Travel preferences for electric sharing mobility services

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Travel preferences for electric sharing mobility services: Results from stated preference experiments in four European countries

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ABSTRACT

Electric sharing mobility services (ESMS) are gaining popularity as a promising solution for green transport. For sustainable mobility planning, it is important to understand the factors affecting the use behavior of ESMS and the substitution patterns of conventional transport modes. To that end, we carried out a stated preference experiment to elicit travel preference toward ESMS considering various alternatives, contexts, and traveler characteristics. Results from a scaled error component model applied to a large sample of respondents from four European countries (France, Italy, Netherlands, and Spain) show that ESMS have the potential to reduce dependency on private cars. While heterogeneity is found across countries, people at young ages, highly educated, with high income, and living in city centers are commonly associated with a higher probability of adopting ESMS for urban mobility. The substitution patterns reveal a relatively lower preference for ESMS from private car users compared to users of public transport and active modes. Operational implications are discussed for sharing mobility planners and operators to avoid unintended substitution effects.

1. Introduction

To tackle the negative externalities associated with the excessive use of conventional cars, electric sharing mobility services (ESMS), such as electric car-sharing (ECS) and electric micro-mobility services (EMS), are gaining momentum as sustainable solutions. ESMS consist of short-term rentals of electric vehicles that can be picked up and dropped off in designated areas. ECS have a longer history compared to EMS, but the adoption of EMS lately increased much faster in the last years, especially due to the deployment of e-scooters (hereafter, e- stands for electric) sharing services. ESMS are expected to make a positive impact on the sustainability of urban mobility. Preferences for electric mobility services are slightly higher compared to those for non-electric counterparts. This may be due to the novelty effects or users' attitudes toward the environmental sustainability of the services, as found by Cartenì et al. (2016) and Paundra et al. (2017). Quite a few studies show that the introduction of sharing mobility services can reduce vehicle usage and have an impact on car ownership, by reducing or postponing car purchases (Le Vine & Polak, 2019; Martin & Shaheen, 2011). A simulation study conducted in 247 cities estimates that in 2050, ESMS could reduce CO_2 emissions by 6.3% (Tikoudis et al., 2021).

The usages of ESMS vary across user profiles, service characteristics, and contextual variables. Previous research investigated the user profile of ESMS and the service characteristics affecting people's intention to use them. ESMS are particularly attractive for males, younger generations, more educated, and the wealthier population (Aguilera-García et al., 2020; Bai & Jiao, 2020; Curtale et al.,

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2021a, 2022; Kopp et al., 2015; Prieto et al., 2017). Nonetheless, in some cases, EMS such as e-bikes seem to be more attractive to people with low income and lower education levels (Campbell et al., 2016), and the users are younger than car-sharing users due to the great use by students (Wielinski et al., 2017). Service characteristics are found to have an impact on people's intention to use ESMS. Lower costs and the possibility of parking the vehicles as close as possible to users' destinations increase the probability of using ESMS (Herrmann et al., 2014). As a consequence, free-floating (as opposed to station-based) sharing mobility services are preferred by the end users. However, the free-floating or dense one-way station-based sharing scheme requires unsustainable operational costs to move vehicles to avoid supply–demand mismatches (Li & Liao, 2020; Wang & Liao, 2021). As a way to minimize fleet management costs, researchers and practitioners are now investigating the attractiveness and feasibility of user-based relocation strategies (Curtale et al., 2021b; Wang & Liao, 2023).

Regarding usage patterns, there is abundant literature investigating preferences for ECS and EMS from users through revealed spatiotemporal usage data and from both users and non-users through surveys investigating behavioral intention and user behavior. The majority of studies have investigated one single sharing mobility service at a time amidst a set of traditional transport modes, but the body of research comparing different sharing services in the same analysis is growing in recent years (Abouelela et al., 2021; Brezovec & Hampl, 2021; Krauss et al., 2022; Lazarus et al., 2020; Manca et al., 2019; McKenzie, 2019; Reck et al., 2021; Wielinski et al., 2017; Younes et al., 2020; Zhu et al., 2020). In particular, comparisons across micro-mobility services are the most common, for instance, docked versus dockless or conventional versus electric. They show that micro-mobility services are a complementary means of transport for urban mobility that serve heterogeneous groups of people and substitute partly several traditional transport modes. There is evidence that docked services are used more frequently for commuting purposes in the USA (Lazarus et al., 2020; McKenzie, 2019) and Switzerland (Reck et al., 2021) and that e-vehicles are used for longer trip distances than regular bikes (Lazarus et al., 2020). E-scooters are used more frequently in areas that are not well covered by public transport (Cao et al., 2021) and in areas with a denser presence of tourist attractions (Zhu et al., 2020). In general, micro-mobility services cover a wide spectrum of needs and can improve the resilience of mobility when public transport services encounter operational issues (Manca et al., 2019).

Relatively less is known about the comparison of EMS and ECS, with some exceptions provided by Wielinski et al., 2017), Abouelela et al. (2021), Brezovec & Hampl (2021), and Krauss et al. (2022). Wielinski et al. (2017) investigated the differences in mobility behavior between car-sharing and bike-sharing users in Montreal (Canada). They found that car-sharing users are older and with higher car ownership compared to bike-sharing users. In addition, both users present different substitution patterns when deprived of the services. They shift to public transport in case of unavailability of the sharing services, with walking representing an alternative for bike-sharing users while private car for car-sharing users. Abouelela et al. (2021), through a stated preference (SP) survey in Munich (Germany), investigated young users' willingness to shift from ECS to e-scooters. They found that in the best scenario, up to 23% of ECS would shift to e-scooter, with a higher propensity for males compared to females. In addition, the willingness to pay for car-sharing is higher compared to that for e-scooter, with the chance of accidents representing a deterrent to using the latest. Brezovec & Hampl (2021) investigated the adoption of ECS and e-scooter in the mobility as a service (MaaS) framework through a choice-based conjoint survey in Austria. They found that bundles with ECS are favorite over those including e-scooter in a setting where public transport and docked bikes are the baseline means of transport in the MaaS package. Krauss et al. (2022) investigated travel preferences for e-scooter, e-bike, carsharing, and ridesharing through an SP experiment amongst 1,445 residents of 83 largest cities in Germany. They found a significant impact of travel time and cost for all transport modes with the highest shift to sharing mobility services in response to changes in the cost of private cars and public transport. The above-mentioned empirical studies offer useful evidence of the potential of EMS and ECS as complementary modes for urban mobility. However, they have been conducted in single countries, focusing on urban areas and not considering the willingness to switch to ESMS depending on the current modes. Therefore, little is known about the heterogeneity of preferences across different spatial settings and the potential to replace the status quo options.

In this study, we aim to investigate people's mode-switching patterns from their current means of transport to ESMS in different spatial contexts, through an SP experiment estimated with a scaled error component multinomial logit. Compared to previous studies, we contribute to the literature by (i) conducting the SP experiment across countries, including residents not only from cities but also from smaller towns, suburbs, and rural areas; (ii) involving different trip purposes (i.e., leisure in the city/town of residence, leisure in another city, and business/study) and contextual variables (i.e., COVID-19 situation, weather conditions, time of day); (iii) exploring heterogeneity of preferences in a multi-country setting.

This paper is a follow-up of a study conducted in the Netherlands on preferences for ECS (Curtale et al., 2021b), which showed (i) a higher preference for ECS from male, young, and car-deficient users, especially for work, study, and business-related trips, (ii) willingness to participate to user-based relocation strategies by choosing ECS with incentives (hereafter ECS-I), and (iii) higher substitution effect for train users compared to private car users. We intend to expand the analysis by including EMS as an additional mobility solution, to investigate the profile of current users and the characteristics affecting the probability of using ESMS as a whole for urban mobility, and to compare the results from four European countries (i.e., France, Italy, Netherlands, and Spain) characterized by the heterogeneous presence of ESMS and travel habits. The main results of this study highlight heterogeneous preferences across countries and possible unintended substitution effects. Specifically, the preference for ESMS is the highest in Italy and lowest in the Netherlands, where, together with France, the preference for EMS is lower compared to that for ECS. Unintended substitution effects refer to the higher preference for ESMS from current users of public transport, bike, or walking. Therefore, the introduction of ESMS might not reduce car use but only re-distribute travelers who already use sustainable transport modes. Thus, an analysis of the context and travel habits is of utmost importance for the formulation of policies aiming at promoting the use and adoption of ESMS.

The remainder of this paper is structured as follows. Section 2 describes the research method and materials, while Section 3 shows the analysis results. Section 4 discusses the relevance of the outcomes with the literature, explores policy and managerial implications, and points out the limitations of the present study for future research directions. Finally, Section 5 concludes this study.

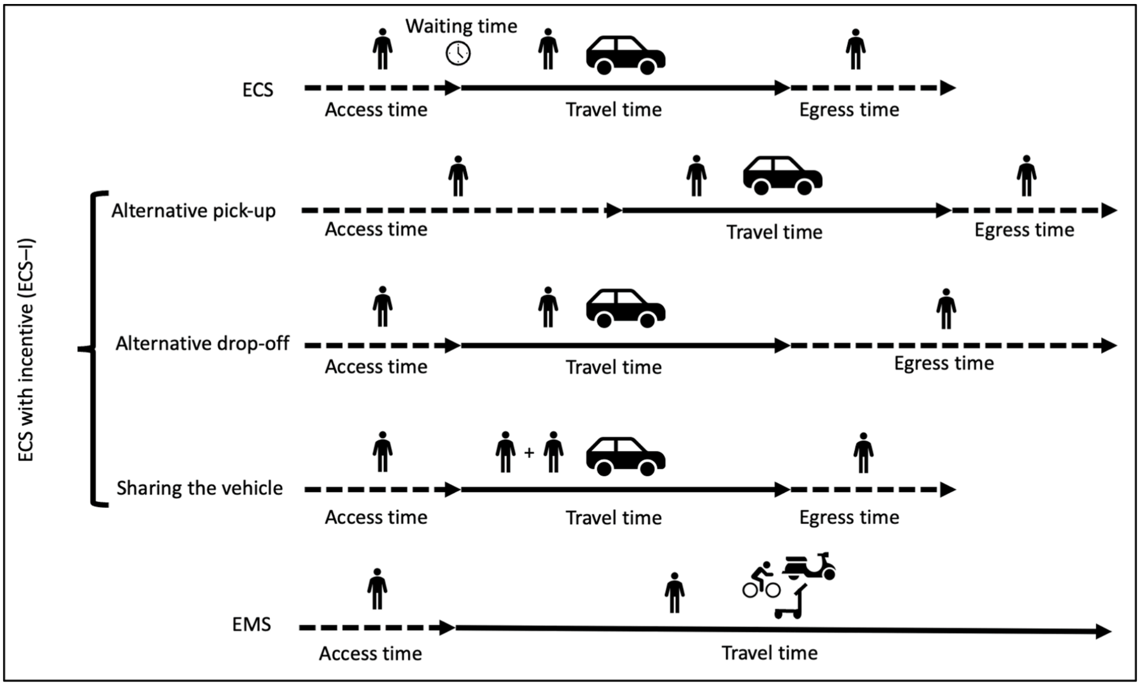

Fig. 1. ESMS alternatives to the status quo in the SP experiment.

Table 1
Contextual variables in the experiment.

Contextual variable	Level
Coronavirus-related	Low contagion of COVID-19
	Medium-high contagion of COVID-19 but no lockdown
	Post-COVID-19
Weather	On a rainy day
	Not on a rainy day
Time of day	Night
	Day (in peak hours)
	Day (in non-peak hours)
Trip purpose	Business, work, and study-related
	Day out in your city (e.g., shopping, museum, social visit)
	Day out in another city (e.g., shopping, museum, social visit)

2. Method and materials

We conducted an SP experiment to investigate respondents' willingness to switch from their current means of transport to ESMS. Specifically, we considered respondents' preferences for three alternative one-way ESMS: standard ECS, ECS-I of three variations to compensate for user-based relocation, and EMS. The experiment design is an extension of the one from Curtale et al. (2021b), with a reconfiguration of ECS-I and the addition of EMS as an alternative. Respondents' preferences for the different ESMS have been collected through surveys in four European countries, namely France, Italy, Netherlands, and Spain. The four countries have been selected due to the heterogeneous travel habits, car dependencies, and penetrations of ESMS (Curtale et al., 2022).

The ESMS are specifically characterized by heterogeneous travel times. The total travel time for the standard ECS is composed of access time to reach the shared car, potential waiting time in case of car shortage, in-vehicle travel time, and egress time to reach the destination. Incentivized to moderating the supply–demand dynamics, the modified ECS (ECS-I) involve discounted price to comply with one of three user-based relocation strategies: alternative pick-up, alternative drop-off, and sharing the vehicle. In the alternative pick-up, users are requested to pick up an alternative car from an under-demanded zone. The alternative drop-off requests the user to leave the car in an under-supplied zone. The former requires longer access time than originally planned, while the latter requires longer egress time; the in-vehicle travel times of both remain the same as that of the standard ECS. Sharing the vehicle involves sharing the ride with another user planning the same route with the same travel time of the standard ECS. The EMS normally requires a shorter access time to pick up the closest vehicle, but its travel time may be longer than ECS due to the lower speed of e-bikes or e-scooters. Meanwhile, there is no significant egress time due to the high density of parking spots for such small-sized vehicles. The salient

Table 2
Alternatives, attributes, and attribute levels in the experiment.

Alternative	Attribute	Attribute level	
		4 km level	Variation in the 10 km level
Status quo	(*Information is not provided; the status quo was stated by the respondent at the outset for both the 4 km and 10 km trip distance levels.*)		
ECS	Walking time	(1, 8, 15) min	
	Waiting time	(0, 5, 10) min	
	In-vehicle time	(6, 9, 12) min	(12, 18, 24) min
	Travel cost	(0.10, 0.25, 0.40) €/min	
	Possibility of delay	N/A	(0, 25, 50) %
ECS-I	Walking time	= Walking time of ECS + (3, 10) min	
	In-vehicle time	= In-vehicle time of ECS	
	Cost discount over ECS	(10, 30, 50) %	
	Service variation	(alt. pick-up, alt. drop-off, sharing the vehicle)	
	Possibility of 5-min delay	N/A	= Possibility of delay (ECS)
EMS	Walking time	(1, 5, 9) min	
	In-vehicle time	(9, 12, 15) min	(20, 26, 32) min
	Unlock fee	(free, 1 €)	
	Travel cost	(0.10, 0.20, 0.30) €/min	
	Possibility of 5-min delay	N/A	(0, 10, 20) %

(N/A: not applicable; where unspecified, attribute levels are the same for the 4 km and 10 km trips)

attributes of the ESMS alternatives are illustrated in Fig. 1.

2.1. Survey design

To rigorously study the travel preferences and substitution effects, the survey consists of two main parts after collecting the respondents' basic socio-demographic information. In the first part, respondents are requested to indicate the current means of transport to undertake an urban trip of short (4 km) or medium distance (10 km) under several trip contexts. In the second part, given the same trip contexts and a group of systematically varied attributes of ESMS, the respondents are again requested to make mode choices in the presence of ESMS alternatives. The two distance levels have been considered to test the differences in preferences because they are typical travel ranges for one-way short-term rentals of ESMS for urban mobility. The different trip contexts are characterized by four contextual variables: the degree of contagion of COVID-19, weather conditions, time of the day, and trip purpose, as shown in Table 1. The degree of contagion has been included to control for the background of the COVID-19 pandemic, and the other three contextual variables are often included in mode choice experiments.

With three 3-level and one 2-level contextual variables, there is a total of 54 contexts ($3^3 \times 2$), of which we selected 9 contextual profiles through an efficient design. In the SP experiment, every respondent received one of the nine trip contexts for the two trip distance levels, respectively. For each trip distance level and context, respondents first indicated their favorite current means of transport, referred to as the status quo (see Fig. A1 in the appendix). To limit the burden exerted on the respondents, we randomly assigned two different trip contexts to each respondent. For each respondent, we proposed four choice tasks for the 4 km trip distance level and two for the 10 km distance level, to investigate respondents' willingness to switch from the status quo to ESMS.[1] We requested them to indicate their preferences between the status quo and three ESMS alternatives, namely, ECS, ECS-I, and EMS, characterized by a group of attributes. For the status quo, no information about the specific attributes was shown and the respondents had to make self-references based on their travel experiences. For the ESMS, the attributes include components of travel time (walking time and in-vehicle time), travel cost (trip cost, discount, and unlock fee), convenience (waiting time and possible delay), and ECS-I variants. Walking time in the standard ECS involves access and egress time. For the ECS-I option, we specified that the users would be incentivized to select ECS by participating in a user-based relocation scheme. This is done by selecting a different pick-up location, leaving the shared car at a different drop-off location, or sharing the vehicle with other passengers on the same route. ECS-I offers discounted prices trading for slight conveniences to moderate the supply–demand imbalance of shared cars. As shown in Table 2, there are nine 3-level and two 2-level attributes for a 4 km trip, while eleven 3-level and two 2-level attributes for a 10 km trip. The 10 km trip has variations in in-vehicle times and two extra attributes related to a possibility of a short delay of 5 min. To systematically vary the attribute levels, two efficient designs of 27 choice profiles were generated for the 4 km and 10 km trip distance levels, respectively. The experimental design software Ngene[2] was used to generate the D-efficient designs). To facilitate the understanding of the alternatives, a simplified example of a choice task is depicted in Fig. A2 in the appendix.

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[1] For the 10 km trip distance, we randomly assigned four choice tasks, spitted into two groups: two complete choice tasks and two reduced choice tasks with some attributes omitted. Only the two complete choice tasks have been included in this study. We leave the reduced choice tasks to test attribute non-attendance in future work.

[2] https://www.choice-metrics.com.

Table 3

Sample socio-demographic characteristics and travel patterns (N = 2,451).

Variables	Netherlands	Italy	France	Spain
Number of respondents	648	620	607	576
Gender				
male	49.7%	49.0%	48.1%	52.6%
female	50.3%	51.0%	51.9%	47.4%
Age				
less than 20 years old	6.6%	5.8%	7.1%	5.0%
21–30 years old	15.3%	13.1%	12.9%	14.9%
31–40 years old	17.0%	20.8%	18.5%	24.8%
41–50 years old	16.7%	21.0%	22.7%	22.7%
51–60 years old	18.7%	16.6%	12.7%	16.7%
61–70 years old	17.3%	17.3%	20.1%	12.2%
more than 70 years old	8.5%	5.5%	6.1%	3.6%
Education				
low (high school diploma or lower)	51.1%	61.5%	47.6%	48.4%
high (bachelor’s degree or higher)	48.9%	38.5%	52.4%	51.6%
Income				
low (below 2 k €/month net)	54.9%	73.7%	55.7%	76.4%
high (higher than 2 k €/month net)	45.1%	26.3%	44.3%	23.6%
City size				
small (less than 20 k)	27.3%	27.3%	47.6%	20.3%
medium (between 20 k and 500 k)	54.9%	53.4%	40.5%	50.5%
large (more than 500 k)	17.7%	19.4%	11.9%	29.2%
4 km trip				
Car	46.5%	61.4%	52.7%	49.2%
Bike	29.3%	5.6%	8.0%	5.5%
E-Bike	9.5%	4.8%	3.4%	4.2%
Moto	1.0%	3.5%	2.1%	4.2%
Publlic transport	6.5%	7.2%	13.3%	14.4%
Car-sharing and ECS	1.6%	6.4%	2.4%	3.0%
EMS	1.2%	1.6%	1.9%	1.7%
Walking	3.7%	7.0%	12.6%	15.7%
Others (taxi, ride-sharing)	0.7%	2.5%	3.7%	2.0%
10 km trip				
Car	64.3%	71.9%	66.9%	63.2%
Bike	12.8%	2.7%	6.5%	3.7%
E-Bike	9.3%	3.6%	3.6%	3.2%
Moto	1.3%	3.8%	2.7%	5.6%
Publlic transport	7.4%	7.8%	10.1%	14.4%
Car-sharing and ECS	1.9%	6.1%	3.9%	2.8%
EMS	0.8%	1.3%	1.4%	1.6%
Walking	0.5%	1.1%	2.4%	2.6%
Others (taxi, ride-sharing)	1.6%	1.7%	2.5%	2.9%

2.2. Sample characteristics

The survey was conducted simultaneously in the aforementioned four European countries between November and December 2020 when these countries were experiencing the second wave of the COVID-19 pandemic. With translations provided by native speakers, the survey in the same format was administered in the respective languages online. A pilot test was launched internally at a small scale, followed by a soft launch for 50 respondents per country and a full launch till a specific timeline. Data were collected via specialized market research agencies that have access to representative panels from the four countries. The final sample is composed of 2,451 respondents, whose composition is shown in Table 3.

The sample is representative in terms of gender, age, and income structure within the four countries. There is a slight over-representation of high education due to the high internet penetration of this group, as it often happens in surveys administered via market research agencies. The French sample has a higher representation of respondents from small cities. In terms of current means of transport for urban mobility, the car is the preferred alternative in all countries for 4 km or 10 km trips. The Netherlands is the only country where the sum of public transport and active or electric modes (bike, e-bike, walking) for 4 km trips is higher than the car. On the other end, the Dutch sample has the least respondents favoring ride-sharing services. Furthermore, compared to the other samples, the Spanish sample has a higher preference for public transport for both short and medium-distance trips, while the Italian sample has the highest preference for sharing mobility services. The preliminary information indicates heterogeneous preferences across countries.

2.3. Model specification

Respondents’ travel preferences were estimated through a scaled error component multinomial logit (EC-MNL) model, which offers

Table 4
Frequencies of choices in the SP experiment for 4 km and 10 km trips.

	Status quo	ECS	ECS-I	EMS
4 km trip				
Average	63.8%	10.8%	13.5%	11.9%
Spain	55.9%	**13.5%**	15.3%	15.3%
France	62.0%	13.4%	14.8%	9.9%
Italy	55.3%	11.3%	**17.6%**	**15.8%**
Netherlands	**78.9%**	5.9%	7.7%	7.4%
10 km trip				
Average	63.9%	10.8%	13.5%	11.7%
Spain	56.0%	**13.7%**	14.4%	**15.9%**
France	61.9%	12.5%	15.1%	10.5%
Italy	57.1%	11.8%	**17.4%**	13.7%
Netherlands	**79.5%**	5.7%	7.5%	7.3%

Table 5
Comparison of MNL, NL, and EC-MNL.

	MNL	NL	EC-MNL
Number of respondents	2,415	2,415	2,415
Number of observations	13,888	13,888	13,888
Number of estimated parameters	170	171	172
Null log-likelihood	–19.252.86	–19.252.86	–19.252.86
Final log-likelihood	–15,021.13	–13,882.64	–12,705.84
Adjusted R^2 value	0.219	0.277	0.338
BIC	30,385.65	28,118.46	25,774.15

flexibility in controlling for correlations across the choice alternatives compared to the standard MNL and nested logit models (Train, 2009; Liao et al., 2020). Maximum simulated likelihood estimation is applied with 500 Modified Latin Hypercube Sampling using the APOLLO package (Hess & Palma, 2019). Following the random utility maximization theory, we define the utility U_{njt} of respondent n for alternative j in choice situation t in the experiment as

$$U_{njt} = \mu_c \mu_d (V_{njt} + \xi_{njt}) + \epsilon_{njt} \tag{1}$$

where V_{njt} represents the deterministic part of the system utility; μ_c and μ_d are the scale parameters capturing the variance differences between countries and trip distances, respectively; ξ_{njt} is a normally distributed error component with mean 0 and variance σ_j^2, specific for every ESMS alternative. The stochastic part ϵ_{njt} follows an extreme-value distribution. The deterministic parts of the alternatives are described in Eq. (2).

$$V_{njt} = ASC_j + \beta^X X_{njt} + \beta^Y Y_{njt} + \gamma Z_n \tag{2}$$

where $V_{njt}$is the system utility of respondent n for alternative j in choice situation t; ASC_j is the alternative-specific constant (ASC) of alternative j, which is set equal to 0 for car for identification purposes; X_{njt} and Y_{njt} are vectors of alternative and contextual attributes, respectively; Z_n is the vector containing the socio-demographic characteristics of respondent n. β^X, β^Y, and γ are the corresponding vectors of coefficients for alternative, contextual, and socio-demographic attributes, respectively. We use Eq. (2) to define utility functions for all labeled alternatives, including ASCs where needed and attributes where the levels of the status quo alternatives are fixed.

3. Results

We applied discrete choice models to analyze the collected data from the experiment. Given the focus on mode-switching, we excluded the proportion of respondents who selected sharing mobility services for their status quo (4.8% of total data points), resulting in a sample of 2,415 respondents. Each respondent completed 6 choice tasks, except for those who selected sharing mobility services as status quo in the 4 km (they completed only two choice tasks of the 10 km scenario) or in the 10 km scenario (they completed only the 4 choice tasks of the 4 km scenario), making a total of 13,888 observations. The frequencies of the mode choice in the SP experiment are shown in Table 4. The majority of the respondents are quite reluctant to shift to ESMS. The Dutch respondents present a higher degree of loyalty to the status quo (78.9% for 4 km and 79.5% for 10 km), while the share is slightly over 50% in the Italian (55.3% and 57.1%) and the Spanish samples (55.9% and 56%). The Spanish respondents present the highest preference for ECS in both 4 km (13.5%) and 10 km urban trips (14,4%), while the Italians, in general, seem particularly fond of ECS-I (17.6% for 4 km and 17.4% for 10 km). The EMS have the highest potential in Italy for 4 km trips (15.8%) and in Spain for 10 km trips (15.9%). The lowest preference for EMS is in the Netherlands (7.4% for 4 km trips, 7.3% for 10 km trips), which is reasonable for a country with a strong bike culture.

Table 6
Results of the EC-MNL model for the SP experiment.

Variables	ECS	EMS	Car	Bike	E-bike	Motorcycle	Walking	Public transport	Others
	Est.	Est.	Est.	Est.	Est.	Est.	Est.	Est.	Est.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)
Attributes			reference						
ASC (NL)	−3.738***	−2.768***		−0.28	0.759	−0.395	1.566**	−0.123	2.148**
	(0.327)	(0.361)		(0.469)	(0.608)	(0.977)	(0.746)	(0.514)	(1.221)
ASC (IT)	−1.708***	−1.022***		−0.25	−0.275	0.573	0.924*	0.465	−0.071
	(0.308)	(0.325)		(0.556)	(0.649)	(0.841)	(0.616)	(0.513)	(0.927)
ASC (FR)	−2.222***	−2.555***		−1.101**	−0.603	−0.638	1.449***	−0.044	−1.833**
	(0.34)	(0.396)		(0.572)	(0.765)	(0.924)	(0.622)	(0.507)	(1.004)
ASC (ES)	−2.328***	−2.384***		−1.779***	−0.224	0.267	0.969*	−0.17	−0.584
	(0.349)	(0.38)		(0.643)	(0.712)	(0.81)	(0.603)	(0.503)	(0.996)
Travel time (NL)	0.016	−0.02	−0.008	−0.008	−0.008	−0.008	−0.015*	−0.008	−0.008
	(0.027)	(0.024)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008) (0.006)	(0.007)	(0.007)
Travel time (IT)	−0.015	−0.055**	−0.03*	−0.03*	−0.03*	−0.03*	−0.021**	−0.03*	−0.03*
	(0.044)	(0.023)	(0.016)	(0.016)	(0.016)	(0.016)	(0.009)	(0.016)	(0.016)
Travel time (FR)	−0.01	−0.031	0.01	0.01	0.01	0.01	−0.018*	0.01	0.01
	(0.020)	(0.027)	(0.039)	(0.039)	(0.039)	(0.039)	(0.011)	(0.039)	(0.039)
Travel time (ES)	−0.009	0.008	0.018	0.018	0.018	0.018	−0.011	0.018	0.018
	(0.021)	(0.021)	(0.024)	(0.024)	(0.024)	(0.024)	(0.015)	(0.024)	(0.024)
Waiting time (NL)	0.053								
	(0.162)								
Waiting time (IT)	−0.112								
	(0.126)								
Waiting time (FR)	−0.285*								
	(0.136)								
Waiting time (ES)	0.004								
	(0.092)								
Travel cost (NL)	−0.206***	−0.206***	−0.206***	−0.206***	−0.206***	−0.206***	−0.206***	−0.206***	−0.206***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Travel cost (IT)	−0.102***	−0.102***	−0.102***	−0.102***	−0.102***	−0.102***	−0.102***	−0.102***	−0.102***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Travel cost (FR)	−0.064**	−0.064**	−0.064**	−0.064**	−0.064**	−0.064**	−0.064**	−0.064**	−0.064**
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Travel cost (ES)	−0.08***	−0.08***	−0.08***	−0.08***	−0.08***	−0.08***	−0.08***	−0.08***	−0.08***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Distant drop-off (NL)	0.165								
	(0.155)								
Distant drop-off (IT)	0.186*								
	(0.128)								
Distant drop-off (FR)	−0.181								
	(0.147)								
Distant drop-off (ES)	0.223*								
	(0.155)								
Sharing the ride (NL)	0.146								
	(0.151)								
Sharing the ride (IT)	0.137								
	(0.13)								
Sharing the ride (FR)	−0.133								
	(0.143)								
Sharing the ride (ES)	−0.057								
	(0.162)								
Risk of delay (NL)	0.023	0.023							
	(0.176)	(0.176)							
Risk of delay (IT)	−0.106	−0.106							
	(0.16)	(0.16)							
Risk of delay (FR)	−0.039	−0.039							
	(0.177)	(0.177)							
Risk of delay (ES)	−0.175	−0.175							
	(0.175)	(0.175)							
Error components	2.355***	2.167***							
	(0.147)	(0.143)							
Socio-demographics			reference						
Female	−0.167	−0.19*		−0.112	−0.102	−0.667*	−0.526**	0.109	0.214
	(0.137)	(0.145)		(0.233)	(0.331)	(0.437)	(0.286)	(0.241)	(0.528)

(*continued on next page*)

Table 6 (*continued*)

Variables	**ECS**	**EMS**	**Car**	**Bike**	**E-bike**	**Motorcycle**	**Walking**	**Public transport**	**Others**
	Est.	Est.	Est.	Est.	Est.	Est.	Est.	Est.	Est.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)
Less than 30 years old	0.808***	0.885***		0.242	0.083	0.117	0.255	−0.111	0.992*
	(0.182)	(0.187)		(0.263)	(0.441)	(0.49)	(0.377)	(0.282)	(0.616)
More than 60 y.o.	−0.906***	−1.171***		0.17	−1.233***	0.275	0.061	−0.449*	1.027*
	(0.181)	(0.204)		(0.329)	(0.407)	(0.664)	(0.357)	(0.326)	(0.741)
High education	0.246**	0.234*		0.184	−0.071	0.799**	0.198	0.196	0.476
	(0.146)	(0.153)		(0.245)	(0.349)	(0.468)	(0.288)	(0.26)	(0.546)
High income	0.398**	0.436**		−0.08	−0.939**	−0.45	−1.141**	−0.887**	−1.095
	(0.235)	(0.246)		(0.349)	(0.514)	(0.616)	(0.588)	(0.385)	(0.974)
Big city	0.718***	0.649***		0.453*	0.41	0.373	0.623**	0.77***	2.134***
	(0.201)	(0.208)		(0.336)	(0.45)	(0.496)	(0.374)	(0.298)	(0.758)
Context			reference						
During COVID	−0.033	−0.05		0.346*	−0.386	0.079	0.144	−0.01	−0.268
	(0.099)	(0.113)		(0.215)	(0.304)	(0.411)	(0.273)	(0.221)	(0.498)
During peak hours	−0.084	−0.077		−0.077	−0.053	−0.009	−0.254	−0.21	0.48
	(0.119)	(0.135)		(0.254)	(0.353)	(0.476)	(0.31)	(0.258)	(0.575)
At night	0.041	−0.033		−0.032	0.011	−0.839**	−0.417*	−0.268	−0.153
	(0.116)	(0.132)		(0.248)	(0.354)	(0.494)	(0.324)	(0.255)	(0.573)
On a rainy day	−0.167*	−0.228**		−0.057	−0.547**	−0.596*	−0.263	−0.33*	0.39
	(0.104)	(0.118)		(0.216)	(0.291)	(0.411)	(0.265)	(0.228)	(0.534)
Business purposes	0.102	0.126		0.162	−0.014	−0.661*	−0.035	0.124	−0.972**
	(0.12)	(0.136)		(0.254)	(0.359)	(0.511)	(0.315)	(0.264)	(0.585)
Leisure in another city	0.007	−0.023		−0.002	−0.112	−0.11	−0.159	0.036	0.001
	(0.111)	(0.128)		(0.242)	(0.339)	(0.469)	(0.304)	(0.247)	(0.599)

(***: p-value less than 0.01, **: p-value less than 0.05, *: p-value less than 0.1; S.E.: standard error; s: the parameter is alternative-specific; NL: Netherlands, IT: Italy, FR: France, ES: Spain)

Scaled multinomial logit (MNL), nested logit (NL), and EC-MNL models were estimated separately. The model summary is shown in Table 5. With the highest adjusted R^2 value and the lowest BIC, the EC-MNL model outperformed the MNL and NL models. Therefore, the EC-MNL model results are considered the final analysis outcomes.

The results of the EC-MNL model are reported in Table 6, where the estimates are shown before the scaling. Regarding the impact of alternatives' attributes, the estimation results show that preferences for ESMS and the marginal values of the attributes are mode-specific and heterogeneous depending on the country and socio-demographic characteristics of the respondents.

In line with economic theory, travel time and cost have a negative impact on mode choice with variations across modes and countries. The Dutch sample has the highest marginal value of travel cost. We made an attempt to investigate the interaction between travel cost and income level. High-income earners showed a lower marginal value of travel cost in the Dutch sample, but the effect was canceled out when the mode-specific main effect of high income was included. The Italians present the highest marginal value of travel time, especially for the EMS alternative. Waiting time for the ECS has a strong negative effect in the French sample, while it is not significant in other countries. Regarding the user-based relocation strategies in ECS-I, the distant drop-off seems to be favored in Italy and Spain, while other countries do not present a particular preference for one strategy over the others. The insignificant coefficient of the possibility of delay indicates that it is not a deterrent to using ESMS.

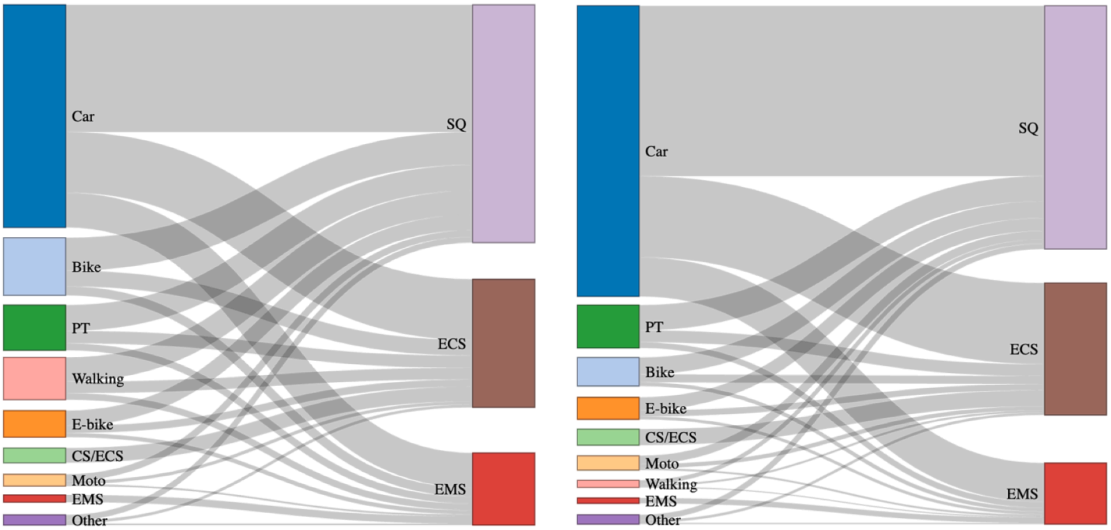
Regarding socio-demographic characteristics, all the variables apply dummy coding. In line with results from previous studies, respondents more willing to use ESMS are the younger generations ("Less than 30 years old" estimated with a positive and significant coefficient, while "Older than 60 years old" negative and significant), high-income earners ("High income" positive and significant) and citizens living in larger cities ("Large city" positive and significant). Males are more attracted by EMS, and similarly, highly educated people have high preferences for ESMS ("High education" positive and significant). The significant error component coefficients confirm the random effects and correlations among the ESMS alternatives.

The travel context has an impact on mode choice. Preference for bike is higher during COVID-19, while at night there is a lower preference for motorcycle and walking. The weather shows the highest impact on mode choice. On a rainy day, there is a lower

Table 7
Mode- and country-specific WTP.

	ECS	**EMS**	**Car**	**Bike**	**E-bike**	**Motorcycle**	**Walking**	**Public transport**	**Others**
Netherlands	−0.078	0.097	0.039	0.039	0.039	0.039	**0.073**	0.039	0.039
Italy	0.147	**0.539**	**0.294**	**0.294**	**0.294**	**0.294**	**0.206**	**0.294**	**0.294**
France	0.156	0.484	−0.156	−0.156	−0.156	−0.156	**0.281**	−0.156	−0.156
Spain	0.113	−0.100	−0.225	−0.225	−0.225	−0.225	0.138	−0.225	−0.225

(Note: values are in bold if both the marginal values of travel time and cost are significant.)



(a) for 4 km trips

(b) for 10 km trips

Fig. 2. Sankey diagram of the current mode choice (left) and the chosen alternatives in the experiment (right) for 4 km (Subfigure a) and 10 km trips (Subfigure b), respectively. (Note: SQ = Status quo, PT = public transport, CS = Car-sharing services, ECS = Electric car-sharing services, EMS = Electric micro-mobility services, moto = motorcycle, Other = ride-sharing, taxi.)

Table 8
The current mode of respondents who selected ECS and EMS.

Current mode	Percentage of selecting ECS or EMS							
	Electric Car-sharing (ECS)							
	4 km				10 km			
	ES	FR	IT	NL	ES	FR	IT	NL
Car	44.3%	46.4%	60.0%	39.4%	64.5%	63.4%	67.9%	59.7%
Bike	9.6%	9.9%	8.2%	31.2%	5.0%	9.1%	4.6%	12.4%
E-bike	6.0%	6.0%	7.7%	12.5%	6.3%	5.6%	6.9%	12.4%
Motorcycle	5.3%	3.3%	4.0%	1.5%	4.7%	4.7%	4.9%	2.0%
Public transport	16.5%	20.3%	9.5%	11.4%	13.8%	11.2%	11.8%	12.9%
Walking	16.2%	11.3%	9.1%	2.9%	4.1%	3.8%	2.6%	0%
Other	2.0%	2.8%	1.5%	1.2%	1.6%	2.1%	1.3%	0.5%
	Electric Micro-mobility Sharing (EMS)							
	4 km				10 km			
	ES	FR	IT	NL	ES	FR	IT	NL
Car	51.6%	45.7%	57.2%	37.0%	56.7%	59.8%	69.1%	47.5%
Bike	7.8%	13.2%	7.4%	32.9%	4.3%	10.3%	4.4%	12.5%
E-bike	7.5%	9.3%	11.3%	9.6%	4.8%	9.3%	5.9%	18.8%
Motorcycle	2.6%	3.5%	5.6%	3.2%	8.6%	4.7%	8.8%	3.8%
Public transport	15.4%	15.1%	10.5%	12.3%	16.6%	8.4%	7.4%	13.8%
Walking	12.5%	10.9%	6.7%	4.6%	4.3%	2.8%	0.7%	3.8%
Other	2.6%	2.3%	1.3%	0.5%	4.8%	4.7%	3.7%	0%

(Note: due to the rounding effect, the sum of percentages across one ESMS alternative, one country, and one distance level might not always be 100%.)

preference for ESMS, e-bike, motorcycle, and public transport. For business trip purposes, there is a lower preference for motorcycle and other means of transport such as ride-sharing modes.

Combining the coefficients of travel time and cost, we investigated the willingness to pay (WTP) to save a minute of travel time, obtained by dividing the travel time coefficient by that of travel cost. We calculated mode- and country-specific WTP, as shown in Table 7, where values are in bold if both the marginal values of travel time and cost are significant. The WTP is not significant for the ECS. For EMS, the WTP is significant only in Italy, with a value of 0.53 €/min, which is higher compared to the WTP for other modes (0.29 €/min). The value of the WTP corresponds to a value of time of 31.8 €/hour, which is higher compared to 23.7 €/hour estimated by Krauss et al. (2022) in Germany, and 16 €/hour by Baek et al. (2021) in South Korea, in which sharing mobility was considered as the last-mile solution instead of for the entire trip. For the WTP for other modes, we did not find significant differences across modes.

Table 9
Simulated shares of SQ, ECS, and EMS, depending on the current mode.

Current mode	SQ 4 km	ECS	EMS	SQ 10 km	ECS	EMS
Spain	**64.7% [61.8–70]**	**23.9% [19.5–26]**	**11.4% [10.5–12.1]**	**63.7% [57.3–72.7]**	**24.3% [17.3–29]**	**12.0% [10.0–13.7]**
Car	67.2% [64.5–72.5]	22.2% [17.9–24.2]	10.5% [9.6–11.3]	65.6% [59.3–74.4]	23.0% [16.2–27.6]	11.4% [9.4–13.1]
Bike	45.3% [42.2–51.6]	37.0% [31.5–39.4]	17.8% [16.9–18.5]	52.9% [46.6–63.4]	31.4% [23.2–36.4]	15.7% [13.4–17]
E-bike	47.5% [44.4–53.7]	35.6% [30.2–38.0]	17% [16.1–17.6]	49.1% [42.3–59.2]	34.2% [25.6–38.9]	16.7% [15.2–18.8]
Moto	63.0% [59.8–68.2]	24.9% [20.7–27.3]	12.1% [11.2–12.9]	60.4% [53.6–69.3]	26.6% [19.5–31.5]	13.0% [11.3–14.9]
PT	62.8% [59.7–68.4]	25.3% [20.7–27.6]	11.8% [10.9–12.7]	64.7% [58.3–73.8]	23.7% [16.6–28.5]	11.7% [9.5–13.3]
Walking	70.9% [68.3–75.8]	19.8% [15.8–21.7]	9.3% [8.4–10.1]	56.4% [50.1–66.9]	29.6% [20.9–33.8]	14.1% [12.2–16.1]
Other	67.9% [65.1–72.9]	21.7% [17.6–23.8]	10.4% [9.4–11.1]	60.1% [53.1–69.3]	26.5% [19.4–31.8]	13.4% [11.3–15.1]
France	**72.1% [67.8–78.4]**	**21.4% [16–24.7]**	**6.5% [5.6–7.5]**	**70.3% [63.8–79.6]**	**24.1% [16.4–29.3]**	**5.6% [4–6.9]**
Car	77.2% [73.1–82.9]	17.5% [12.7–20.6]	5.3% [4.5–6.3]	74.4% [68.3–83.0]	20.8% [13.6–25.7]	4.8% [3.3–6.0]
Bike	62.2% [57.0–70.4]	28.8% [21.7–32.7]	9.0% [7.9–10.3]	65.3% [58.2–76.0]	28.0% [19.1–33.7]	6.7% [4.8–8.1]
E-bike	39.8% [34.7–48.4]	46.5% [38.4–50.4]	13.7% [13.1–14.9]	47.2% [38.9–58.9]	42.8% [33.2–49.7]	10.0% [8.0–11.4]
Moto	49.0% [43.6–57.6]	38.8% [31.3–43.2]	12.2% [11.1–13.2]	47.9% [40.4–59.8]	42.7% [32.2–48.2]	9.5% [8.0–11.4]
PT	65.6% [60.9–73.1]	26.3% [19.9–30.0]	8.1% [7.0–9.1]	65.8% [58.7–76.2]	27.9% [19.0–33.4]	6.3% [4.7–7.9]
Walking	79.5% [75.9–84.8]	15.7% [11.3–18.5]	4.7% [3.9–5.6]	67.1% [59.2–76.8]	26.7% [18.7–33.3]	6.2% [4.4–7.5]
Other	66.1% [61.9–72.7]	25.9% [20.0–29.0]	8.0% [7.3–9.0]	62.1% [55.1–72.1]	30.4% [22.5–36.6]	7.5% [5.4–8.4]
Italy	**65.3% [58.8–75.7]**	**23.2% [15.6–26.6]**	**11.5% [8.7–14.6]**	**66.1% [55.8–81.0]**	**26.6% [15–33.6]**	**7.4% [4.0–10.7]**
Car	69.6% [63.2–79.4]	20.3% [13.2–23.8]	10.1% [7.4–13]	71.3% [61.2–85.2]	22.5% [11.7–29.5]	6.2% [3.1–9.4]
Bike	61.7% [54.1–72.8]	25.8% [17.5–29.6]	12.5% [9.7–16.3]	47.3% [36.9–68.5]	40.6% [24.7–47.5]	12.2% [6.8–15.5]
E-bike	35.6% [29.2–48.6]	43.2% [33.2–45.9]	21.2% [18.2–24.9]	28.9% [19.7–47.8]	56.6% [41.4–61.3]	14.5% [10.7–19.1]
Moto	57.2% [50.8–69.1]	28.8% [19.9–31.9]	14.0% [11.0–17.4]	49.7% [38.6–68.3]	39.0% [25.1–46.7]	11.2% [6.6–14.7]
PT	61.8% [55.0–73.2]	25.4% [17.2–29.1]	12.8% [9.6–15.9]	53.8% [42.6–72.9]	36.2% [21.3–43.5]	10.0% [5.8–14]
Walking	61.8% [54.6–72.9]	25.5% [17.4–29.3]	12.7% [9.7–16.1]	42.9% [32.5–63.6]	45.7% [29.3–52.6]	11.4% [7.0–14.9]
Other	63.8% [57.0–73.9]	24.0% [16.6–27.5]	12.1% [9.5–15.5]	50.8% [40.0–68.8]	37.4% [24.7–45.7]	11.8% [6.5–14.2]
Netherlands	**91.9% [89.1–95.8]**	**4.9% [2.5–6]**	**3.2% [1.7–4.8]**	**89.9% [85.0–96.6]**	**7.4% [2.5–10.2]**	**2.7% [0.8–4.8]**
Car	93.5% [91.1–96.7]	3.9% [2–4.9]	2.6% [1.3–4]	92.2% [87.9–97.5]	5.7% [1.9–8.2]	2.1% [0.6–3.9]
Bike	92.4% [89.5–96.1]	4.5% [2.3–5.8]	3.1% [1.6–4.7]	89.7% [84.7–96.8]	7.5% [2.4–10.4]	2.8% [0.8–4.9]
E-bike	91.4% [88.4–95.5]	5.4% [2.8–6.7]	3.3% [1.7–4.9]	87.9% [82.8–96.2]	9.3% [2.9–12.1]	2.8% [0.9–5.1]
Moto	73.9% [66.9–83.8]	15.5% [9.5–18]	10.6% [6.7–15.1]	62.4% [50.0–82.6]	26.5% [13.0–33.8]	11.1% [4.4–16.2]
PT	80.2% [74.2–89.0]	12.2% [6.5–14.2]	7.7% [4.4–11.5]	78.3% [69.3–91.8]	15.7% [6.1–20.8]	6.0% [2.1–9.9]
Walking	95.3% [93.8–97.7]	2.8% [1.3–3.4]	2.0% [0.9–2.8]	85.8% [81.4–95.9]	10.2% [3.0–12.4]	4.0% [1.1–6.2]
Other	97.3% [96.3–98.7]	1.7% [0.8–2.1]	0.9% [0.5–1.6]	93.1% [90.4–97.9]	5.1% [1.6–6.6]	1.7% [0.5–3]

(Note: the values before the brackets indicate the shares obtained by assuming for each attribute the middle level, and the values within brackets indicate the shares in percentages obtained with the attribute levels that minimize or maximize the probability of choosing ECS and EMS.)

For example, the WTP in Italy (0.29 €/min) is very close to that (17.5 €/hour) for using car estimated in a *meta*-analysis conducted in Europe (Wardman et al., 2016).

To investigate the heterogeneity of choices depending on the current mode, we analyzed the flows from the current means of transport (outflows hereafter) to the choices in the SP experiment (inflows), for both 4 km and 10 km trips (Fig. 2) using the values of the middle attribute levels. The left columns in a subfigure indicate the current modes, while the columns on the right indicate the choices in the SP experiment. The higher one column is, the larger the number of respondents selecting the corresponding mode. The grey linkages show the flows. The thicker the linkage, the larger the number of respondents in the flow. The flows are indicative of potential substitution patterns. The outflows highlight that, in relative terms, car users have the lowest propensity to switch to ESMS. On the other side, the inflows show that the majority of respondents who chose the ESMS options in the experiment are not current car users. This evidence highlights the possibility of ESMS being considered as an alternative option with lower interest by car users compared to other mode users.

We investigated potential substitution patterns in specific countries by analyzing the relationship between the current mode and mode choice in the SP experiment (Table 8). The table shows the distribution of the current modes of respondents who selected ECS (above), and EMS (below). The results are based on the observed responses to all the choice tasks presented in the experiment whose design is explained in Section 2.1. For example, among those who selected ECS in the 4 km distance, 44.3% are current car users, 9.6% are current bike users, and so on. The values are based on frequencies in the SP experiment. We observe that the car is the most frequent current mode in all the countries for both 4 km and 10 km trip distances. The result seems to indicate that ESMS could induce a reduction in car use. However, it is important to notice that for 4 km trips, depending on the context, substantial demand for ESMS would come from sustainable modes. For example, in the Netherlands, up to 32.9% of the demand for EMS would come from bike users, while in Spain 16.4% of ECS demand would come from public transport users.

The attractiveness of ESMS is sensitive to changes in their attributes and varies with the current transport modes. In Table 9, we show the simulated shares of ESMS, depending on the current transport mode and attribute levels. To calculate the simulated shares, we changed the values of the attribute and estimated the share of respondents who would select the status quo (SQ), ECS, and EMS, in response to changes in attributes' levels. The estimates are based on the results of the model discussed in Table 6. The values before the brackets indicate the shares obtained by assuming for each attribute the middle level of those presented in Table 2; values between brackets indicate the shares obtained with the attribute levels that minimize or maximize the probability of choosing ECS and EMS. For every simulated choice, we included the individual-specific socio-demographic variables and the same context of the design. The socio-demographic characteristics and the context are kept in the simulation for all the scenarios so that the changes in the simulations are only the effects of changes in alternatives' attributes. As shown, in the Netherlands, the respondents in general are less willing to switch to ESMS compared to the other countries. For a 4 km trip, 91.9% of respondents are expected to keep using the status quo, with a value ranging from 89.1% to 95.8% depending on the attribute levels. Looking at mode-specific simulated shares, it is important to note that for car users, the resistance to change (i.e., the shares of respondents loyal to the status quo) is always higher than the average. The introduction of ESMS thus seems to be more attractive for respondents whose current modes are sustainable modes of transport such as public transport or bike. For example, for a 4 km trip, 67.2% of car users in Spain are expected to maintain the status quo, compared to 45.3% of bike users and 62.8% of public transport users, and so on.

4. Discussion

In this section, we discuss the results with relevance to the evidence from the literature regarding the profile of current and potential users of ESMS, the impact of service characteristics, and the substitution patterns of mode choice. Reflections on the potential unsustainability of ESMS are also provided, together with practical implications.

4.1. *Profile of current and potential users*

The current users of ESMS in our sample correspond to younger generations, highly educated, high-income earners, and those living in large cities, which is in line with previous research (Aguilera-García et al., 2020; Bai & Jiao, 2020; Burkhardt & Millard-Ball, 2006; Campbell et al., 2016; Cartenì et al., 2016; Curtale et al., 2021a, 2021b; Kopp et al., 2015; Prieto et al., 2017). For the current nonusers, the results of the SP experiment show that ESMS represent an attractive solution for urban mobility, with ECS being more attractive than EMS for longer distances. Preferences for ESMS are heterogeneous across respondents depending on socio-demographic characteristics. The analysis confirms the evidence of the literature about potential ESMS users being more attractive to young and wealthier groups, especially those living in large cities. Unexpectedly, we did not find significant gender differences, different from previous studies that found a higher preference for males in the USA (Bai & Jiao, 2020), the Netherlands (Curtale et al., 2021a, 2021b), and other urban contexts such as Salerno (Italy) (Cartenì et al., 2016), London (UK), Madrid (Spain), Paris (France) and Tokyo (Japan) (Prieto et al., 2017).

Regarding the country-level comparison, the preference for ESMS and in particular EMS is the lowest in the Netherlands, confirming the finding that e-scooters are less compatible in context with a strong bike culture. The intrinsic preference for ESMS is highest in Italy, while in France the preference for EMS is lower compared to that for ECS.

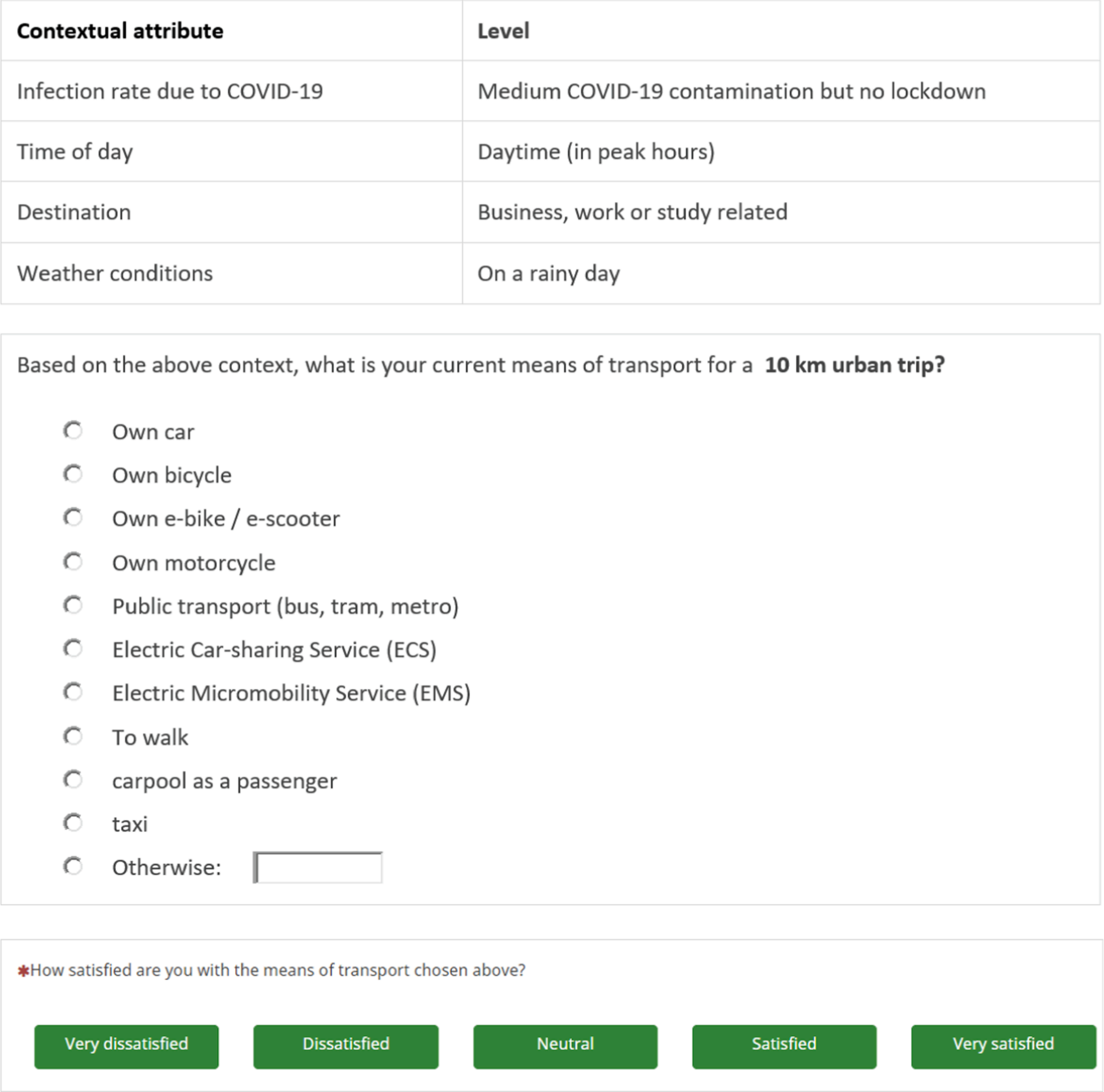
4.2. *The impact of ESMS characteristics*

ESMS-related characteristics have an impact on respondents' preferences. In general, the respondents prefer shorter travel times and lower costs, in line with the conventional travel behavioral theory. The total trip travel time is made up of different components, such as in-vehicle travel time, walking time to access and egress the vehicles, and waiting time. In our SP experiment, we did not find significant differences in the perceptions of in-vehicle travel time and walking time. For the user-based relocations, the alternative drop-off appears favored by respondents in Italy and Spain, but the respondents in other countries do not show a particular preference for the incentives. Previous studies show that sharing the vehicle is usually less preferred (Curtale et al., 2021a; Wu et al., 2020), but it seems that the major hassle is due to the extra travel time to collect other passengers rather than the presence of the other passengers itself (Lavieri & Bhat, 2019), which is not the case in our study.

4.3. *The potential unsustainability of ESMS*

The analysis of substitution patterns of mode choice indicates that heterogeneous adoptions depend on travel distance levels, countries, and status quo options. The results of the SP experiment show that current car users have a weaker preference for ESMS compared to the users of other means of transport.

Although several studies show that ECS have a huge potential to replace private ICE vehicles (Le Vine & Polak, 2019; Martin & Shaheen, 2011) and EMS are particularly useful as the last-mile solution (Baek et al., 2021; Fearnley et al., 2020), our study shows that unintended substitutions might happen. For example, EMS might be considered as an alternative for the whole trip and replace conventional transport modes with lower emissions. ECS are more likely to substitute public transport compared to private ICE vehicles, while EMS are more likely to substitute an active or electric mode trip. These results seem to indicate that depending on the context and substituted means of transport, the adoption of ESMS might not always reduce trip-related emissions from a life-cycle assessment perspective. As an example, a study in the USA showed that a positive environmental impact of e-scooter takes place only if they substitute private ICE vehicles, while in 65% of the cases, their environmental impact is higher than the substituted modes (Hollingsworth et al., 2019). The main reason is that the environmental cost of running those services is non-negligible due to the material manufacturing, the daily collection for charging, the rebalance of vehicles from over-supplied to under-supplied areas, the repairing of broken vehicles, and the rate of stolen ones, which has been shown in life-cycle assessment studies of e-scooter (Hollingsworth et al., 2019) and e-bikes (Luo et al., 2019). In addition, a study conducted in 30 European cities (Li et al., 2022) showed an average of 33% of wasted energy during idle times, indicating inefficiencies in fleet management.



Contextual attribute	**Level**
Infection rate due to COVID-19	Medium COVID-19 contamination but no lockdown
Time of day	Daytime (in peak hours)
Destination	Business, work or study related
Weather conditions	On a rainy day

Based on the above context, what is your current means of transport for a **10 km urban trip?**

- ○ Own car
- ○ Own bicycle
- ○ Own e-bike / e-scooter
- ○ Own motorcycle
- ○ Public transport (bus, tram, metro)
- ○ Electric Car-sharing Service (ECS)
- ○ Electric Micromobility Service (EMS)
- ○ To walk
- ○ carpool as a passenger
- ○ taxi
- ○ Otherwise: ☐

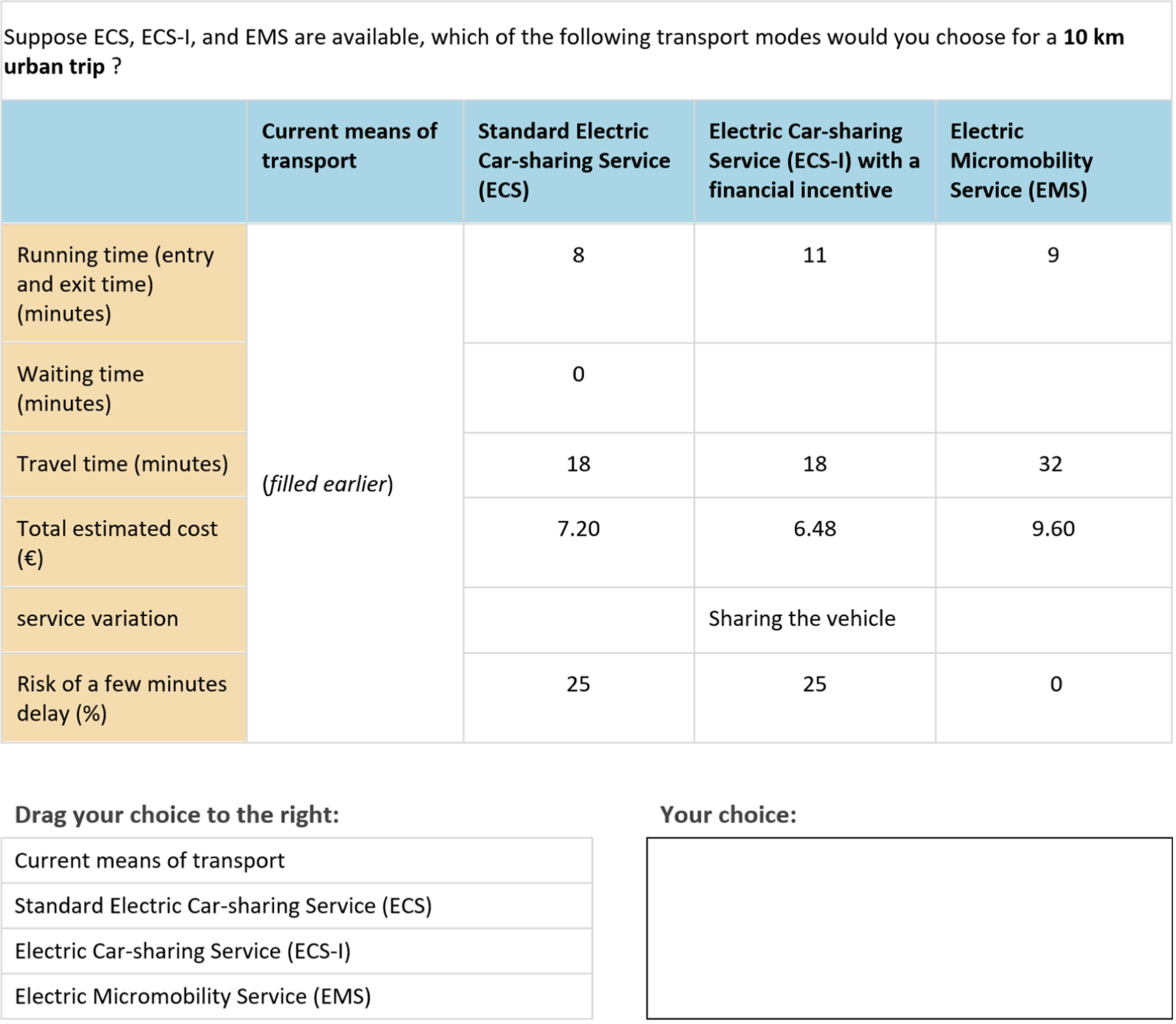
*How satisfied are you with the means of transport chosen above?

Fig. A1. Screenshot of survey page on the choice of status quo option.

With technological advances, ESMS can reduce the environmental impact of CO_2 equivalent per km only if they substitute enough private ICE vehicles. In the case of substituting active modes or public transport, ESMS have a higher environmental impact than the replaced transport modes, especially due to their short lifespan. Therefore, to make urban mobility more sustainable, with technologies available at the time of writing, there should be a massive substitution from ECS and EMS to private ICE vehicle usage. However, the results from the SP experiment show non-negligible unintended substitution effects. Hence, without proper interventions, the introduction of ESMS could result in higher greenhouse gas emissions from a life-cycle perspective.

4.4. Practical implications

Several practical implications can be formulated for sharing mobility service operators and public institutions. The most imperative action to be taken by transport planners is to guarantee that ESMS will result in a substitution of private ICE vehicles and not in a reallocation of travelers already adopting sustainable alternatives. Lower prices of ESMS and the reduction of access and egress time through a denser distribution of stations and fleets appear to spark ESMS usage. For municipalities aiming at regulating the use of ESMS, it is necessary to have a clear understanding of current travel patterns for formulating adequate policies. ESMS can increase, as intended, the resilience of urban mobility, but from a sustainability perspective, the higher replacement of public transport and active modes from ESMS might have a negative environmental impact. Possible measures to limit the unintended substitution effects could be



Suppose ECS, ECS-I, and EMS are available, which of the following transport modes would you choose for a **10 km urban trip** ?

	Current means of transport	**Standard Electric Car-sharing Service (ECS)**	**Electric Car-sharing Service (ECS-I) with a financial incentive**	**Electric Micromobility Service (EMS)**
Running time (entry and exit time) (minutes)	*(filled earlier)*	8	11	9
Waiting time (minutes)		0		
Travel time (minutes)		18	18	32
Total estimated cost (€)		7.20	6.48	9.60
service variation			Sharing the vehicle	
Risk of a few minutes delay (%)		25	25	0

Drag your choice to the right:

- Current means of transport
- Standard Electric Car-sharing Service (ECS)
- Electric Car-sharing Service (ECS-I)
- Electric Micromobility Service (EMS)

Your choice:

Fig. A2. Screenshot of a choice task at the 10 km trip level.

reducing the parking supplies for private cars at points of interest and deploying targeted promotion of ESMS to current car users compared to other travelers, for example, through advertisements in parking areas.

To increase the sustainability of ESMS deployment, it is necessary to alleviate the rebalance needs, improve the efficiency of fleet management to reduce energy waste, and increase the substitution of private ICE vehicle usage (Li et al., 2022; Luo et al., 2019). To reduce the rebalance needs, municipalities and ESMS operators can share data about usage patterns and deploy efficient mobility services (Anthony Jnr et al., 2020), such as a strategic allocation of ESMS vehicles. Concerning the substitution of private ICE vehicles in areas with high car dependency, the introduction of ESMS could be beneficial. Contrarily, in areas with large adoption of sustainable transport modes, the introduction of ESMS might just result in the reallocation of travelers with a current low mobility-related environmental impact. In those areas, additional soft and hard measures would be needed, such as the integration of ESMS into MaaS platforms, or the establishment of ESMS-dedicated areas and private ICE vehicle-restricted areas. As for MaaS platforms that are attractive not only in big cities but also in suburban areas, they should prioritize the inclusion of ECS, given that the higher preference for MaaS bundles including ECS is over those with EMS (Brezovec & Hampl, 2021). The promotion of MaaS would be particularly indicated for medium-distance trips and in countries with a higher car dependency, such as Italy or France. In addition, the inclusion of ECS-I in MaaS could have the potential to attract price-sensitive consumers and reduce the rebalancing cost for ECS operators.

4.5. Limitations and future work

This study presents limitations that can be used as indications for future studies. First of all, this paper does not consider the built environment information, such as the availability of bicycle lanes and the density of charging stations, which are relevant aspects of EMS and ECS respectively. Second, the results are based on choice observations in repeated hypothetical choice scenarios. The absence of real choices limits the reliability of the results, and the administration of several choices to the same respondent might affect the estimates due to autocorrelation across answers. The extension of the present study with revealed preference data and the collection of one observation per respondent may provide more robust evidence. Third, this study has been conducted in four different European countries where the conventional mobility infrastructure is relatively well-developed. The implications may be transferred, with adequate caution, to other countries with similar penetration of car use and infrastructure, but it would be interesting to replicate the study in emerging markets where the ESMS have large space for rolling-out. Fourth, some assumptions were used to generate the experimental designs, for example, the same travel time for ECS and ECS-I. Different travel times can be considered in the future. In addition, the parameters of travel time for ECS and EMS turned out to be not significant in NL, FR, and ES. A different design focusing on the exploration of the heterogeneity of travel time would allow us to (i) check whether the effect is due to the characteristics of the design in those countries, and (ii) provide further analysis, such as the calculation of travel time elasticity and the comparison with travel cost elasticity. Fifth, the impacts on mobility demand (Liao et al., 2013), accessibility (Qin & Liao, 2021), and emissions (Labee et al., 2022) associated with different substitution patterns in a multimodal system are not calculated and could be an objective of future studies. We will address these issues in future work.

5. Conclusions

In this study, we investigate preferences for ESMS in four different European countries to understand their potential for urban mobility. Our results show that ESMS have a higher potential to attract younger generations and a wealthier population. The degree of substitution of ESMS alternatives is higher for public transport and other sustainable modes than for cars. Therefore, ESMS represent a complementary means of transport that can contribute to the resilience of urban mobility, but their effectiveness in increasing the sustainability of urban transport is context-dependent. In fact, due to the high environmental costs of production and operations associated with the ESMS, the introduction of ESMS for urban mobility might have a negative impact in contexts where there is already a high usage of conventional sustainable modes. The results of this study offer insights into the current and potentially substituted patterns of urban mobility, which can be utilized by transport authorities and ESMS operators for sustainably deploying ESMS.

CRediT authorship contribution statement

Riccardo Curtale: Conceptualization, Investigation, Formal analysis, Writing – original draft. **Feixiong Liao:** Conceptualization, Investigation, Formal analysis, Writing – review & editing, Supervision.

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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Appendix A

(See Figs. A1-A2).

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