasing use of shared mobility solutions, particularly in cities, have triggered a rapidly increasing body of related research (see recent reviews, e.g. Eren & Uz, 2020; Ferrero et al., 2018; Kazemzadeh & Sprei, 2022; Khavarian-Garmsir et al., 2021; Liao & Correia, 2022; Mouratidis et al., 2021). Supporting shared mobility in cities is often seen as an attractive strategy for reducing environmental impacts of transport, reducing traffic congestion, and bringing economic, equity, and well-being benefits (Miskolczi et al., 2021). Shared mobility options provide alternatives to the use of private cars and, at the same time, complement public transport (Fearnley et al., 2022; Hjorteset & Böcker, 2020). However, shared mobility often does not manage to achieve environmental and social sustainability goals. In certain cases, if not properly regulated, shared mobility options have been found to induce negative environmental outcomes (e.g. Henao & Marshall, 2019; Tirachini, 2020) and transport inequities (e.g. Uteng et al., 2020). During the coronavirus disease (COVID-19) pandemic, the use of shared mobility modes declined in many contexts (Hu et al., 2021) as did mobility in general and especially public transport (Nordbakke, 2022). However, shared mobility still played an important role in providing alternative transport solutions during the pandemic (Alonso-Almeida, 2022; Bustamante et al., 2022; Chen et al., 2022; Mouratidis, 2021), and its use is expected to grow substantially in the post-COVID-19 era (Shokouhyar et al.,

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2021).

Researchers have been examining the conditions needed for supporting shared mobility. Shared mobility systems, ICT systems, transport infrastructure, urban form, residents' sociodemographic profile, and weather conditions are some of the factors influencing the adoption and use of shared mobility options (e.g. Chibwe et al., 2021; Shokouhyar et al., 2021). Although research on the factors possibly affecting the use of different shared mobility options has been growing in recent years, more knowledge is needed from urban regions where shared mobility use is maturing. Especially studies investigating the use of multiple, diverse shared mobility options in the same urban region are scarce.

This paper addresses these needs and makes four contributions to knowledge. (1) It is the first study, as far as we are aware, to examine and compare factors associated with the use of four different shared mobility options (bike-sharing, e-scooter sharing, car-sharing, ridehailing) in the same urban region. (2) Contrary to several other studies, it draws on data from an urban region where these mobility options are maturing, and therefore examines regular use and not intentions, attitudes, or simple enrollment in shared mobility programs. This provides much-needed evidence on the actual use of four shared mobility options among urban residents. (3) It examines a wide range of variables: numerous sociodemographics including more sensitive information such as disability and income, access to a private car, attitudes towards climate change, and built environment characteristics. By including all these possibly contributing factors, the study reduces the risk of being subject to confounding problems. (4) It is one of the first studies on the use of shared mobility to include built environment data based on the exact residential address of each survey participant. Built environment variables are assessed at the individual level via geographic information systems (GIS). Such an assessment is expected to more accurately estimate the role of the residential built environment compared to neighborhood-level assessments.

The research question addressed in the study is "How do sociodemographic characteristics, climate change concern, access to a car, and the residential built environment relate to the use of bike-sharing, e-scooter sharing, car-sharing, and Uber?" The study draws on survey data and GIS-measured, individual-level geospatial data ($N = 1796$) from the city of Oslo and its surrounding region Viken in Norway. The analysis consists of descriptive statistics and binary logistic regression modeling. Oslo and Viken represent a good case for this study as all the examined shared mobility options are currently present and used by their residents. Oslo and its surrounding municipalities have been implementing a smart transport program (Project STOR: Smartere transport i Osloregionen) that focuses, among others, on shared mobility options.

The remainder of the paper is organized as follows. Section 2 presents a review of previous literature investigating the factors examined in this study (sociodemographics, environmental concern, access to a car, and built environment) in relation to bike-sharing, e-scooter sharing, car-sharing, and ridehailing. Section 3 describes the study area and data collection methods. Section 4 presents the results of the analysis, while Section 5 provides a discussion and interpretation of the results as well as concluding remarks.

## 2. Literature review

### 2.1. Bike-sharing

*Sociodemographic characteristics*: Several studies have examined how bike-sharing use differs between diverse groups of people (Eren & Uz, 2020). Young people are more willing to use bike-sharing (Ge et al., 2020; Politis et al., 2020) and are more likely to actually use bike-sharing based on evidence from several different contexts (Böcker et al., 2020; Fishman et al., 2015; Murphy & Usher, 2015; Ricci, 2015). Males generally use bike-sharing more often (Böcker et al., 2020; Fishman, 2016; Goodman & Cheshire, 2014) and for longer trips than females (Ogilvie & Goodman, 2012). A higher socioeconomic profile of medium-high income and upper-level education has also been linked to a higher probability of using bike-sharing in some urban regions (Murphy & Usher, 2015; Ogilvie & Goodman, 2012; Ricci, 2015; Rixey, 2013). Studies from the US also report that nonwhite populations are less likely to use bike-sharing (Rixey, 2013).

*Environmental concern*: Bike-sharing is probably the most environmentally friendly shared mobility option (Mouratidis et al., 2021) and is also viewed as environmentally friendly by citizens (Nikitas, 2018). The environmental benefits of bike-sharing are especially valued by people with environmental concerns (Kim et al., 2017). Intentions to use bike-sharing have been found to be higher among those with environmental concerns in studies from Brazil and China (Cerutti et al., 2019; Wang et al., 2018). However, a choice experiment from Argentina did not find any association between environmental concern and intentions to use bike-sharing (Picasso et al., 2020). Despite all this relevant research, not much evidence exists on whether the actual use of bike-sharing is linked with environmental concerns.

*Access to a car*: Few previous studies have examined the link between car ownership (or access to a car) and bike-sharing. Findings from China and Poland suggest that those who own more cars are more likely to use bike-sharing (Bieliński et al., 2019; Fishman et al., 2013).

*Built environment*: Bike-sharing is mostly used in urban centers where cycling infrastructure is well-developed, and, more precisely, in densely populated parts of cities with good public transport infrastructure and numerous facilities and services (Duran-Rodas et al., 2019; Shaheen et al., 2010; Wang & Lindsey, 2019; Zhuang et al., 2019). Research has also shown that bike-sharing use is greater when bike-sharing stations are located near public transport stops (Noland et al., 2016).

### 2.2. E-scooter sharing

*Sociodemographic characteristics*: Intentions to use as well as the actual use of e-scooters are lower among older citizens and females (Fearnley et al., 2020; Hosseinzadeh et al., 2021; Mitra & Hess, 2021; Nikiforiadis et al., 2021). Safety-related barriers to e-scooter use are more often reported among women than men (Sanders et al., 2020) and this could to some degree explain the lower use among women. Some research studies have found that shared e-scooter use is more prevalent in neighborhoods with highly educated people (Jiao & Bai, 2020). However, an association between education level and shared e-scooter use is not supported by other studies (Mitra & Hess, 2021). The presence of children in the household was also not associated with shared e-scooter use according to previous research (Sanders et al., 2020).

*Environmental concern*: Previous studies show that the main motivations for using e-scooters are time savings, recreation, and cost savings, while the hierarchy of these motivations varies across studies and seems to be context-dependent (Christoforou et al., 2021; Fearnley et al., 2020; Kopplin et al., 2021). Environmental concern does not appear to be a key driver of shared e-scooter use. Studies examining environmental impacts of e-scooters report possible negative outcomes due to travel behavior changes (replacing more environmentally friendly modes), materials and manufacturing burdens, and overnight transportation of e-scooters to established locations (Hollingsworth et al., 2019; Reck et al., 2022).

*Access to a car*: The relationship between access to a car and the use of e-scooters seems to be context-dependent. Owning a car was found to be unrelated to intentions to use shared e-scooters in previous research from Toronto, Canada (Mitra & Hess, 2021). Research from Zurich, Switzerland suggests that shared e-scooters are more often used by households without access to a car (Reck & Axhausen, 2021), while findings from Austin, Texas in the US report opposite findings: car owners were more likely to use shared e-scooters (Blazanin et al., 2022).

*Built environment*: Shared e-scooters are more prevalent in high-density urban areas and in denser, walkable, transit-oriented, and mixed-use urban neighborhoods located close to city centers (Bai & Jiao, 2020; Fearnley et al., 2020; Hosseinzadeh et al., 2021; Huo et al., 2021; Jiao & Bai, 2020; Nikiforiadis et al., 2021). This can be attributed

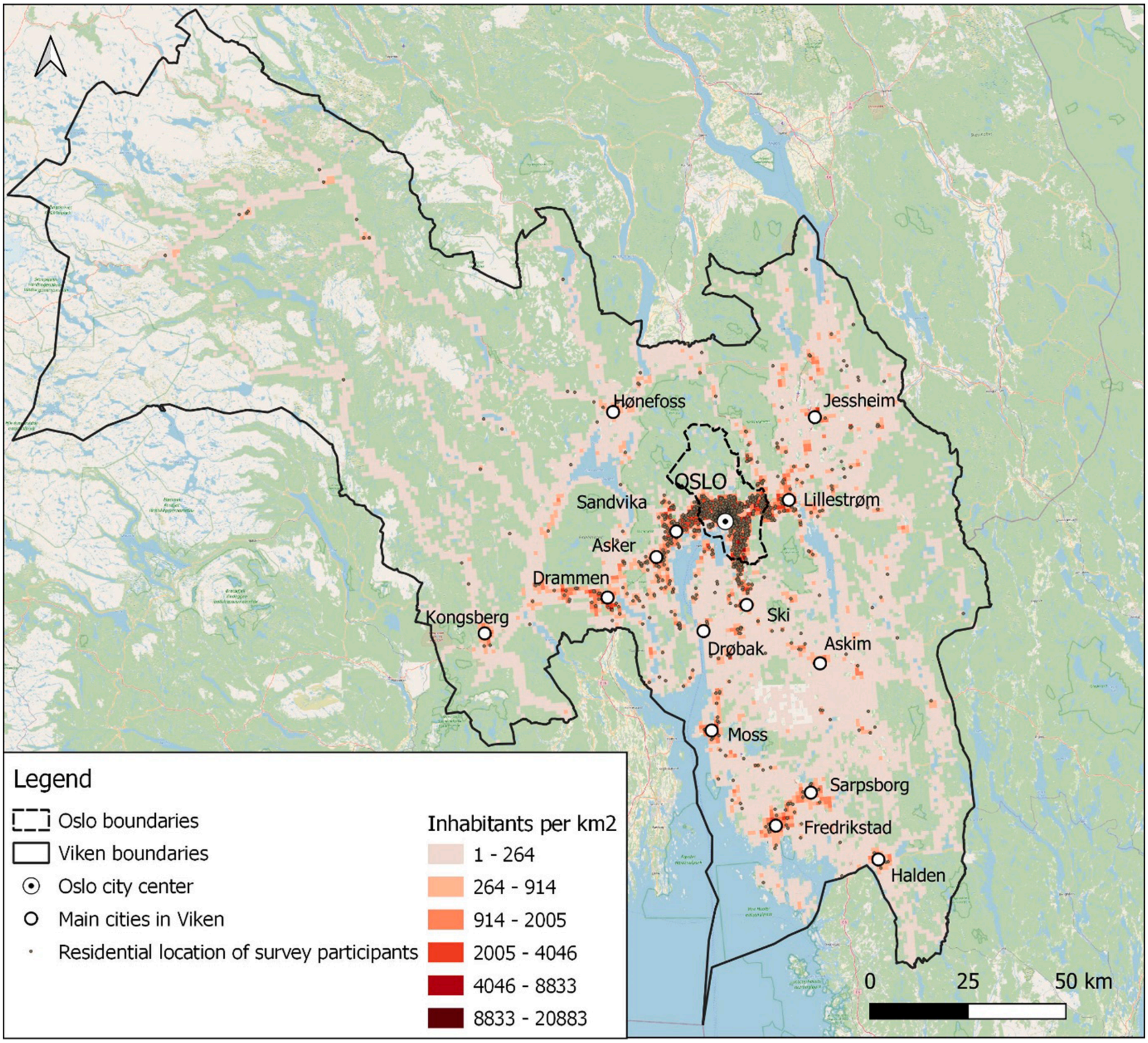


**Fig. 1.** Map of Oslo and Viken showing population densities and approximate residential locations of survey participants. *Source*: Mouratidis (2022).

to the higher fleet density in such urban neighborhoods (Reck et al., 2021).

### 2.3. Car-sharing

*Sociodemographic characteristics*: Males are more likely to use car-sharing than females (Hjorteset & Böcker, 2020; Prieto et al., 2017). Highly educated citizens are more likely to use car-sharing than citizens without tertiary education (Becker et al., 2017; Prieto et al., 2017). Young and middle-aged people use or intend to use car-sharing more than older adults (Becker et al., 2017; Efthymiou et al., 2013; Lempert et al., 2019; Prieto et al., 2017).

*Environmental concern*: Environmentally conscious citizens and those with attitudes against regular car use are more likely to be members of car-sharing schemes, according to previous findings (Becker et al., 2017; Burkhardt & Millard-Ball, 2006; Hjorteset & Böcker, 2020). Attitudes towards car-sharing were found to be more positive among environmentally conscious citizens (Acheampong & Siiba, 2020). Also, intentions to use car-sharing were higher among environmentally conscious citizens (Efthymiou et al., 2013). Other research suggests that the main motivations to use car-sharing among women are business and personal benefits (Alonso-Almeida, 2019). Findings from qualitative interviews with users however suggest that environmental sustainability is just a positive side effect but not an important driver of using car-sharing (Hartl et al., 2018). Positive associations between environmental concern and car-sharing use or attitudes could be attributed to possible positive impacts with regard to sustainable mobility (Kent, 2014; Sioui et al., 2013).

*Access to a car*: Car-sharing is more applicable to areas with lower car ownership (Celsor & Millard-Ball, 2007) and higher availability of car-sharing schemes (ter Schure et al., 2012). Previous research shows that car ownership is strongly related to car-sharing intentions and actual use. Those who do not own a car are more likely to enroll in a car-sharing scheme or to regularly use car-sharing (Hjorteset & Böcker, 2020; ter Schure et al., 2012; Ye et al., 2019).

*Built environment*: Car-sharing is more often present in denser, walkable, and transit-oriented cities and not so much in car-dependent cities (Münzel et al., 2020). Even within urban areas, car-sharing is usually found in denser and mixed-use neighborhoods that facilitate active travel and public transport (Becker et al., 2017; Hjorteset et al., 2021; Kent & Dowling, 2013; Stillwater et al., 2009). It has been suggested that car-sharing is mainly used to complement lifestyles oriented towards public transport (Becker et al., 2017). However, a study on car-sharing members in Shanghai, China suggested that those who use car-sharing for commuting are more likely to live in suburban areas where public transport is limited (Ye et al., 2019).

### 2.4. Ridehailing (e.g. Uber)

*Sociodemographic characteristics*: Younger and highly educated citizens are more likely to use ridehailing (also called ridesourcing) according to research findings from the US (Alemi et al., 2018). Other studies also from the US suggest that ridehailing can support public transport, especially in lower-income, disadvantaged or remote, low-density neighborhoods (Hall et al., 2018; Li et al., 2022; Yang et al., 2022). However, the offer of ridehailing in such neighborhoods is often limited (Khavarian-Garmsir et al., 2021) and ridehailing use has been associated with higher incomes in US studies (Dias et al., 2017). More research from other contexts is needed to assess how sociodemographic characteristics relate to ridehailing use.

*Environmental concern*: People with pro-environmental attitudes are more likely to use ridehailing in California, US (Alemi et al., 2018). This could be attributed to the green image of ridehailing (Jin et al., 2018) and arguments about the potential of ridehailing to reduce CO2 emissions (Tikoudis et al., 2021), which are however not supported by some research studies reporting negative transport-related environmental impacts of ridehailing (Erhardt et al., 2019; Henao & Marshall, 2019; Tirachini, 2020).

*Access to a car*: Findings from the US suggest that citizens who more strongly prefer owning a car are less likely to frequently use ridehailing (Alemi et al., 2019) and that those who do not own a car are more likely to use ridehailing (Conway et al., 2018; Wang et al., 2021). However, research from Chile did not find any relationship between owning a car and using ridehailing (Tirachini & del Río, 2019).

*Built environment*: People living in denser, mixed land use neighborhoods with numerous points of interest are more likely to use ridehailing (Alemi et al., 2018; Brown, 2020; Dias et al., 2017; Li et al., 2022; Li et al., 2019). Both employment and residential density in cities largely contribute to the use of ridehailing (Bi et al., 2022).

## 3. Data and methods

### 3.1. Case area

Data were collected in Oslo and Viken in Norway (Fig. 1) for the purposes of a research project focusing on new forms of urban mobility (Mouratidis & Peters, 2020). In 2022, Oslo municipality had a population of around 700,000 residents, and Viken, its surrounding region, had a population of around 1250,000 residents. Together Oslo and Viken comprise a quite monocentric area characterized by higher population densities near Oslo city center and much lower ones in the periphery (see Fig. 1). Oslo city center has a high concentration of jobs, facilities, and services, and is connected to the rest of the Oslo-Viken area with urban and regional transport infrastructure. A large number of residents of the Oslo-Viken area regularly travel to Oslo city center for commuting purposes or to access facilities and services. For several years, Oslo and its surrounding region have been taking steps toward limiting sprawl and developing a more compact urban form (Næss, 2022a, 2011). At the same time, Oslo and Viken have been focusing on sustainable mobility with an effective, multimodal public transport system, increasing and improving infrastructure for active travel, and imposing several restrictions on cars, especially in the urban core of Oslo (Mouratidis et al., 2019; Næss et al., 2019; Tennøy & Hagen, 2021). During the last years, Oslo, and to some extent some surrounding municipalities, have been increasingly embracing, testing, and implementing emerging forms of urban mobility including shared mobility options such as bike-sharing (docked bike-sharing called “bysykkel”) car-sharing (provided by both businesses and cooperatives), shared e-scooters (dockless, free-floating e-scooters by several private companies), and ridehailing (Uber) (Böcker et al., 2020; Fearnley et al., 2020; Uteng et al., 2019) as well as autonomous vehicles (Mouratidis & Cobeña Serrano, 2021). The bike-sharing scheme in Oslo has approximately 100,000 registered users and resulted in over 2.7 million shared bike trips in 2018 (www.oslobysykkel.no/en/about). The e-scooter sharing scheme in Oslo comprises a total fleet of 8000 e-scooters, limited by the city’s regulation, and this must be divided equally between 12 e-scooter sharing companies (Fearnley et al., 2022). Car-sharing in Norway is offered by 11 service providers, as of 2018, giving access to over 7000 vehicles to more than 200,000 reported registered members, although actual users are considerably fewer (George & Julsrud, 2018). At the time pertinent to data collection for this research, Uber was operating in Oslo with the services Uber Black, Lux, and UberXXL (https://www.uber.com/en-NO/blog/oslo-uber-launching-new-products) which are licensed as luxurious forms of taxi (Oppegaard, 2020). The co-existence of major shared mobility options makes Oslo and Viken a good study area for the purposes of this research as it allows empirical investigation and comparisons of the actual use of these different mobility options.

### 3.2. Data sources

The study draws on data from an online survey with Oslo and Viken residents and geospatial data extracted with analysis in GIS. The survey sample consists of 1796 adults living in Oslo and Viken with ages ranging from 19 to 95 years. A list of addresses of all the population of Oslo and Viken was acquired from the Norwegian Tax Administration. Next, an invitation to participate in the survey was distributed by post to 20,000 residents in June 2020. A unique ID number was assigned to each invited resident. The invitation included a link that participants had to type in their web browsers to access the online survey. Letters were sent only to adults and only to one person in each household. Answers were collected until August 2020. The sampling strategy aimed to collect answers from various urban forms and geographical locations and achieve a good representation of users of emerging forms of mobility (see also Mouratidis, 2022). The 20,000 letters were distributed as follows: 12,000 letters were sent to residents of Oslo municipality and 8000 letters were sent to residents of Viken. In Oslo, 8000 letters were distributed in the inner city and 4000 letters in the outer city. In Viken, 4000 letters were distributed in outer suburban parts of Oslo and 4000 letters in rural areas and towns on the periphery. Random selection was applied within each of these zones. The final sample includes residents of all parts of Oslo and Viken as seen in Fig. 1. The invitation (sent by post) and the online survey were written in two languages: Norwegian and English. A pilot survey was developed and tested. Revisions were then made before distributing the final version. Incentives were not offered to survey participants. The survey response rate was 9.4% (after excluding letters that were returned due to wrong residential addresses). A table comparing the sociodemographic characteristics of the sample with those of the population of Oslo metropolitan area is presented in Appendix A (Table A1). While several of the sample’s characteristics are similar to those of the population, respondents in the survey are slightly older and have higher incomes and level of education, while foreign residents are under-represented. This research is registered with the Norwegian Center for Research Data (NSD) and has been approved for collecting and handling personal data. The project reference number is 869419.

Geospatial data were collected with analysis in GIS after the online survey was concluded. Survey participants had to type their survey ID number when answering the survey. This ID was linked to their residential address based on the list of residential addresses in Oslo and Viken. Moreover, for crosschecking purposes, participants were asked to write their residential addresses in the online survey. The residential addresses of the 1796 participants were then all georeferenced and inserted in GIS. Next, built environment characteristics were assessed with analysis in GIS at the individual level for each residential location.

**Table 1**
Descriptive statistics of the whole sample and shared mobility users among the sample.

| | Min/Max | Mean Whole sample (*N* = 1796) | Bike-sharing users (*N* = 99) | E-scooter sharing users (*N* = 121) | Car-sharing users (*N* = 73) | Uber users (*N* = 61) |
|---|---|---|---|---|---|---|
| *Sociodemographic variables* | | | | | | |
| Age (years) | 19/95 | 49.67 | 36.46 | 35.67 | 46.22 | 41.02 |
| Female | 0/1 | 0.50 | 0.47 | 0.38 | 0.52 | 0.48 |
| Unemployed | 0/1 | 0.04 | 0.06 | 0.06 | 0.10 | 0.02 |
| Living with partner/spouse | 0/1 | 0.69 | 0.51 | 0.59 | 0.78 | 0.59 |
| Non-Norwegian | 0/1 | 0.10 | 0.15 | 0.12 | 0.18 | 0.15 |
| College degree or higher | 0/1 | 0.70 | 0.84 | 0.67 | 0.77 | 0.64 |
| Household with children | 0/1 | 0.33 | 0.20 | 0.3 | 0.45 | 0.30 |
| Disability | 0/1 | 0.16 | 0.08 | 0.07 | 0.16 | 0.16 |
| Adjusted household income (1000s NOK) | 0/4899 | 735.96 | 723.76 | 754.99 | 780.3 | 875.10 |
| *Environmental concern* | | | | | | |
| Worry about climate change | 1/5 | 3.19 | 3.56 | 3.22 | 3.33 | 3.03 |
| *Access to a car* | | | | | | |
| Has access to a private car | 0/1 | 0.66 | 0.36 | 0.50 | 0.27 | 0.56 |
| *Built environment* | | | | | | |
| Distance to city center (km) | 0.40/217.17 | 17.56 | 4.66 | 5.83 | 5.95 | 6.10 |
| Neighborhood density (people/hectare within 1 km radius) | 0.43/173.66 | 64.36 | 112.05 | 101.26 | 93.32 | 83.70 |
| Public transport (number of stops within 1 km radius) | 0/233 | 48.08 | 86.67 | 76.42 | 80.32 | 67.31 |

Notes: Min/Max values refer to the whole sample. For binary variables (0/1), mean values refer to proportions.

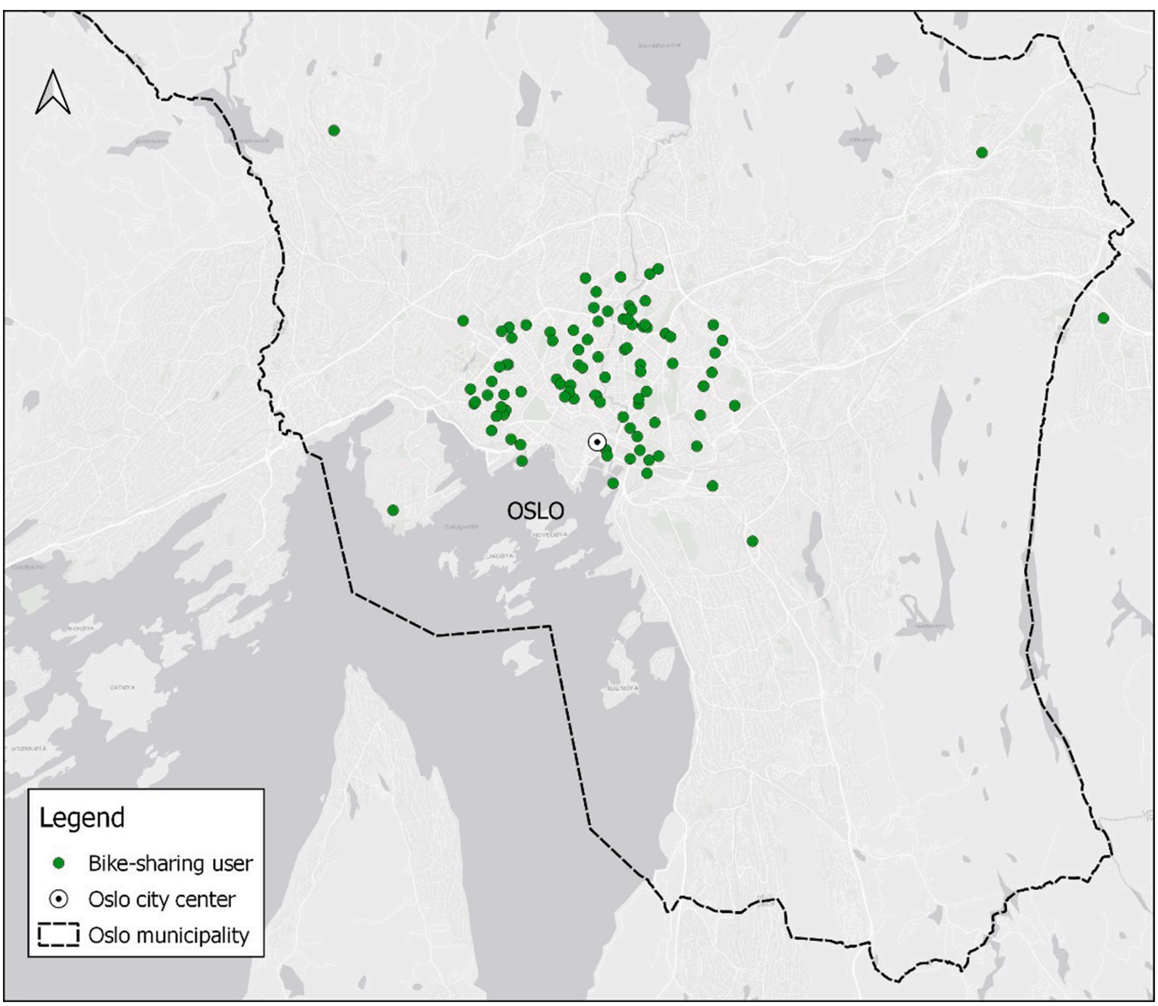


**Fig. 2.** Map of Oslo showing residential locations of bike-sharing users.

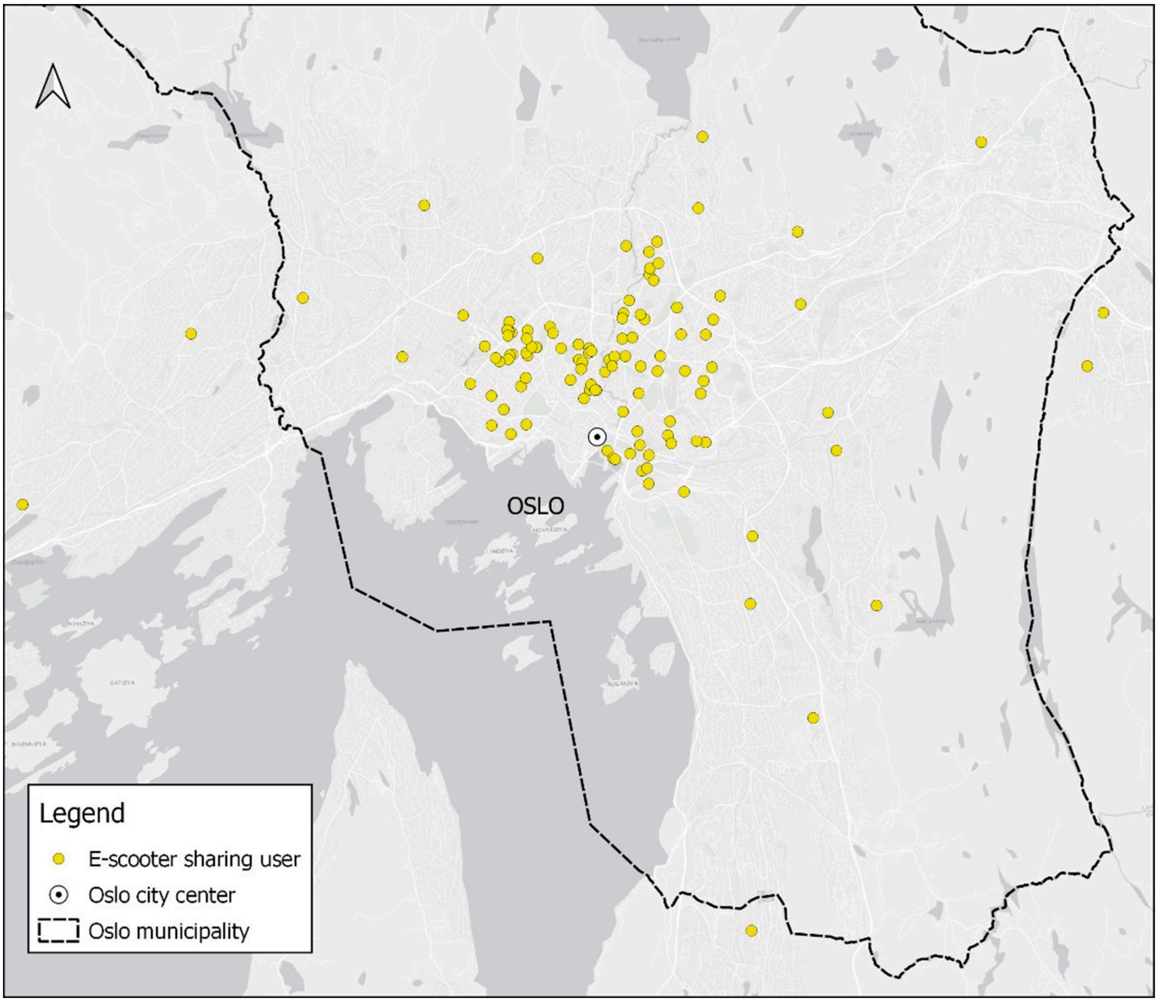


**Fig. 3.** Map of Oslo showing residential locations of e-scooter sharing users.

The built environment variables used in the study are described in detail in Section 3.3.

### 3.3. Variable descriptions

The dependent variables in the study are four binary variables of whether the respondent is a user of bike-sharing, car-sharing, shared e-scooters, and Uber. These data were obtained via the survey and then recoded into binary variables. The survey included two questions capturing the use of different travel modes during weekdays and weekends: "On a typical weekday, for how long do you use each of the following travel modes? As typical weekday: consider one day of the week (excluding Saturday and Sunday) that better represents your daily travel routine." and "On a typical weekend, for how long do you use each of the following travel modes (sum of both Saturday and Sunday)? As typical weekend: consider your travel routines during both days of an ordinary weekend (the sum of both Saturday and Sunday)." The questions were asked for a range of travel modes including the four shared mobility options examined in the study. These were described as: "bike-share (bysykkel / city bikes)", "car-sharing (Din Bybil etc.)", "electric scooter (shared - e.g. Lime)", and "Uber (or similar)". The following durations were given as response options: "not at all", "1–15 min", "16–30 min", "31–45 min", "46–60 min", "61–90 min", "91–120 min", and "more than 2 h". Since shared mobility users are largely outnumbered by non-users and users tend to use shared mobility options for short total travel times, the use of shared mobility was recoded into binary variables (where 1 = user and 0 = non-user) instead of ordinal ones that would measure the amount of use. Users were considered those who used a shared mobility option on a typical weekday and/or on a typical weekend, independently of travel durations. This conceptualization defines as users those who use a shared mobility option at least once per week and therefore captures (relatively) regular users. Based on these considerations, 99 bike-sharing users, 121 e-scooter sharing users, 73 car-sharing users, and 61 Uber users were identified among the sample (Table 1).

Although the survey was carried out in June-August 2020, corresponding to the early phases of the coronavirus pandemic, the aim was to assess travel behavior related to shared mobility options during normal conditions. To ensure this, the survey included an explicit instruction before travel behavior questions: "For the following questions, please consider your life right before the coronavirus pandemic (COVID-19)." Moreover, each of the two questions used to obtain the dependent variables of this study was followed by a parenthesis "(before COVID-19)" reminding participants that these questions correspond to normal circumstances.

Variables on sociodemographic characteristics, environmental concern, and access to a private car were also obtained through the survey (Table 1). The following sociodemographic variables were captured: age, employment status, level of education, gender, citizenship, cohabitation status, having a disability, household with children, and household income. These variables were coded as shown in Table 1. To adjust for household size, household income (annual gross income from all sources) was divided by the square root of the number of household members. An attitudinal question on environmental concern

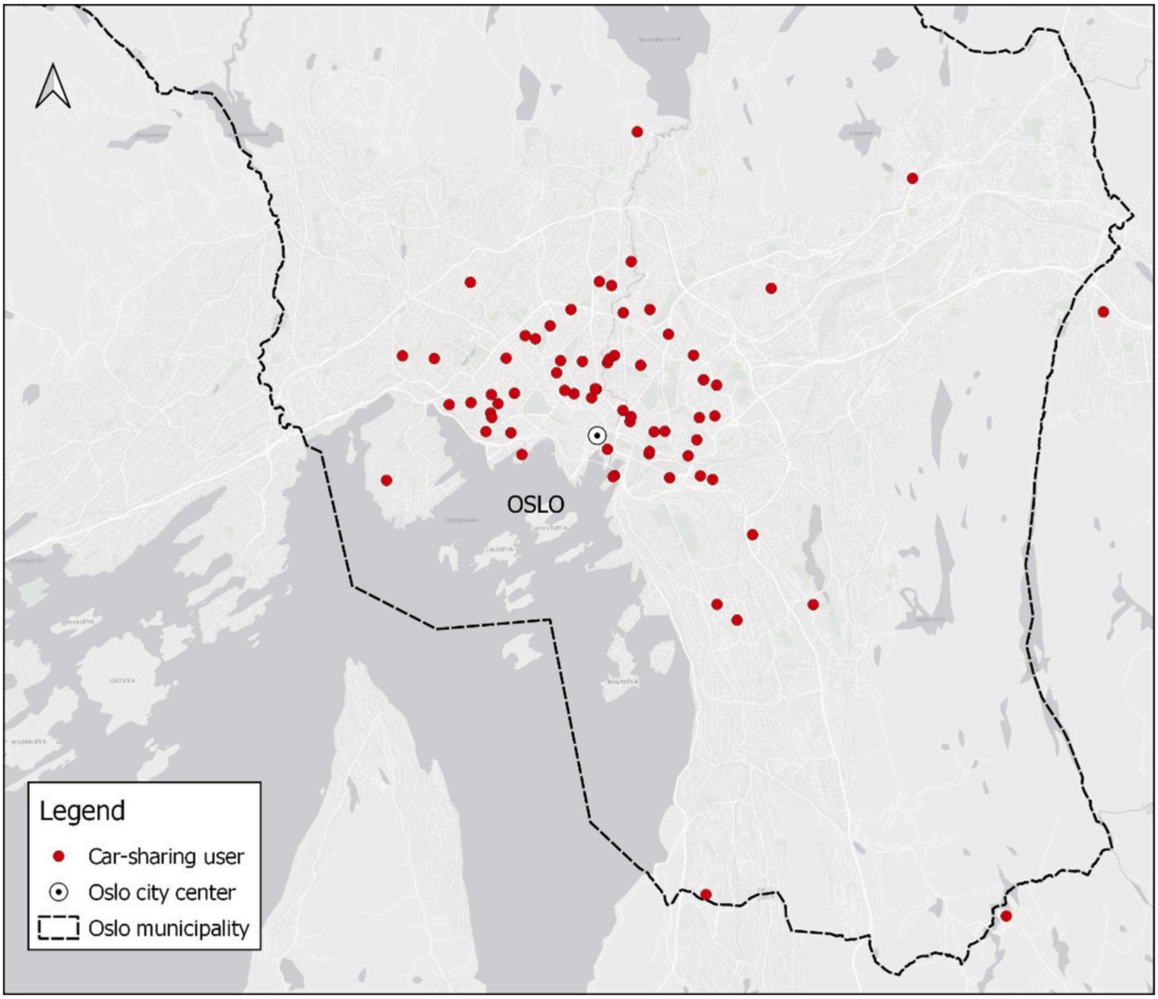


**Fig. 4.** Map of Oslo showing residential locations of car-sharing users.

asked participants "how worried are you about climate change?" on a scale "(1) not at all worried", "(2) not very worried", "(3) somewhat worried", "(4) very worried", and "(5) extremely worried". To assess the access to a private car, the survey asked: "do you have access to a private car?", and the answer options were: "no", "yes sometimes", and "yes always". Having access to a private car were considered those who answered: "yes always". Including those who answered "yes sometimes" as having access to a car in the binary variable (1 = has access to a private car, 0 = no access) was also tested but was discarded for theoretical reasons as well as for yielding weaker correlations with the dependent variables of the study.

Three built environment characteristics are assessed as independent variables in the study: distance to city center, neighborhood density, and public transport (Table 1). These were captured with analysis in GIS at the individual level for the residential location of each survey participant. As explained by Næss (2022b), these built environment characteristics are strongly interrelated as follows. Proximity to city center is linked to higher local area population density, and together proximity to city center and local area density are conducive to more public transport provisions. Distance to city center was calculated with network analysis (walking network was used) in GIS from each participant's home address to the city center of Oslo. Neighborhood density was measured with GIS using data from the 2019 population dataset by Statistics Norway (250 m × 250 m). It was estimated as the number of people per hectare within a radius of 1 km from each participant's home address. Public transport provisions were assessed with GIS using OpenStreetMap data on public transport stops. They were estimated as the total number of public transport stops (metro, bus, tram, and train) within a radius of 1 km from each participant's home address.

## 4. Results

### 4.1. Descriptive statistics

The first step in the analysis is a descriptive exploration of the characteristics of shared mobility users. This was done with descriptive statistics on sociodemographic variables, environmental concern, access to a car, and built environment characteristics for the whole sample as well as for users of different shared mobility options. Table 1 presents descriptive statistics on the characteristics of users of different shared mobility options. These can offer some first observations on differences between users; however, a more robust investigation is done with the logistic regression models below. Based on Table 1, it is observed that, overall, shared mobility users tend to be younger, have less access to a private car, and live closer to Oslo city center compared to the whole sample. Moreover, some noticeable differences between users of diverse shared mobility options are observed. Females tend to use shared e-scooters less than males, while for other shared mobility options the share of females and males seems relatively balanced. Uber users tend to have higher incomes than users of other shared mobility options and than the whole sample on average. Fewer people with disabilities tend to use bike-sharing and e-scooter sharing compared to car-sharing and Uber and to the whole sample on average. A higher proportion of people living with a partner or spouse is using car-sharing compared to other

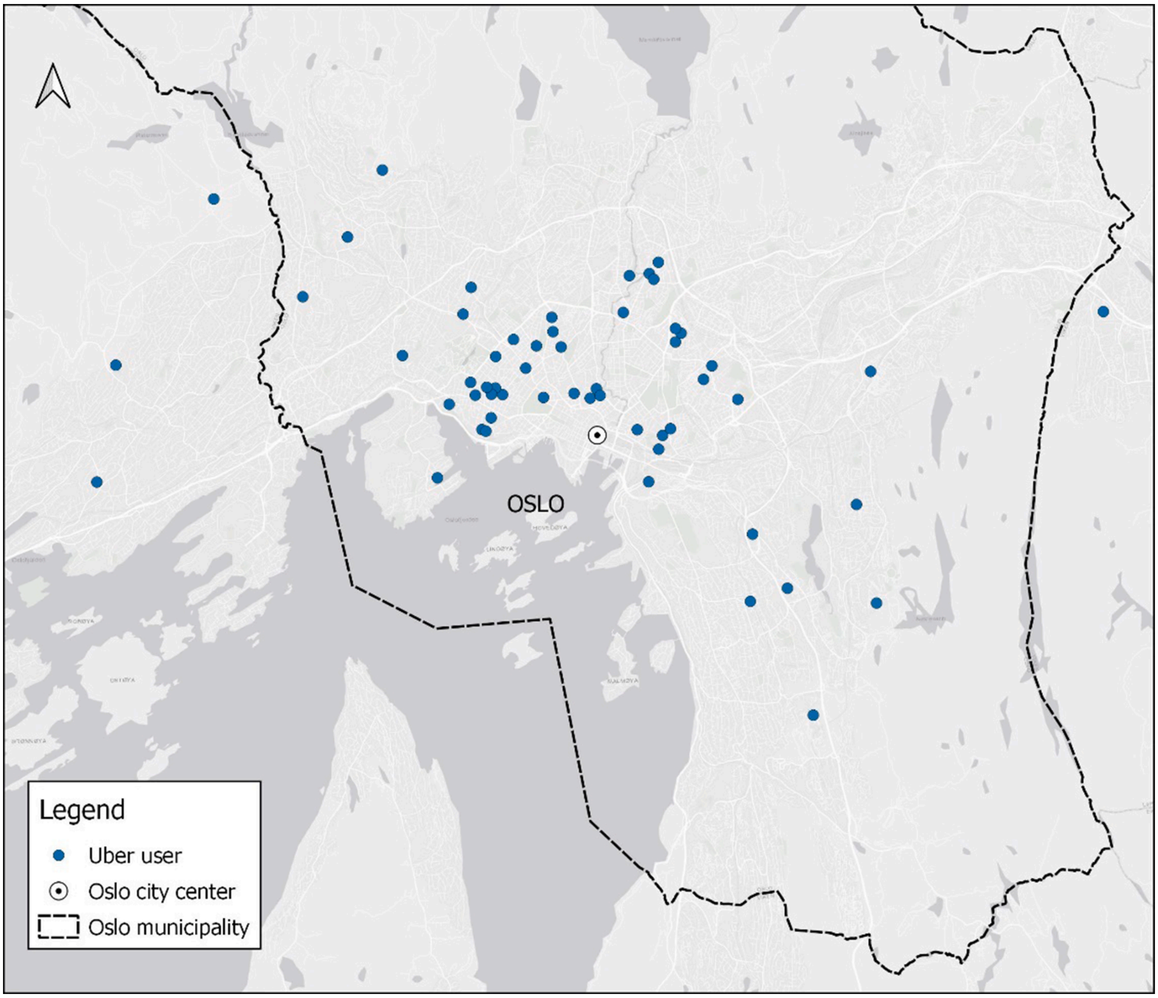


**Fig. 5.** Map of Oslo showing residential locations of Uber users.

**Table 2**
Binary logistic regression models of bike-sharing use.

| Variables | Bike-sharing use | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) |
| *Sociodemographic variables* | | | | | |
| Age | 0.943*** (0.927, 0.960) | 0.945*** (0.929, 0.962) | 0.949*** (0.932, 0.966) | 0.950*** (0.933, 0.967) | 0.951*** (0.934, 0.969) |
| Female | 0.675[a] (0.438, 1.040) | 0.623* (0.402, 0.965) | 0.659[a] (0.427, 1.016) | 0.658[a] (0.422, 1.026) | 0.627* (0.400, 0.982) |
| Unemployed | 1.224 (0.492, 3.046) | 1.218 (0.485, 3.058) | 1.224 (0.492, 3.045) | 1.508 (0.592, 3.840) | 1.513 (0.591, 3.872) |
| Living with partner/spouse | 0.572* (0.361, 0.908) | 0.559* (0.351, 0.889) | 0.615* (0.386, 0.978) | 0.642[a] (0.403, 1.022) | 0.619* (0.386, 0.991) |
| Non-Norwegian | 1.358 (0.746, 2.470) | 1.273 (0.696, 2.327) | 1.269 (0.695, 2.317) | 1.152 (0.622, 2.136) | 1.096 (0.587, 2.048) |
| College degree or higher | 2.294** (1.288, 4.085) | 2.075* (1.158, 3.718) | 2.176** (1.220, 3.884) | 1.667[a] (0.924, 3.007) | 1.557 (0.859, 2.823) |
| Household with children | 0.542* (0.320, 0.920) | 0.568* (0.334, 0.964) | 0.609[a] (0.355, 1.044) | 0.785 (0.453, 1.361) | 0.803 (0.459, 1.404) |
| Disability | 0.621 (0.288, 1.338) | 0.586 (0.270, 1.271) | 0.600 (0.278, 1.297) | 0.562 (0.255, 1.238) | 0.525 (0.235, 1.169) |
| Adjusted household income | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) |
| *Environmental concern* | | | | | |
| Worry about climate change | | 1.465** (1.135, 1.890) | | | 1.353* (1.042, 1.757) |
| *Access to a car* | | | | | |
| Has access to a private car | | | 0.594* (0.362, 0.974) | | 1.007 (0.600, 1.691) |
| *Built environment* | | | | | |
| Distance to city center | | | | 0.988 (0.962, 1.015) | 0.988 (0.962, 1.014) |
| Neighborhood density | | | | 1.011*** (1.004, 1.017) | 1.010** (1.003, 1.016) |
| Public transport | | | | 1.005* (1.000, 1.011) | 1.005* (1.000, 1.011) |
| *Pseudo R-square* | | | | | |
| Nagelkerke R-square | 0.160 | 0.174 | 0.167 | 0.234 | 0.242 |

Notes: [a]$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Sample size: $N = 1796$.

**Table 3**
Binary logistic regression models of e-scooter sharing use.

| Variables | E-scooter sharing use | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) | Odds ratio (95% C.I.) |
| *Sociodemographic variables* | | | | | |
| Age | 0.930*** (0.914, 0.945) | 0.930*** (0.914, 0.945) | 0.930*** (0.913, 0.946) | 0.935*** (0.919, 0.952) | 0.931*** (0.914, 0.948) |
| Female | 0.474*** (0.316, 0.711) | 0.475*** (0.316, 0.716) | 0.474*** (0.316, 0.712) | 0.435*** (0.287, 0.660) | 0.455*** (0.298, 0.693) |
| Unemployed | 1.249 (0.534, 2.919) | 1.249 (0.534, 2.919) | 1.249 (0.534, 2.919) | 1.477 (0.623, 3.503) | 1.513 (0.634, 3.610) |
| Living with partner/spouse | 0.935 (0.603, 1.450) | 0.936 (0.603, 1.452) | 0.934 (0.599, 1.455) | 1.004 (0.648, 1.555) | 0.967 (0.620, 1.507) |
| Non-Norwegian | 1.032 (0.57, 1.860) | 1.034 (0.574, 1.865) | 1.034 (0.572, 1.868) | 0.876 (0.478, 1.607) | 0.938 (0.510, 1.728) |
| College degree or higher | 0.721 (0.467, 1.113) | 0.724 (0.467, 1.123) | 0.722 (0.467, 1.116) | 0.506** (0.323, 0.795) | 0.533** (0.338, 0.842) |
| Household with children | 0.845 (0.548, 1.302) | 0.843 (0.546, 1.301) | 0.843 (0.541, 1.314) | 1.181 (0.749, 1.864) | 1.085 (0.681, 1.728) |
| Disability | 0.487[a] (0.235, 1.012) | 0.488[a] (0.235, 1.015) | 0.488[a] (0.235, 1.014) | 0.448* (0.210, 0.955) | 0.471[a] (0.220, 1.006) |
| Adjusted household income | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) |
| *Environmental concern* | | | | | |
| Worry about climate change | | 0.988 (0.791, 1.233) | | | 0.908 (0.722, 1.142) |
| *Access to a car* | | | | | |
| Has access to a private car | | | 1.008 (0.644, 1.579) | | 1.587[a] (0.993, 2.536) |
| *Built environment* | | | | | |
| Distance to city center | | | | 0.979[a] (0.956, 1.002) | 0.978[a] (0.955, 1.002) |
| Neighborhood density | | | | 1.009** (1.003, 1.015) | 1.010** (1.004, 1.016) |
| Public transport | | | | 1.002 (0.997, 1.007) | 1.003 (0.997, 1.008) |
| *Pseudo R-square* | | | | | |
| Nagelkerke R-square | 0.179 | 0.179 | 0.179 | 0.242 | 0.248 |

Notes: $^{a}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Sample size: $N = 1796$.

shared mobility options and the whole sample. Finally, bike-sharing users, on average, reside closer to the city center than users of other shared mobility options.

### *4.2. Visualization of residential locations of shared mobility users*

Next, maps are presented showing the residential location of users of different shared mobility options. These maps can also point to trends in locations where shared mobility options are used. Fig. 2, Fig. 3, Fig. 4, and Fig. 5 depict the residential locations of users of bike-sharing, e-scooter sharing, car-sharing, and Uber, respectively. The maps focus on Oslo municipality as this includes most of the users of shared mobility options among the sample, while only a few users reside in areas of Viken. These maps indicate certain trends in the residential locations of shared mobility users. First, shared mobility users are more likely to live in the inner city of Oslo. Second, bike-sharing users appear to live in a more concentrated area around Oslo city center compared to the other three shared mobility options that seem to be somewhat more dispersed. This is in line with the descriptive statistics on distance to city center shown in Table 1. More accurate empirical investigations are carried out with logistic regressions presented below.

### *4.3. Modeling shared mobility use*

The third step in the analysis was to develop and test binary logistic regression models to identify whether and to what extent sociodemographic variables, environmental concern, access to a car, and built environment characteristics relate to the use of shared mobility options. Binary logistic regression was preferred over other approaches such as ordinal or linear regression. Travel times with shared mobility modes are short – most of them within the range 1–15 min – so regression models with travel time as an ordinal or continuous dependent variable would not be suitable. Instead, binary models with dependent variables coded as user versus non-user were developed (see also Section 3.3 above). The sample size ($N = 1796$) is large enough for binary logistic regression analysis, and although the use of shared mobility modes can be considered a rare event in statistical terms, the variation of the dependent variables is expected to be sufficient for performing the analysis (Vittinghoff & McCulloch, 2007).

Four separate analyses were performed: one for each shared mobility option (bike-sharing, e-scooter sharing, car-sharing, Uber) as the dependent variable, coded as binary variable (non-user = 0, user = 1). Each of these four analyses consists of five models. Since certain independent variables are interrelated, a step-by-step approach was followed for the construction of the models. The first model includes only sociodemographic variables. The second includes sociodemographic variables and environmental concern. The third includes sociodemographic variables and access to a car. The fourth includes sociodemographic variables and built environment characteristics. The fifth is the full model including all independent variables, i.e. sociodemographic variables, environmental concern, access to a car, and built environment characteristics. The fifth, full model is the most robust one as it controls for possible confounding.

Table 2 presents models estimating the probability of using bike-sharing. Based on the results on sociodemographic variables (Model 1), bike-sharing use is more prevalent among younger people, males, and those with higher education, while it is less common among those who live with a partner and those who live in a household with children. The association between the presence of children in the household and the probability of using bike-sharing disappears when built environment variables are included in the models. Similarly, the association between education level and bike-sharing use disappears when all variables are included in the analysis (Model 5). Results on environmental concern indicate that those who are worried about climate change are more likely to use bike-sharing. Results on access to a car suggest that those who have access to a private car are less likely to use bike-sharing. This association disappears when built environment variables are included in Model 5. This could be attributed to the link between the built environment and car ownership, with car ownership being less common in the denser, walkable, and transit-oriented inner-city of Oslo. Finally, results on the built environment indicate that bike-sharing use is more prevalent in residential locations of high density and more public transport provisions.

Table 3 presents models estimating the probability of using e-scooter sharing. It is found that younger people and males are more likely to use shared e-scooters. People with disabilities are (somewhat) less likely to use shared e-scooters. Worry about climate change is not associated with e-scooter sharing use. When built environment characteristics are included in the analysis, it is found that those having access to a private car are (somewhat) more likely to use e-scooter sharing, while those having higher education are less likely to use e-scooter sharing. Results on built environment characteristics indicate that e-scooter sharing use

**Table 4**
Binary logistic regression models of car-sharing use.

| Variables | Car-sharing use | | | | |
|---|---|---|---|---|---|
| | 1 Odds ratio (95% C.I.) | 2 Odds ratio (95% C.I.) | 3 Odds ratio (95% C.I.) | 4 Odds ratio (95% C.I.) | 5 Odds ratio (95% C.I.) |
| *Sociodemographic variables* | | | | | |
| Age | 0.989 (0.973, 1.006) | 0.990 (0.974, 1.007) | 1.011 (0.994, 1.028) | 1.001 (0.984, 1.019) | 1.016[a] (0.998, 1.034) |
| Female | 1.061 (0.656, 1.716) | 1.026 (0.632, 1.666) | 0.863 (0.527, 1.413) | 1.114 (0.679, 1.826) | 0.933 (0.563, 1.545) |
| Unemployed | 2.473* (1.057, 5.787) | 2.504* (1.068, 5.868) | 2.362[a] (0.981, 5.687) | 2.876* (1.195, 6.919) | 2.564* (1.042, 6.313) |
| Living with partner/spouse | 1.442 (0.787, 2.640) | 1.444 (0.788, 2.643) | 2.201* (1.196, 4.050) | 1.826* (0.992, 3.361) | 2.318** (1.255, 4.283) |
| Non-Norwegian | 1.776[a] (0.938, 3.361) | 1.748[a] (0.923, 3.310) | 1.325 (0.689, 2.547) | 1.573 (0.818, 3.024) | 1.255 (0.645, 2.440) |
| College degree or higher | 1.284 (0.723, 2.281) | 1.225 (0.685, 2.190) | 1.107 (0.614, 1.995) | 0.985 (0.545, 1.780) | 0.924 (0.503, 1.697) |
| Household with children | 1.506 (0.923, 2.457) | 1.536[a] (0.941, 2.509) | 2.149** (1.302, 3.548) | 2.230** (1.329, 3.743) | 2.658*** (1.573, 4.490) |
| Disability | 1.283 (0.664, 2.479) | 1.278 (0.661, 2.471) | 1.014 (0.513, 2.004) | 1.169 (0.592, 2.311) | 0.999 (0.496, 2.011) |
| Adjusted household income | 1.000 (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.001* (1.000, 1.001) | 1.000 (1.000, 1.001) | 1.001[a] (1.000, 1.001) |
| *Environmental concern* | | | | | |
| Worry about climate change | | 1.167 (0.880, 1.547) | | | 1.083 (0.811, 1.446) |
| *Access to a car* | | | | | |
| Has access to a private car | | | 0.108*** (0.060, 0.197) | | 0.163*** (0.087, 0.305) |
| *Built environment* | | | | | |
| Distance to city center | | | | 0.970[a] (0.937, 1.005) | 0.977 (0.946, 1.009) |
| Neighborhood density | | | | 1.001 (0.994, 1.009) | 0.999 (0.991, 1.006) |
| Public transport | | | | 1.011*** (1.005, 1.017) | 1.009** (1.003, 1.016) |
| *Pseudo R-square* | | | | | |
| Nagelkerke R-square | 0.035 | 0.038 | 0.148 | 0.121 | 0.188 |

Notes: $^a p < 0.10$, $^* p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$. Sample size: $N = 1796$.

is more prevalent among those who live in denser areas close to the city center.

Table 4 presents models estimating the probability of using car-sharing. Results of Model 1 indicate that unemployed and non-Norwegian citizens are more likely to use car-sharing. In the full model, older age is (weakly) associated with a higher likelihood of car-sharing use. Being worried about climate change is not associated with car-sharing use. Not having access to a private car is strongly associated with using car-sharing. When car access is included in the analysis, we observe that living with a partner or spouse, living with children in the household, and having higher household income are all associated with a higher probability of using car-sharing. The association between non-Norwegian citizenship and car-sharing use disappears when car access is included in the analysis (Models 3 and 5). Residents of areas with more public transport provisions are found to be more likely to use car-sharing.

Table 5 presents models estimating the probability of using Uber. Younger citizens and those with higher incomes are found to be more likely to use Uber. Uber use is (somewhat) more prevalent among those who are less worried about climate change. When built environment variables are included in the analysis (Models 4 and 5), having tertiary education is associated with a lower probability of using Uber. Those living near the city center are found to be more likely to use Uber.

## 5. Discussion and conclusions

### 5.1. Comparisons of different shared mobility options

This is the first study, as far as we are aware, to explore factors associated with the use of four different shared mobility options – bike-sharing, e-scooter sharing, car-sharing, and ridehailing (Uber) – in the same urban region. Factors examined were sociodemographic characteristics, worry about climate change, access to a private car, and built environment characteristics of residential locations. The analyses were based on GIS and survey data from Oslo and its surrounding Viken county in Norway.

Exploring factors behind the use of different shared mobility options within the same urban region offers valuable input for direct comparisons between shared mobility options. Important similarities but also several differences between users of bike-sharing, e-scooter sharing, car-sharing, and Uber were revealed in the study's findings. Similarities and differences in terms of sociodemographic characteristics, worry about climate change, access to a private car, and built environment characteristics are described and discussed as follows.

*Sociodemographic characteristics*: Age seems to be an important predictor of the use of shared mobility options. Younger people were found to be more likely to use three out of four shared mobility options: bike-sharing, e-scooter sharing, and Uber. Conversely, car-sharing use was not associated with younger age. Gender may also play a role in how likely one is to use shared mobility and specifically bike-sharing and e-scooter sharing. Males were found to be more likely to use bike-sharing and e-scooter sharing. The gender difference in the use of bike-sharing and e-scooter sharing is consistent with previous studies (Fearnley et al., 2020; Fishman, 2016; Goodman & Cheshire, 2014; Uteng et al., 2020) and is linked with "spatial inequalities favoring central male-dominated employment areas" (Böcker et al., 2020, p. 389). It has to be mentioned though that the gender differences in the use of bike-sharing are found to be much smaller in Oslo, based on this and previous studies (Böcker et al., 2020), compared to other contexts such as the UK where bike-sharing use was found to be dominated by male citizens (Goodman & Cheshire, 2014; Murphy & Usher, 2015). Unemployment was found to be associated only with car-sharing use. Unemployed citizens were more likely to use car-sharing. Living with a partner or spouse was associated with an increased probability of using car-sharing but a reduced probability of using bike-sharing. The level of education seems to be mainly linked with e-scooter sharing and Uber use. Citizens without tertiary education were more likely to use both e-scooter sharing and Uber, contrasting previous studies from other contexts reporting that highly educated people are more likely to use e-scooters and Uber (Alemi et al., 2018; Jiao & Bai, 2020). The presence of children in the household was mainly associated with car-sharing use. Living with children in the household was associated with a higher likelihood of using car-sharing when access to a private car is accounted for. Having a disability was associated with a lower probability of using e-scooters, while it was not associated with the use of other shared mobility options. Those with a higher household income were more likely to use car-sharing and Uber. Household income was not associated with the use of bike-sharing or e-scooter sharing. The finding on bike-sharing contrasts previous findings from a variety of contexts reporting that people with higher income are more likely to use

**Table 5**
Binary logistic regression models of Uber use.

| Variables | Uber use 1 Odds ratio (95% C.I.) | 2 Odds ratio (95% C.I.) | 3 Odds ratio (95% C.I.) | 4 Odds ratio (95% C.I.) | 5 Odds ratio (95% C.I.) |
|---|---|---|---|---|---|
| *Sociodemographic variables* | | | | | |
| Age | 0.963*** (0.946, 0.980) | 0.961*** (0.944, 0.979) | 0.963*** (0.945, 0.982) | 0.967*** (0.950, 0.985) | 0.965*** (0.947, 0.984) |
| Female | 0.915 (0.537, 1.558) | 0.978 (0.571, 1.677) | 0.912 (0.535, 1.555) | 0.880 (0.515, 1.503) | 0.948 (0.551, 1.631) |
| Unemployed | 0.297 (0.040, 2.213) | 0.297 (0.040, 2.216) | 0.296 (0.040, 2.209) | 0.295 (0.039, 2.225) | 0.306 (0.041, 2.301) |
| Living with partner/spouse | 0.697 (0.390, 1.246) | 0.706 (0.394, 1.264) | 0.702 (0.389, 1.266) | 0.782 (0.439, 1.396) | 0.784 (0.436, 1.408) |
| Non-Norwegian | 1.610 (0.766, 3.385) | 1.660 (0.788, 3.497) | 1.598 (0.755, 3.381) | 1.461 (0.691, 3.091) | 1.546 (0.725, 3.296) |
| College degree or higher | 0.626 (0.357, 1.098) | 0.677 (0.383, 1.199) | 0.623 (0.354, 1.096) | 0.502* (0.283, 0.890) | 0.544* (0.305, 0.970) |
| Household with children | 0.838 (0.469, 1.498) | 0.809 (0.451, 1.450) | 0.845 (0.468, 1.525) | 0.941 (0.516, 1.713) | 0.900 (0.490, 1.651) |
| Disability | 1.432 (0.694, 2.955) | 1.462 (0.708, 3.016) | 1.429 (0.692, 2.950) | 1.477 (0.713, 3.057) | 1.529 (0.737, 3.175) |
| Adjusted household income | 1.001*** (1.000, 1.001) | 1.001*** (1.000, 1.001) | 1.001*** (1.000, 1.001) | 1.001** (1.000, 1.001) | 1.001** (1.000, 1.001) |
| *Environmental concern* | | | | | |
| Worry about climate change | | 0.771[a] (0.574, 1.035) | | | 0.746[a] (0.552, 1.008) |
| *Access to a car* | | | | | |
| Has access to a private car | | | 0.995 (0.519, 1.754) | | 1.196 (0.642, 2.229) |
| *Built environment* | | | | | |
| Distance to city center | | | | 0.942* (0.898, 0.989) | 0.942* (0.897, 0.988) |
| Neighborhood density | | | | 0.996 (0.988, 1.004) | 0.997 (0.989, 1.005) |
| Public transport | | | | 1.002 (0.994, 1.009) | 1.002 (0.994, 1.009) |
| *Pseudo R-square* | | | | | |
| Nagelkerke R-square | 0.076 | 0.082 | 0.076 | 0.114 | 0.122 |

Notes: $^{a}p < 0.10$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$. Sample size: $N = 1796$.

**Table A1**
Sociodemographic characteristics of survey participants.

| | Survey participants ($N =$ 1796) Mean | Population Mean |
|---|---|---|
| Age (for aged 18 or older)[1] | 49.67 | 46.30 |
| Female[1] | 50.20% | 50.30% |
| Living with partner/spouse[1] | 69% | 48% |
| Unemployed[2] | 4.20% | 2.50% |
| Adjusted household income (1000s NOK)[1] | 735.96 | 582.98 |
| Non-Norwegian[1] | 10% | 21% |
| College degree or higher[2] | 70% | 50% |
| Household size (persons)[1] | 2.38 | 1.94 |
| Household with children[1] | 33% | 26% |

Notes: [1]Population mean for Oslo and Akershus. [2]Population mean for Oslo Municipality. Source: Statistics Norway 2019.

bike-sharing (Eren & Uz, 2020; Murphy & Usher, 2015). The finding that Uber is associated with higher income contrasts with studies from the US suggesting that Uber could be widely used by those with lower incomes (Li et al., 2022; Yang et al., 2022). This might be attributed to the higher prices in Norway – since Uber (and Taxi) is relatively expensive in Norway, it might be used by people who have higher incomes. Contextual differences in transport systems may also contribute to this finding. Public transport provisions and walking and cycling infrastructure are more developed in Oslo and Viken than in several US cities thus making the expensive alternative of Uber less attractive to those with medium and lower incomes.

*Worry about climate change*: Citizens who were worried about climate change were found to be more likely to use bike-sharing than those who are not so worried about climate change. This could be explained by the fact that bike-sharing is possibly the most environmentally friendly shared mobility option (Mouratidis et al., 2021), thus those with environmental concerns may be more willing to use it. Conversely, those who were worried about climate change were found to be (somewhat) less likely to use Uber. Again, this could be attributed to the possible negative environmental implications of Uber (Tirachini, 2020). However, this finding contrasts with findings from California, US reporting positive associations between environmental concern and Uber use (Alemi et al., 2018). E-scooter sharing and car-sharing were not found to be associated with worry about climate change. The finding on e-scooters is in accordance with previous research, but the finding on car-sharing differs from previous findings reporting pro-environmental attitudes among car-sharing members in Oslo (Hjorteset & Böcker, 2020). The latter could be explained by differences in the measurement of environmental concern as well as car-sharing use.

*Access to a private car*: Not having access to a private car was found to be strongly linked with car-sharing use. This may indicate that car-sharing may be used to replace at least some of the functions of a private car for certain residents, and thus might enable reduced car ownership. This finding is in line with previous studies reporting a car-sharing impact on car ownership (Hjorteset & Böcker, 2020; Martin et al., 2010; ter Schure et al., 2012; Ye et al., 2019). On the contrary, having access to a private car was found to be (weakly) associated with a higher probability of using shared e-scooters, in line with a study by Blazanin et al. (2022) suggesting that pro-motorized individuals may find e-scooters appealing as they require less effort compared to e.g. walking or cycling. The use of bike-sharing and Uber was not associated with access to a private car, suggesting that these options do not substantially contribute to car ownership. The finding on Uber is in line with a previous study from Chile that did not find links between car ownership and ridehailing (Tirachini & del Río, 2019).

*Built environment*: Shared mobility users were likely to reside in central locations close to Oslo city center. This is due to higher availability of and better access to all shared mobility options in the central urban core. Bike-sharing users were found to be living mostly in the inner city and in closer proximity to the city center than the users of e-scooter sharing, car-sharing, and Uber. This can be explained by the fact that bike-sharing docks are mainly located in the inner city of Oslo. While e-scooter sharing is more often used in Oslo's inner city, it can be also found in several municipalities of Viken so its use is more dispersed than that of bike-sharing. Moreover, e-scooters are dockless and this also facilitates a more widespread use. Car-sharing options and Uber are more accessible in central Oslo, but they can be also accessed from other locations so again their use is more geographically dispersed than that of bike-sharing. Neighborhood density and public transport provisions, both influenced by proximity to city center, were found to be linked with shared mobility use. Bike-sharing use is more prevalent in areas with higher densities and good access to public transport. This is in accordance with studies suggesting that bike-sharing programs are successful in denser, vibrant, mixed-use environments that provide access to facilities, services, and public space (Duran-Rodas et al., 2019; Wang &

Lindsey, 2019). Shared e-scooter use was found to be enabled by higher densities. This is consistent with previous evidence from Oslo (Fearnley et al., 2020) as well as other contexts such as Austin in the US (Jiao & Bai, 2020). Car-sharing was found to be higher in areas with good access to public transport, in line with previous findings from Oslo (Hjorteset et al., 2021) as well as other contexts (Kent & Dowling, 2013; Stillwater et al., 2009). Uber use was found to be mainly facilitated by proximity to city center. This finding is similar to previous ones suggesting that ridehailing is more often used in more central, accessible locations (Alemi et al., 2018; Bi et al., 2022).

### 5.2. Limitations and future research

This study is naturally characterized by limitations that could nevertheless guide future studies. Results from this as well as most previous research come from cross-sectional data. Longitudinal studies are much needed to better understand ongoing trends in shared mobility use. The dataset used in this study does not distinguish between different types of sharing such as B2C, P2P, and cooperative schemes which could have offered more nuanced insights (Lempert et al., 2019; Uteng et al., 2019). Although increasing, the number of shared mobility users is still limited. New research with a greater number of users can offer more reliable results in the future. This new research will also capture possible effects of the COVID-19 era on factors contributing to the use of shared mobility, as the present study is based on pre-COVID-19 data. This study as well as most relevant studies analyze quantitative data. Qualitative research, based on e.g. focus groups or personal interviews with users and non-users, could make a valuable contribution to the understanding of causal pathways behind patterns found in quantitative analyses. Finally, this study has focused on the residential built environment. Examining the built environment at the origin and destination of the trips is important for understanding spatial patterns of emerging forms of mobility.

### 5.3. Policy implications

Findings from this study provide useful insights for decision-makers as well as urban and transport planners. The study has shed light on the profiles of the users of different shared mobility options, which have been shown to be far from homogeneous. Important similarities as well as differences have been revealed. The outcomes of the study could then illuminate factors that facilitate the use of each shared mobility option. Some factors seem to be largely context-dependent, but several other factors seem to be consistent across different contexts. The study provides evidence supporting that shared mobility is strongly favored by the compact city model. Efforts towards densification and limiting urban sprawl could be combined with strategies for sustainable mobility complemented by shared mobility solutions. Furthermore, lessons from the COVID-19 pandemic suggest that, at least in relatively compact urban areas, shared mobility solutions such as bike-sharing and e-scooter sharing could contribute to pandemic-resilient mobility as they are characterized by a low risk of infection and could be used to temporarily replace short or medium distance trips by public transport. Finally, the study has shed light on inequities and unfulfilled expectations related to shared mobility. Inequities include gender differences in the use of bike-sharing and e-scooter sharing as well as the difficulties to use e-scooters by people with mobility issues. The greater use of car-sharing and Uber by higher-income residents represents an unfulfilled expectation of shared mobility supporting the less well-off. Such findings indicate that adjustments need to be made so that shared mobility can help reduce transport inequities and support disadvantaged groups.

## Declaration of Competing Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data Availability

Data will be made available on request.

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## Appendix A

Table A1 Please check appendix table

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