Robotaxis or autonomous shuttles? The role of urban representations and travel habits in tomorrow's mode choice in France

SALLADARRE, Frédéric and LE BOENNEC, Rémy and BEL, Marlène

2021

Robotaxis or autonomous shuttles? The role of urban representations and travel habits in tomorrow's mode choice in France

Frédéric Salladarré [1,2], Rémy Le Boennec [*,3], Marlène Bel [3]

[*] *Address for Correspondence:* remy.leboennec@gmail.com
[1] CREM - UMR 6211, Univ Rennes, CNRS, F-35000 Rennes, France
[2] LEMNA, Université de Nantes, Chemin de la Censive du Tertre, BP 52231, 44322 Nantes Cedex 3, France
[3] VEDECOM Institute, 23 bis, Allée des Marronniers, 78000 VERSAILLES, France

Abstract: Autonomous vehicles (AVs) will profoundly modify our travel habits. The collective impact of AVs will differ according to the autonomous mode choice. In this paper, we apply a simultaneous-equation model to a database from an original 2017 survey of French mobility users to analyze their acceptance of two forms of autonomous transport mode: autonomous shuttles and robotaxis (N=3,297). Our results show that the intention to use autonomous shuttles is on average greater than robotaxis. Gender and age influence autonomous mode choice, as well as the current transport mode. In addition, location and urban representations play a central role.

Keywords: robotaxi; autonomous shuttle; autonomous vehicle; urban representation; travel habit; intention to use; acceptance; transport mode; autonomous mode choice; simultaneous-equation model

To cite this version: Salladarré, F., Le Boennec, R., & Bel, M. (2021). Robotaxis or autonomous shuttles? The role of urban representations and travel habits in tomorrow's mode choice in France. *Journal of Transport Economics and Policy (JTEP)*, *55*(3), 237-259.

1.0 Introduction

Autonomous Vehicles (AVs) are expected to profoundly modify our travel habits within the next five to ten years. Beyond the technological performance of the continuously-developing connected systems of driverless or self-driving vehicles, the question has recently risen of the impacts of AVs on the roads (Fagnant and Kockelman 2015; Berrada and Leurent 2017). It is commonly accepted that these impacts will vary widely according to the particular autonomous modes of transport put forward: (1) autonomous shuttles, (2) privately-owned self-driving cars and (3) robotaxis. The first corresponds to collective mobility, as autonomous shuttles are mostly supposed to complement existing public transport networks as the 'first-mile/ last-mile' solution to/from mass transport nodes such as railway stations (Merat et al. 2017; Shen et al. 2018). On the contrary, the second and the third types of AVs refer to individual mobility, whether personal (private self-driving cars) or on-demand (robotaxis).[1]

Much is expected of autonomous modes of transport. AVs are supposed to enhance mobility, especially for permanently- (disabled or elderly) or temporarily- (medication or alcohol) impaired drivers (Becker and Axhausen 2017). At the same time, they are expected to reduce congestion (Payre et al. 2014; Berrada and Leurent 2017). As driverless vehicles are imagined to be electric, there are no associated greenhouse-gas emissions, and the noise exposure of urban inhabitants will also fall. The greatest expectation concerns road-safety issues, as AVs are hoped to lead to sharply lower road-mortality rates (Schoettle and Sivak 2014; Lang et al. 2016). Last, AVs provide useful time during trips, as with fully-automated driving the 'driver' can 'drive' hands off/ eyes off.[2]

[1] We assume that individuals would not have thought of the particular case of shared robotaxis (in the sense of ridesharing), as this form of mobility (conventional pooling taxis) was not very developed in France when the questionnaire was launched.

[2] The 2014 SAE International classification (revised in 2016) lists the following autonomy levels: (L0) Manual driving; (L1) Either lateral (for example, lane-keeping system) or longitudinal (for example advanced cruise control) control are automated, and the driver must always pay attention to the road; (L2) Automated lateral and longitudinal control (for example Tesla), and the driver must always pay attention to the road; (L3) L2 + the driver

These benefits do not appear equally for the different autonomous modes of transport. With private or on-demand mobility, the congestion externality will be reduced via the greater prevalence of self-driving cars (a queue of automated cars is supposed to be able to start at exactly at the same time when traffic lights turn green, for example). However, this benefit may not be as large as expected if every private conventional car is systematically replaced by a self-driving car (with no change in the number of vehicles on the road). Moreover, vehicles without drivers may be found on the road, either going to fetch the mobility user or looking for parking if not in use (Poulhès and Berrada 2019). One knock-on effect is that the useful time gained from the use of private self-driving cars may lead users to choose more-distant residential locations, as the time spent in the car, now not used for driving, can be devoted to other activities (Orfeuil and Leriche 2019). Beyond the current benefits of public transport in crowded urban areas, public autonomous mobility may, in certain situations, better tackle congestion in the future than private or on-demand autonomous mobility.

Most of the work on the determinants of autonomous mode choice is quite recent. That in social psychology takes into account the concept of acceptance to determine autonomous mode choice. The acceptance of a new object (a technology, service or method) is a prerequisite for the use of this object (Bel et al. 2019). The analysis of object acceptance corresponds to study social representations that will make the object useful and attractive (Bobillier Chaumon 2013). Individual acceptance of a new technology is a three-step process: *a priori* acceptability (the first step), acceptance to use (the second step) and appropriation to use (the third step). We here focus on the first step (*a priori* acceptability), as the two travel objects we analyze are forthcoming innovations and most individuals will not have had the opportunity to use them and can only form vague ideas about them (Bel et al. 2016). At this stage, (1) object acceptance

---

does not need to monitor the road continuously, but must be ready to recover control of the vehicle at any time; (L4) L3 + the vehicle is capable of performing a safety maneuver (for example stop alone) if after a request for manual recovery the driver has not taken control; and (L5) Fully-automated driving with no need for a driver.

comes from the comparison between the current situation and the future benefits brought about by the new technology (Bobillier Chaumon and Dubois 2009) and (2) this acceptance is measured by the intention to use the new object, which is the direct determinant of real use (for example, Venkatesh and Bala 2008; Venkatesh et al. 2003). Throughout the rest of the manuscript, we will use the term 'acceptance' for ease of reading.

Three types of analysis of the acceptance or intention to use AVs have been carried out. In the first, the intention to use AVs (or the acceptance of AVs) is estimated for different autonomy levels (highly-automated cars or fully-automated cars): Rödel et al. (2014), Schoettle and Sivak (2015), Abraham et al. (2017), Liu et al. (2019). The second group focuses on the intention to use various autonomous modes of transport: personal (single-occupant privately-owned cars), on-demand (robotaxis) and collective (autonomous shuttles): Krueger et al. (2016), Wang and Akar (2019), Pettigrew et al. (2019), Berrada et al. (2020). Kamel et al. (2019) simulate the respective modal shares of an on-demand mobility offer as a function of the current transport mode: conventional private car, public transit (with a driver) and active modes. The last group of analyses focus on particular categories of mobility users (Abraham et al. 2017, for the elderly) or trip characteristics (Wang and Akar 2019, Zhou et al. 2020).

We in this paper focus on the determinants of modal shift. We first consider a transport mode that is expected to encourage car-owners to give up, under certain conditions, their personal vehicle: on-demand mobility in the form of robotaxis. We then turn to a more environmentally-friendly autonomous mode of transport, autonomous shuttles, given the higher average vehicle-occupancy rates, the connection to existing transport networks and the need to walk to the stop. We thus ask respondents about their intention to use one of those transport modes, were they to be available. To our knowledge, ours is the first analysis comparing the results regarding on-demand *versus* collective autonomous mobility.

A number of explanatory variables of the intention to use AVs commonly appear in the literature cited above: sociodemographic variables (gender, age, marital status, number of children, education and income), technophilia characteristics, attitudes (happiness score and the perception of the future) and mobility variables (having a driver's license, driver experience, the number of crashes and current transport mode). More innovative are location and urban representations (the way individuals view the city), given that urban residents are usually considered more likely to accept or intend to use AVs (Bansal et al. 2016; Wang and Akar 2019). In this paper, we further investigate location, both objective (living in large, medium or small urban areas, or in isolated municipalities) and subjective, via the way in which respondents perceive urban areas (as a place to live or a place to carry out activities, for example).

The relationships between urban forms and mobility patterns are key issues for policy makers. Urban planners aim to construct or re-construct livable cities, marrying acceptable levels of housing density, daily-life facilities regarding shopping, education and health, green spaces and innovative solutions for mobility within these areas (ADEME 2018). The particular role to be assigned to the different types of AVs as complements to active modes remains to be established. Some results suggest that AV technology will mostly be accepted (and therefore used) in urban areas. Our results show that this view is too simplistic, with the role of multipolar areas. This yields new insights regarding the areas where AVs may be deployed in France, the desired destinations, and the relevant ways of getting there. As autonomous shuttles are mostly viewed as a way to travel the first or last mile, robotaxis are considered to provide a better service in terms of the variety of destinations, but at a greater cost to the user.

The remainder of the paper is structured as follows. Section 2 discusses our research design, data, and the simultaneous-equation model that we use for the estimation. Section 3 presents and discusses our results. Last, we provide some concluding remarks in Section 4.

2.0 Materials and method

2.1 Research design

We use an original online survey conducted in 2017 on 3,297 French respondents to look at the determinants of the intention to use different forms of fully-autonomous mobility (robotaxis and autonomous shuttles). We explain this intention by sociodemographic characteristics, attitudinal variables, technophilia characteristics and mobility variables.

We assume different intentions to use one or the other autonomous mode. Indeed, recent studies have shown that the nature of the object could induce a difference in acceptance, as could a difference in use (Bel et al. 2019, Berrada et al. 2020). More specifically, we test in this study the following hypotheses (Figure 1).

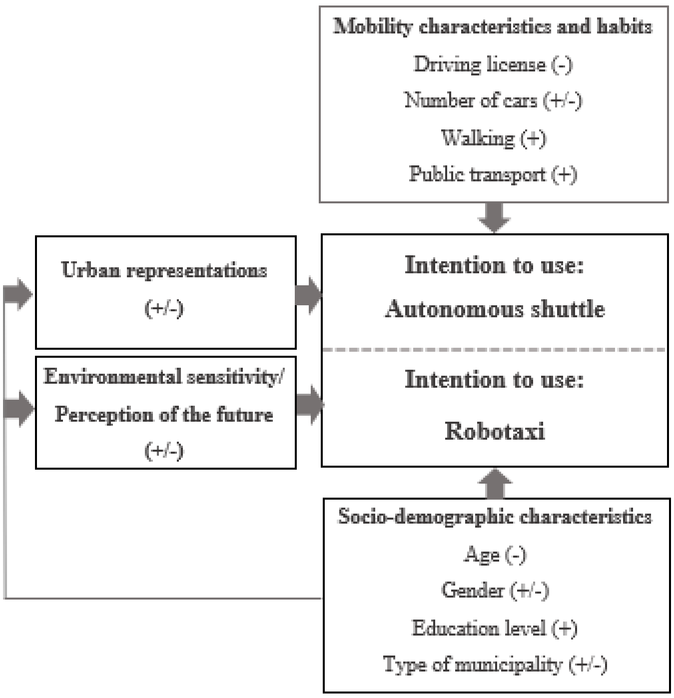


Fig. 1. Hypothetical relationships between the variables

Note: Expected sign of the relationship in parentheses

(1) Certain *sociodemographic characteristics* are expected to directly influence the intention to use AVs. In most previous studies, age is supposed to be conversely related to automation acceptance (Schoettle and Sivak 2014, Bansal et al. 2016), such as education

level (Kyriakidis et al. 2015, Bansal et al. 2016, Wang and Akar, 2019). The results are less clear considering gender or the type of municipality.

(2) Certain *mobility characteristics and travel habits* directly influence the intention to use autonomous shuttles or robotaxis. Concerning the main mode of transport currently used, Krueger et al (2016) find that multimodality (including public transport) is positively associated with the acceptance of shared automated vehicles.

(3) Certain *attitudinal variables* are expected to directly influence the intention to use AVs. In this paper, we intend to verify the influence of environmental sensitivity or perception of the future on the intention to use any of the autonomous modes under consideration. We also consider the influence of urban representations, such as depicted in the next Subsection. We do not *a priori* expect a positive or negative influence of these variables on AVs acceptance.

(4) In turn, the *attitudinal variables* are supposed to be influenced by sociodemographic characteristics.

2.2 Data and descriptive statistics

The data used for our empirical analysis come from an online survey on French mobility use and representations towards future transport modes. This survey is a part of a larger project on urban representations and emerging uses of the city. This project is split up into a number of topics, including the local urban economy, carbon-footprint reduction, distance-working and unavoidable mobility. The survey was carried out by L'ObSoCo, a French observatory of society and consumption, on a representative sample of the French population with 4,000 questionnaires completed online in 2017. We used information from 3,297 questionnaires, due to missing information on declared intention to use on-demand and/or collective autonomous vehicles.[3]

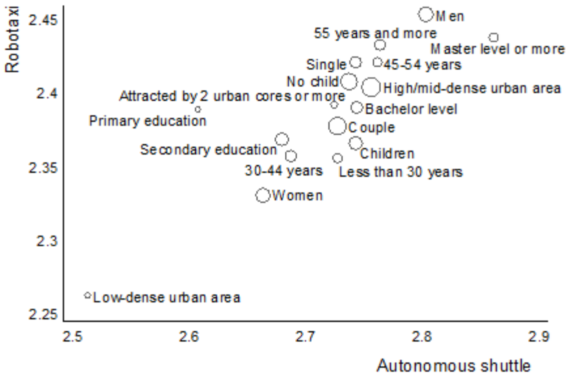
A number of variables in the survey may potentially affect the declared intention to use on-demand and/or collective autonomous vehicles: individual (for example, gender, age and education) and external (for example, type of municipality) variables affect habits (for example, the main transport mode). Habits thus influence attitudes that are given by the positive or negative evaluation of an object (Ajzen 1991). When attitudes are positive, people see the benefits of the object as outweighing its disadvantages; conversely, with negative attitudes individuals consider the object's disadvantages to be more important than its benefits. Attitudes are thus the direct predictor of behavioral intention (Fishbein and Ajzen 2010), and will be used here as an additional determinant of the intention to use AVs.

The descriptive statistics appear in Table A.1. The average age is 44, and women are very slightly over-represented (around 51 per cent) in the sample. Respondents are fairly well-educated (over half have at least a Bachelor's degree), mostly live in a couple (around 70 per cent) and in urban areas (79 per cent), and about 40 per cent live with children. Among the travel habits, private cars are the main transport mode for around 60 per cent of respondents, and public transport for 22 per cent. Only 2 per cent of respondents use innovative forms of active mobility as their main transport mode (micro-mobility objects), 23 per cent are car passengers (private pools) and 4 per cent frequently use other forms of shared or on-demand mobility (carpooling platforms, car-sharing, taxis and private-hire cars). Regarding their ideal trip, 32 per cent of respondents quote active modes of transport, whereas the car is preferred by 29 per cent (see Table A.1).

[3] For further details on the survey, see http://lobsoco.com/. Among the respondents, those who declared 'Don't know' for the intention to use on-demand and/or collective autonomous vehicles questions were dropped from the sample.

The respondents' declared intention to use on-demand and/or collective autonomous vehicles is the central variable in our analysis. Respondents' answers come from the following question: "*If the following services were to become available where you live, would you have the intention to use them?*", with one question for collective AVs, such as autonomous shuttles, and another for on-demand AVs, such as robotaxis. The four ordered possible responses were: (1) No, certainly not, (2) No, probably not, (3) Yes, probably and (4) Yes, certainly. The percentage of 'Yes' answers is higher for autonomous shuttles than for robotaxis (see Figure 2). Around 68 per cent of respondents answered 'Yes, certainly' or 'Yes, probably' for autonomous shuttles, with an analogous figure of around 50 per cent for robotaxis.

The intention to use the two transport modes are positively related: the Kendall rank-correlation coefficient between autonomous shuttles and robotaxis is 0.56 and statistically significant (the hypothesis of independence is rejected at the 0.001 level). The two autonomous modes of transport thus seem to be complementary for the majority of respondents. However, this complementarity is not found for those who answered 'Yes' for one mode and 'No' to the other, with an intention to use autonomous shuttles exclusively that is far higher than that for robotaxis exclusively, applying to almost one-quarter of respondents. We suppose that some variables in the survey may potentially affect differently the declared intention to use on-demand and collective autonomous vehicles. Although some recent studies focus on the comparison of individual and shared used of autonomous vehicles, namely robotaxis (Bansal et al 2018), we thus believe that the importance of the autonomous object is crucial when considering acceptance.



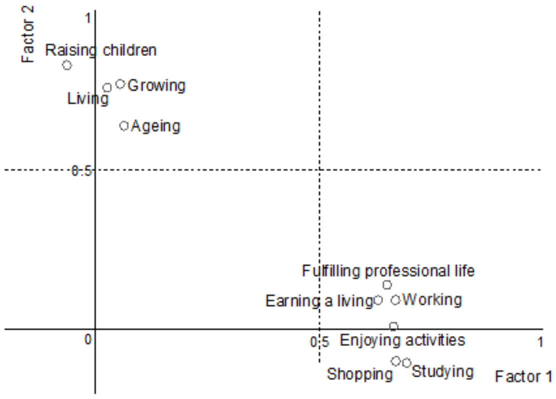


Fig. 2. The distribution of the declared intention to use autonomous vehicles
Note: The ordered variables are treated as continuous. A Gaussian kernel function is used (bandwidth=0.5)
Source: Chronos and L'ObSoCo 2017

Fig. 3. Robotaxi/autonomous shuttle declared intention to use and sociodemographic characteristics
Note: The size of the circles is proportional to the number of observations.
Source: Chronos and L'ObSoCo 2017

Respondents' sociodemographic characteristics may affect their robotaxi/autonomous shuttle intention to use. Figure 3 depicts the mean scores from 1 to 4 of the robotaxi/autonomous shuttle answers for sub-groups by sociodemographic characteristics. For each characteristic, the intention to use autonomous shuttles is greater than that for robotaxis. There are marked differences by gender and education. However, except for those living in low-density urban areas (who are less likely to use robotaxis and autonomous shuttles), the mean intention-to-use scores are fairly similar for most of the variables in the figure.

Beyond the sociodemographic characteristics, respondents' urban representations were analyzed using ten questions answered on a ten-point scale: "*To what extent do you consider that the city is good place to […]?*" The items are as follows: Grow, Live, Raise children, Age, Work, Earn a living, Fulfill your professional life, Enjoy activities, Study and Shop. We calculate a correlation matrix for all criteria to test the consistency of answers. A number of variables are strongly correlated: this may be due to underlying factors that can be detected via factor analysis.[4] Using the Kaiser criterion, two factors emerge from the analysis. In order to

[4] The Bartlett test of sphericity concludes that the factor analysis is relevant, and the Kaiser-Meyer-Olkin measure of sampling adequacy is 0.88, indicating that the sampling method is adequate. The scree plot which shows the eigenvalues and the number of factors indicates the presence of two factors.

interpret these, the factor loadings are depicted in Figure 4 (a higher factor-loading means that the factor is more heavily influenced by the variable). The first factor pools six variables (Work, Earn a living, Fulfill your professional life, Enjoy activities, Study and Shop) and the second four variables (Grow, Live, Raise children and Age). The Cronbach's alpha score of the internal consistency of the survey items is 0.83 for the first factor and 0.85 for the second, which is acceptable according to Nunnally (1978).

Living in the city then corresponds to two perspectives. The first focuses on the use of the city by individuals, who perceive that they can successfully carry out their daily activities there, and the existing literature has shown that this perception of control directly affects behavioral intention and behavior (Fishbein and Ajzen 2010). The second view is that city living matches the individual's major universal values (Schwartz and Bilsky 1990; Schwartz 1996; Schwarz 2011). Attitudes towards the *use* of the object prevail in the first case, whereas the direct attitudes towards the *object* (the city) prevail in the second one. We can then consider the first factor as an instrumental representation of the city and the second as the city as a way of life.

Fig. 4. Factor loadings for the city as a good place to […]
Source: Chronos and L'ObSoCo 2017

Following the factor analysis, we construct two variables for urban representations by calculating the mean values of the items contained in each factor; these are positively correlated (with a coefficient of 0.40).

2.3 Econometric model

From the theoretical section and the descriptive analysis of the data, we hypothesize that the probability of using robotaxis and autonomous shuttles may be explained by a number of variables: sociodemographic characteristics (external and individual variables), attitudinal variables and technophilia characteristics, the main transport modes respondents use, and the urban representations from the factor analysis. Moreover, the views of the city as an instrument and as a way of life are simultaneously considered as a function of the sociodemographic characteristics. The resulting simultaneous-equation model estimates the standard errors taking into account the contemporaneous correlations of the representations of the city as an instrument and as a way of life (due to their Gaussian error distributions). The model can be written as:

$$C_i^* = \alpha + \beta X_i + \varphi H_i + \gamma T_i + \delta V_i + \theta U_i + \lambda F_i + \kappa S_i + \varepsilon_i \quad (1)$$

$$I_i^* = \mu + \pi X_i + \chi H_i + \tau T_i + \varsigma V_i + \zeta U_i + \text{ϙ} F_i + \text{ϲ} S_i + \omega_i \quad (2)$$

$$U_i = \nu + \eta X_i + \vartheta_i \quad (3)$$

$$V_i = \psi + \xi X_i + o_i \quad (4)$$

$$F_i^* = \text{j} + \epsilon X_i + \text{ν}_i \quad (5)$$

$$S_i^* = \varrho + \varpi X_i + \iota_i \quad (6)$$

with C_i^*, I_i^*,F_i^*, and S_i^* being underlying continuous variables and U_i and V_i being continuous variables which vary between the individuals *i*. As Eq.(1) & (2) reflect linear ordered probability equations, they will be estimated through ordered Probit models. The assumption here is that the answers to the autonomous shuttle *C* and robotaxi questions *I* are determined by the underlying continuous variables C^* and I^*. When C* and I^* take values between certain thresholds, the corresponding observable outcomes C and I take the values of 1, 2, 3 and 4.

X_i is a vector of sociodemographic characteristics, H_i a vector of technophilia characteristics, T_i a vector of mobility variables, U_i and V_i vectors reflecting the representations of the city as an instrument and a way of life respectively, F_i a vector reflecting the perception of the future, and S_i a vector reflecting the environmental sensitivity. As U and V are continuous variables, Eq. (3) & (4) reflect linear equations and will be directly estimated by regression models. Eq. (5) & (6) respectively reflect linear ordered probability and linear probability equations which will be respectively estimated by ordered Probit and Probit models. As for Eq. (1) & (2), the answers to the perception of the future F and environmental sensitivity S are determined by the underlying continuous variables F^* and S^*. Last, α, β, φ, γ, δ, θ, λ, κ, μ, π, χ, τ, ς, ζ, ρ, c, ν, η, ψ, ξ, j, ϵ, ϱ, and ϖ are the corresponding parameters to be estimated and ε_i, ω_i, υ_i, o_i, ν_i, and ι_i are the residual error terms assumed normally distributed. The model is estimated via maximum likelihood.

3.0 Results and discussion

Table 1 presents the results of the simultaneous-equation model estimated to study the respondents' intention to use the two forms of autonomous transport modes. This intention is supposed to be explained by sociodemographic characteristics, attitudinal variables, technophilia characteristics and mobility variables. Moreover, marginal effects were estimated for the explanatory variables on their intention to use autonomous shuttles or robotaxis. The marginal effects are presented in Table 2.

Table 1. Estimation results

	Intention to use		Urban representations		Perception of the future	Environmental sensitivity
	Autonomous shuttles	Robotaxis	City as an instrument	City as a way of life		
	(1)	(2)	(3)	(4)	(5)	(6)
Socio-demographic characteristics						
Female	-0.148***	-0.111***	0.097	-0.033	-0.092**	0.079
	(0.039)	(0.039)	(0.073)	(0.070)	(0.040)	(0.081)
Age (ref. Under 30)						
Between 30 and 44	0.037	0.070	0.155	-0.341***	-0.111*	-0.106
	(0.061)	(0.061)	(0.114)	(0.108)	(0.063)	(0.121)
Between 45 and 54	0.128*	0.151**	0.264**	-0.179	-0.143**	-0.076
	(0.066)	(0.065)	(0.122)	(0.117)	(0.068)	(0.132)
55 and over	0.142**	0.162***	0.410***	0.079	-0.146**	-0.073
	(0.063)	(0.062)	(0.112)	(0.107)	(0.062)	(0.122)
Couple (vs. single)	-0.013	-0.040	0.100	-0.245***	-0.054	-0.209**
	(0.048)	(0.048)	(0.088)	(0.084)	(0.049)	(0.094)
Child(ren) at home	0.021	-0.025	-0.000	0.052	0.118**	0.098
	(0.047)	(0.046)	(0.088)	(0.084)	(0.049)	(0.098)
Tertiary education	0.069*	0.039	0.464***	0.270***	0.132***	0.114
	(0.040)	(0.040)	(0.074)	(0.070)	(0.041)	(0.083)
Type of municipality (Ref. Highly or mediumly-dense urban area)						
Low-density urban area	-0.138**	-0.060	-0.307**	-0.877***	-0.054	-0.518**
	(0.070)	(0.070)	(0.132)	(0.126)	(0.073)	(0.221)
Multipolar area	0.109*	0.099*	-0.070	-0.955***	-0.183***	0.112
	(0.060)	(0.059)	(0.111)	(0.106)	(0.063)	(0.116)
Attitudinal variables and technophilia characteristics						
Perception of the future	0.068**	0.085***				
	(0.030)	(0.030)				
Environmental sensitivity	0.175*	0.094				
	(0.098)	(0.096)				
Urban representations						
City as an instrument	-0.034***	-0.037***				
	(0.010)	(0.010)				
City as a way of life	0.039***	0.043***				
	(0.011)	(0.011)				
Technophilia characteristics						
Has a Smartphone	0.153**	0.166***				
	(0.061)	(0.061)				
Has a tablet	0.182***	0.199***				
Mobility characteristics, travel habits and representations						
Has a driving license	0.056	-0.064				
	(0.075)	(0.074)				
Household number of cars	0.057**	-0.022				
	(0.029)	(0.028)				
Main modes of transport						

On foot	0.167***	0.164***				
	(0.046)	(0.045)				
Bicycle	0.022	-0.017				
	(0.071)	(0.070)				
Two-wheeled vehicle	-0.010	0.160				
	(0.104)	(0.102)				
Micro-mobility objects (hoverboards etc.)	0.045	0.167				
	(0.148)	(0.145)				
Public transport	0.300***	0.048				
	(0.055)	(0.054)				
Private car (driver)	0.024	0.064				
	(0.047)	(0.046)				
Private car (passenger)	0.063	0.063				
	(0.047)	(0.047)				
Shared mobility (other forms) or on-demand	0.062	0.142				
	(0.102)	(0.101)				
Daily perceived travel satisfaction	-0.031***	-0.035***				
	(0.010)	(0.010)				
Ideal daily trip (ref. Different possibilities combined)						
Exclusively by collective modes of transport	0.073	-0.021				
	(0.063)	(0.062)				
Exclusively car	-0.348***	-0.179***				
	(0.055)	(0.054)				
Exclusively active modes of transport	-0.104**	-0.135***				
	(0.053)	(0.052)				
Constant			6.604	6.119		-1.676
			(0.106)	(0.101)		(0.113)
Threshold parameters						
Threshold 1	-0.759	-0.653			-0.251	
	(0.157)	(0.155)			(0.059)	
Threshold 2	-0.139	0.146			1.238	
	(0.157)	(0.155)			(0.062)	
Threshold 3	1.216	1.263				
	(0.158)	(0.156)				
Observations			3,297			
Log likelihood (null)			-25659.773 (-26263.271)			

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. For each ordered model, the 95% confidence intervals of threshold parameters do not overlap.
Source: Chronos and L'ObSoCo, 2017

Table 2. Marginal effects

	Autonomous shuttles					Robotaxis				
	AC	(1)	(2)	(3)	(4)	AC	(1)	(2)	(3)	(4)
Socio-demographic characteristics										
Female	-0.026	0.032	0.020	-0.012	-0.040	-0.022	0.033	0.011	-0.021	-0.023
Age (ref. Under 30)										
Between 30 and 44	0.007	-0.008	-0.005	0.003	0.010	0.014	-0.021	-0.007	0.014	0.014
Between 45 and 54	0.022	-0.028	-0.018	0.011	0.035	0.030	-0.045	-0.015	0.029	0.031
55 and over	0.025	-0.004	-0.002	0.022	0.072	0.032	-0.012	-0.004	0.055	0.058
Couple (vs. single)	-0.002	0.003	0.002	-0.001	-0.004	-0.008	0.012	0.004	-0.008	-0.008
Child(ren) at home	0.004	-0.005	-0.003	0.002	0.006	-0.005	0.007	0.002	-0.005	-0.005
Tertiary education	0.012	-0.015	-0.009	0.006	0.019	0.008	-0.011	-0.004	0.007	0.008
Type of municipality (Ref. Highly or mediumly-dense urban area)										
Low-density urban area	-0.025	0.030	0.019	-0.011	-0.038	-0.012	-0.018	0.006	-0.011	-0.012
Multipolar area	0.019	-0.024	-0.015	0.009	0.030	0.020	-0.029	-0.010	0.019	0.020
Attitudinal variables and technophilia characteristics										
Perception of the future	0.012	-0.015	-0.009	0.006	0.018	0.017	-0.025	-0.009	0.016	0.018
Environmental sensitivity	0.030	-0.038	-0.024	0.015	0.048	0.019	-0.028	-0.010	0.018	0.019
Urban representations										
City as an instrument	-0.006	0.007	0.005	-0.003	-0.009	-0.007	0.011	0.004	-0.007	-0.008
City as a way of life	0.007	-0.009	-0.005	0.003	0.011	0.009	-0.013	-0.004	0.008	0.009
Technophilia characteristics										
Has a Smartphone	0.028	-0.033	-0.021	0.013	0.042	0.033	-0.049	-0.017	0.032	0.034
Has a tablet	0.033	-0.040	-0.025	0.015	0.050	0.040	-0.059	-0.020	0.038	0.041
Mobility characteristics, travel habits and representations										
Has a driving license	0.010	-0.012	-0.008	0.005	0.015	-0.013	0.019	0.006	-0.012	-0.013
Household number of cars	0.010	-0.012	-0.008	0.005	0.016	-0.004	0.007	0.002	-0.004	-0.005
Main modes of transport										
On foot	0.029	-0.036	-0.023	0.014	0.045	0.033	-0.049	-0.017	0.032	0.034
Bicycle	0.004	-0.005	-0.003	0.002	0.006	-0.003	0.005	0.002	-0.003	-0.003
Two-wheeled vehicle	-0.002	0.002	0.001	-0.001	-0.003	0.032	-0.048	-0.016	0.031	0.033
Micro-mobility objects (hoverboards etc.)	0.008	-0.010	-0.006	0.004	0.012	0.033	-0.050	-0.017	0.032	0.034
Public transport	0.051	-0.065	-0.041	0.025	0.082	0.010	-0.014	-0.005	0.009	0.010
Private car (driver)	0.004	-0.005	-0.003	0.002	0.007	0.013	-0.019	-0.006	0.012	0.013
Private car (passenger)	0.011	-0.014	-0.009	0.005	0.017	0.012	-0.019	-0.006	0.012	0.013
Shared mobility (other forms) or on-demand	0.011	-0.013	-0.009	0.005	0.017	0.028	-0.042	-0.014	0.027	0.029
Daily perceived travel satisfaction	-0.005	0.007	0.004	-0.003	-0.008	-0.007	0.010	0.004	-0.007	-0.007

Ideal daily trip (ref. Different possibilities combined)										
Exclusively by collective modes of transport	0.013	-0.016	-0.010	0.006	0.020	-0.004	0.006	0.002	-0.004	-0.004
Exclusively car	-0.064	0.076	0.048	-0.029	-0.095	-0.036	0.053	0.018	-0.034	-0.037
Exclusively active modes of transport	-0.019	0.023	0.014	-0.009	-0.028	-0.027	0.040	0.014	-0.026	-0.028

Note: Average Change (AC) and conditional marginal effects for each of the four categories from (1) to (4). (1), (2), (3) and (4) are the marginal effect for each outcome of the dependent variable: (1) for *No, certainly not*, (2) for *No, probably not*, (3) for *Yes, probably* and (4) for *Yes, certainly*.

3.1 Sociodemographic characteristics

Age and gender both turn out to influence the intention to use the two autonomous transport modes (models (1) & (2) in Table 1). Men are more prone to this use than women (with a 2.6 per cent higher probability as indicated by the average marginal change in Table 2), as are the older (45 years and over) relative to the younger. The only other sociodemographic characteristic that stands out is that higher education is associated with a greater intention to use autonomous shuttles, but not robotaxis. Marital status and children in the household do not predict the intention to use either autonomous transportation mode.

As emphasized by the OECD (2017a, 2017b), a number of countries have significant digital divides, particularly urban-rural and between those with high and low incomes, but also between men and women. However, in the previous literature Krueger et al. (2016) find no significant gender difference in autonomous mode choice in five major metropolitan areas in Australia. The number of children is not always significant either (Bansal et al. 2016; Krueger et al. 2016; Wang et al., 2019), but education is mostly associated with greater acceptance of intention to use AVs: Kyriakidis et al. (2015), Bansal et al (2016), Wang et al (2019). Younger people in Anglo-Saxon countries are usually more prone to use AVs (Schoettle and Sivak 2014, and Bansal et al. 2016).[5]

Living in a city or in the countryside likely determines the intention to use on-demand or collective autonomous modes of transport, given their current geographical use (a far higher modal share of public transport in the city, and the more frequent use of private cars elsewhere, Chronos and L'ObSoCo 2017, Orfeuil et al. 2020). Our results in Table 1 reveal a distinction between highly and mediumly-populated areas on the one hand, be they major urban centers or their surrounding areas, and lightly-populated areas (small towns and their surroundings, and isolated municipalities). Multipolar areas form a third geographic group. Living in a low-density urban area reduces the intention to use autonomous shuttles, compared to highly- or mediumly-dense urban areas (a 2.5 per cent lower probability, as indicated by the average marginal change in Table 2), although no significant difference is found for robotaxis. Multipolar areas (which are mostly low-density, as they are not themselves major urban centers) are positively associated with both autonomous transport modes, compared to highly- or mediumly-dense areas (1.9 and 2 per cent higher probability for autonomous shuttles and robotaxis as indicated by the average marginal change in Table 2). As such, autonomous vehicles may have a role to play in linking low-density areas to major urban centers, or moving people within these municipalities for other reasons.

We tested various clusters of location types. Surprisingly, the traditional opposition between urban centers and their surroundings in France does not affect the intention to use either autonomous mode. Equally, no difference was found between major urban centers (the '*Métropoles'* in French, including Paris), which are supposed to be far more attractive than the

[5] The following areas were considered by the authors: Austin, Texas, United States (Bansal et al., 2016); Puget Sound, Washington, United States (Wang et al. 2019); 109 countries (40 countries with at least 25 respondents): Kyriakidis et al (2015); Australia, the United Kingdom and the United States (Schoettle and Sivak 2014).

other areas, the surroundings of these *Métropoles* (still strongly connected to the urban center) and the rest of the country.

In the previous literature, Krueger et al. (2016) find a positive relationship between living in urban areas and the acceptance of autonomous shuttles as the future of public transit. Central locations affect not only public autonomous mobility but also shared mobility for commuting trips (Wang and Akar 2019). This distinction between rural and urban areas regarding AV acceptance is consistent with that in other work (for example, König and Neumayr 2017) showing that individuals in rural areas do not feel concerned by AVs, as the infrastructure may not be adapted there (Bel et al. 2019), which constitutes unfavorable external conditions (Venkatesh et al. 2003).

3.2 Attitudinal variables and technophilia characteristics

Our attitudinal variables here are attitudes towards the future, environmental sensitivity, and urban representations (the 'City as an instrument' or 'City as a way of life'). The attitudinal variables are presumed to influence the intention to use AV and are as well as supposed to be affected by socio-demographic characteristics (Figure 1).

Positive attitudes towards the future are strongly associated with a greater intention to use both autonomous transport modes, as is owning a smartphone or a tablet (having a tablet increases the probability reflecting the intention to use by 3.3 per cent for autonomous shuttles and 4 per cent for robotaxis, as indicated by the average marginal change in Table 2). Furthermore, environmental sensitivity has a significant impact on the intention to use autonomous shuttles, including the most environmentally-friendly autonomous shuttle (which is public transport).

Regarding urban representations, 'City as an instrument' reduces the intention to use both autonomous transport modes, while 'City as a way of life' increases both. Models (3) & (4) in

Table 1 show the correlates of these two urban representations. ‘City as an instrument’ is more common for older and highly-educated respondents, and falls with neighborhood density; ‘City as a way of life’ is also more common for the highly-educated, but less so for the middle-aged, those in couples and in low-density or multipolar areas. The perception of the future (model (5)) is negatively associated with age and female status, but positively associated with parental status and tertiary education. The influence of sociodemographic variables on environmental sensitiveness is quite poor (model (6)): couples are less sensitive than singles; so are inhabitants of low-density urban areas.

Models (1) & (2) in Table 1 show that the city considered as a way of life is positively associated with both autonomous transport modes. AV acceptance may be part of a positive representation of the future associated with middle-aged, highly-educated mobility users. Even so, the “gadget-effect” of these vehicles should not be overlooked, and it would be useful to test AV acceptance over time, that is to say both the “acceptance to use” and “appropriation to use” stages of the acceptance process.

Last, we have not found any work in which technophilia characteristics reduced the intention to use autonomous technology. For automated vehicles, Schoettle and Sivak (2014) and Abraham et al. (2017) in the United States find, as we do, a positive relationship between the intention to use and ‘technology awareness’. Comparable results are found by Bansal et al. (2016) for interest in autonomous technology.

3.3 Mobility characteristics, travel habits and representations

The respondent mobility characteristics here are having a driving license and the number of cars in the household. Surprisingly, holding a driving license is not associated with the intention to use either autonomous shuttles or robotaxis. The transport of those who cannot drive is considered as a future attraction of autonomous mobility.[6] However, having a driving license (91 per cent of respondents) is not inconsistent with an intention to use robotaxis or autonomous shuttles occasionally as a complement to private cars (for example, going home late at night or to go to a nearby urban center to shop). The net effect of having a driving license on autonomous mode choice is then ambiguous.

Wang and Akar (2019) find that autonomous technology benefits those who drive to work more than other types of commuters. This difference from our results may come from (1) the particular sample of employed workers who were asked to complete an online survey, and (2) the specific nature of commuting to work, which is rarely considered as pleasant by drivers (a repeated, unavoidable and often congested trip).

Also surprisingly, household number of cars is associated with a greater intention to use autonomous shuttles, but not robotaxis. Respondents may here consider autonomous shuttles as a complement to private cars (to go to certain congested areas at peak hours), whereas robotaxis may be viewed as a substitute for a second car. Alternatively, cost could be at play, with autonomous shuttles being seen as cheaper than robotaxis for households with multiple cars and higher transport costs than households with one or no cars. Last, autonomous shuttles and robotaxis may be considered respectively, as we already mentioned, as current public transport (for example, buses) and current on-demand mobility offers with reservation systems (like Uber). As the former (public transport) is older than the latter (on-demand mobility offers), individuals' social representations of buses are more anchored than those of on-demand mobility (Abric 1994; Moscovici 2003; Moliner and Guimelli 2015). Individuals may thus more easily imagine themselves using the new services of the former than the latter (Moliner and

[6] We do not here consider privately-owned self-driving cars, as a driver's license may well be required for the use of private cars (even if self-driving) for legal reasons, contrary to autonomous shuttles and robotaxis.

Tafani 1997). This may lie behind the greater intention to use autonomous shuttles than robotaxis (cf. Planned Behavior Theory, Ajzen 1991).

The impact of household car-ownership on the intention to use AVs (and of which type) is generally not clear in the literature. Rödel et al. (2014) and Bansal et al. (2016) respectively consider vehicle miles traveled and driving frequency, without knowing whether these distances are covered by one or more household vehicles. This is also the case in Pettigrew et al. (2019), who look at car-ownership status but do not know how many cars are owned. Even so, car ownership turns out to be insignificant in their analysis. In Wang and Akar (2019), the number of cars per households is negatively correlated with the propensity to use AVs, for both on-demand and shared autonomous mobility.

The travel habits of respondents are expected to affect both the intention to use automated vehicles in general and their preferred autonomous transport mode. We find that the daily transport mode significantly affects the intention to use autonomous modes. There are contrasting results for active modes: walking is significantly associated with the intention to use both autonomous modes, but this is not the case for cycling, which is insignificant. Unsurprisingly, current use of public transport increases the intention to use autonomous shuttles as public transport in the future (a 5.1 per cent higher probability, as mentioned in Table 2). None of the remaining current transport modes is significantly correlated with the intention to use either autonomous mode. These results would probably be different were privately-owned self-driving cars to have been on the list (especially regarding the many respondents who currently drive conventional cars).

Bansal et al. (2016) find that driving frequency (which can be thought of a proxy for private single-occupant car being the main mode of transport) is associated with greater interest in fully-automated technology. However, the authors do not distinguish between private and collective or on-demand AV use. Concerning the current use of alternative modes to private cars, Wang and Akar (2019) emphasize that commuting via public transit, ridesharing or travelling by active modes is always negatively correlated with individual autonomous mobility for commuting (private cars). Krueger et al. (2016) find a positive relationship between multimodality and the acceptance of shared automated vehicles.

Specifically concerning active modes, Wang and Akar (2019) find a negative relationship between current active-mode use and the propensity to use private self-driving cars. However, the authors do not distinguish between walking and cycling. Again, knowing the purpose of the trip (home-to-work in the latter) may help solve this apparent contradiction: a mobility user who walks to work today will probably not need a motorized mode to go to work tomorrow, whatever form it takes. This may not apply for other trip purposes, where walking may be viewed as an unavoidable mode of transport for some trips.

We last have information on the respondent's ideal trip: (1) public transport, (2) private car and (3) active modes (as compared to a combination of these three). This set of questions aims to describe the ideal way of traveling daily (without considering automated vehicles). Respondents who view private cars or active modes as this ideal mode are strongly opposed to the two autonomous transport modes (choosing 'exclusively by car' as ideal trip reduces the probability reflecting the intention to use by 6,4 per cent for autonomous shuttles and 3.6 per cent for robotaxis, as indicated by the average marginal change in Table 2), whereas, this time, public-transport proponents do not consider that autonomous shuttles will suit their travel requirements.

4.0 Conclusions

This empirical paper contributes to the recent scarce work on the intention to use fully-automated vehicles. As we consider in parallel the determinants for modal shift, we did not look at the intention to use privately-owned self-driving cars. We rather considered another form of individual mobility that is separate from ownership (on-demand mobility in the form of robotaxis). As the nature of the autonomous object matters, the intention to use this novel form of mobility was compared to that for autonomous shuttles, which is the expected future form of collective mobility.

Our survey contains a number of attitudinal variables that we use in a simultaneous-equation model to focus on mobility users' representations of the city. Some see the city more as an instrument (to carry out activities) and others as a way of life (corresponding to universal values). The former are older and highly-educated, and do not intend to use either autonomous mode of transport; the second are single, also highly-educated, and are more likely to use both modes. For these two groups there was no difference in the intention to use robotaxis rather than autonomous shuttles.

Apart from attitudes, we considered two other groups of explanatory variables: the classic sociodemographic characteristics of mobility users and their mobility characteristics. Our results regarding sociodemographic variables and some attitudinal variables are in line with the existing literature: men and technology users have a greater intention to use autonomous technology in general. Regarding location, the traditional French contrast between major urban centers and their surrounding areas does not turn out to influence the intention to use AVs. Even so, more generally, those in low-density urban areas are less likely to use autonomous shuttles, although there is no relationship with the intention to use robotaxis. Conversely, living in a multipolar area increases the intention to use both autonomous modes.

These results render policy recommendations complex and challenging. Despite certain novel results in our work, it is difficult to propose sharp autonomous-mobility policy recommendations to local authorities. First, any benefit of autonomous shuttles in low-density areas (essentially to bring first-mile mobility users to mass transport nodes such as railway stations) does not appear in our analysis, although the conclusions are less clear for robotaxis.

This may be less important for local authorities, as robotaxis can be proposed by private operators; nevertheless, the service may fail if it is not profitable, which is not what local authorities desire in terms of the continuity of mobility offers available to their inhabitants. The situation may be the opposite in multipolar areas, where we find an intention to use both autonomous modes. While the key challenge in these areas remains the relevant routes for autonomous shuttles (where should they go?), this could indicate an opportunity for robotaxis, which can likely cover many destinations that the local authority will not have to define *a priori*. Second, the statements of acceptance in our survey only deal with the first stage of the process (when individuals have a number of representations of the potential technology and its use). As a result, recommendations must be made with caution: these here come from an initial analysis and may not be valid once individuals (start and) continue to use the service.

As car drivers do not intend to use any of the autonomous modes, it is also not clear how to effect a sizeable modal shift between the main current transportation mode and future autonomous modes. Our results here do not allow us to make recommendations. The results regarding the ideal transport mode do not correspond to the intention to use AVs, as mobility users who consider the car as the ideal way to travel daily very likely do not intend to use any of the future autonomous modes.

As pedestrians and public transport users claim that they would use autonomous shuttles if available, we can conclude that autonomous technology will retain the current users of public transport, whether there is a driver is behind the wheel or not. For autonomous shuttles (and robotaxis), the emphasis is on the autonomous aspect of the object. While the technology is innovative, the use is not. With respect to the use, an autonomous shuttle has the same features as a current bus (and a robotaxi the same functionality as a current on-demand mobility offer like Uber). We have shown that, under certain conditions, current users would be inclined to use these new autonomous transport modes. This is unsurprising, as individuals stick to their existing habits (Bel 2016). For privately-owned self-driving cars (not analyzed here), the underlying technology is innovative but, unlike the two other new forms of mobility, so is the use: the driver will change his/her activity during this interaction with the autonomous vehicle. He/she will be able to do something else inside his/her vehicle. On the contrary, in shuttles or robotaxis, users do not change their habits or their use. There is no paradigm shift in this case (Bel et al. 2019).

Although this topic is important for the future of mobility, our work here suffers from a number of limitations. In particular, some explanatory variables that were not available in our dataset were not considered, although they appear frequently in other work. Including trip characteristics to overcome these limitations would be a useful subject for further research.

Acknowledgements: We thank two anonymous reviewers for their fruitful comments. We thank the VEDECOM Institute who provided financial support for the conduct of this research, Chronos and L'ObSoCo for the elaboration of the questionnaire and data collection, Mireille Appel-Muller, Yuna Conan and Patricia Jonville for their implication in the construction of the questionnaire. VEDECOM was also involved in the decision to submit the article for publication.

References

Abraham, H., Lee, C., Brady, S., Fitzgerald, C., Mehler, B., Reimer, B., and J.F. Coughlin (2017): 'Autonomous vehicles and alternatives to driving: trust, preferences, and effects of age', in *Proceedings of the Transportation Research Board 96th Annual Meeting, January 2017.*

Abric, J. C. (1994): 'L'organisation interne des représentations sociales : système central et système périphérique', *Structures et transformations des représentations sociales*, 73-84.

ADEME (2018): *Faire la ville dense, durable et désirable.* Paris (France) : Collection Expertises.

Ajzen, I. (1991): 'The theory of planned behavior', *Organizational behavior and human decision processes*, 50(2), 179-211.

Bansal, P., Kockelman, K. M. and A. Singh (2016): 'Assessing public opinions of and interest in new vehicle technologies: An Austin perspective', *Transportation Research Part C: Emerging Technologies*, 67, 1-14.

Bansal, P., and R.A. Daziano (2018): 'Influence of choice experiment designs on eliciting preferences for autonomous vehicles', *Transportation Research Procedia*, 32, 474-481.

Bel, M. (2016) : *Prédire l'utilisation d'une technologie nouvelle : Le cas des systèmes de transports intelligents coopératifs*, PhD thesis, University of Grenoble-Alpes, France.

Bel., M., Coeugnet, S., and P. Watteau (2019): *Acceptabilité du véhicule autonome.* Report delivered by Vedecom the 25th of March 2019 to the Direction Générale des Infrastructures, des Transports et de la Mer (DGITM).

Bel, M., Somat, A., Page, Y., Moessinger, M., and P. Pansu (2016): 'Predicting the use of upcoming in-car technologies: A driver support systems acceptance model', *6th International Conference on Traffic and Transport Psychology, August 2016, Brisbane* (Australia).

Berrada, J., and F. Leurent (2017): 'Modeling Transportation Systems involving Autonomous Vehicles: A State of the Art', *Transportation Research Procedia*, 27, 215-221.

Berrada, J., Mouhoubi, I., and Z. Christoforou (2020): 'Factors of successful implementation and diffusion of services based on autonomous vehicles: users' acceptance and operators' profitability', *Research in Transportation Economics*, 83, 100902.

Becker, F., and K.W. Axhausen (2017): 'Literature review on surveys investigating the acceptance of automated vehicles', *Transportation*, 44(6), 1293-1306.

Bobillier Chaumon, M.E. (2013): *Conditions d'usage et facteurs d'acceptation des technologies: Questions et perspectives pour la psychologie du travail,* Habilitation à Diriger des Recherches (HDR), University of Pierre Mendès-France, Grenoble (France).

Bobillier Chaumon, M., and M. Dubois (2009) : 'L'adoption des technologies en situation professionnelle : quelles articulations possibles entre acceptabilité et acceptation ?', *Le travail humain*, 72(4), 355-382.

Chronos and L'ObSoCo (2017) : *L'Observatoire des Usages Emergents de la Ville, Vague 1,* Report.

Fagnant, D. J., and K. Kockelman (2015): 'Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations', *Transportation Research Part A: Policy and Practice*, 77, 167-181.

Fishbein, M. and I. Ajzen (2010): *Predicting and changing behavior: The reasoned action approach,* Psychology Press, New York.

Kamel, J., Vosooghi, R., Puchinger, J., Ksontini, F., and G. Sirin (2019): 'Exploring the impact of user preferences on shared autonomous vehicle modal split: a multi-agent simulation approach', *Transportation Research Procedia*, 37, 115-122.

König, M., and L. Neumayr (2017): 'Users' resistance towards radical innovations: The case of the self-driving car', *Transportation Research Part F: Traffic Psychology and Behaviour*, 44, 42-52.

Krueger, R., Rashidi, T. H., and J.M. Rose (2016): 'Preferences for shared autonomous vehicles', *Transportation Research Part C: Emerging Technologies*, 69, 343-355.

Kyriakidis, M., Happee, R., and J.C. de Winter (2015): 'Public opinion on automated driving: Results of an international questionnaire among 5000 respondents', *Transportation Research Part F: Traffic Psychology and Behaviour*, 32, 127-140.

Lang, N., Rüßmann, M., Mei-Pochtler, A., Dauner, T., Komiya, S., Mosquet, X., and X. Doubara (2016): 'Self-driving vehicles, robo-taxis, and the urban mobility revolution', *The Boston Consulting Group*, 7, 2016.

Liu, H., Yang, R., Wang, L., and P. Liu (2019): 'Evaluating Initial Public Acceptance of Highly and Fully Autonomous Vehicles', *International Journal of Human–Computer Interaction*, 35(11), 919-931.

Merat, N., Madigan, R., and S. Nordhoff (2017): *Human factors, user requirements, and user acceptance of ride-sharing in automated vehicles,* International Transport Forum Discussion Paper, No. 2017-10.

Moliner, P., and C. Guimelli (2015) : *Les représentations sociales : fondements historiques et développements récents,* Presses universitaires de Grenoble, Grenoble (France).

Nunnally, J., (1978): *Psychometric methods*.

Moliner, P., and E. Tafani (1997): 'Attitudes and social representations: a theoretical and experimental approach', *European Journal of Social Psychology*, 27(6), 687-702.

Moscovici, S. (2003): 'Des représentations collectives aux représentations sociales : éléments pour une histoire', in *Les représentations sociales*, Presses Universitaires de France, Vol. 7, pp. 79-103, Paris (France).

OECD (2017a): *Digital Economy Outlook 2017,* OECD Publishing.

OECD (2017b): *OECD Science, Technology and Industry Scoreboard 2017,* OECD Publishing.

Orfeuil, J.P., Apel-Muller, M., Chaubet, C., and D. Leviselli (2020) : 'Attitudes et opinions sur les véhicules autonomes en France et dans le monde', Report, 29 p.

Orfeuil, J.P., and Y. Leriche (2019): *Piloter le véhicule autonome,* Descartes et Compagnie, Paris.

Payre, W., Cestac, J., and P. Delhomme (2014): 'Intention to use a fully automated car: Attitudes and a priori acceptability', *Transportation Research Part F: Traffic Psychology and Behaviour*, 27, 252-263.

Pettigrew, S., Dana, L. M., and R. Norman (2019): 'Clusters of potential autonomous vehicles users according to propensity to use individual versus shared vehicles', *Transport Policy*, 76, 13-20.

Poulhès, A., and J. Berrada (2019): 'Single vehicle network versus dispatcher: user assignment in an agent-based model', *Transportmetrica A: Transport Science*, 1-23.

Rödel, C., Stadler, S., Meschtscherjakov, A., and M. Tscheligi (2014): 'Towards autonomous cars: the effect of autonomy levels on acceptance and user experience', in *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, September 2014*, ACM, pp. 1-8.

Schoettle, B., and M. Sivak (2014): *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia,* University of Michigan, Ann Arbor, Transportation Research Institute.

Schoettle, B., and M. Sivak (2015): *Motorists' preferences for different levels of vehicle automation,* University of Michigan, Ann Arbor, Transportation Research Institute.

Schwartz, S. H. (1996): 'Value priorities and behavior: Applying of theory of integrated value systems', in *C. Seligman, J. M. Olson, and M. P. Zanna (Eds.), The Psychology of Values: The Ontario Symposium,* Hillsdale, NJ, Erlbaum, Vol. 8, pp. 1–24.

Schwartz, S. H. (2011): 'Studying values: Personal adventure, future directions', *Journal of Cross-Cultural Psychology*, 42(2), 307-319.

Schwartz, S. H., and W. Bilsky (1990): 'Toward a theory of the universal content and structure of values: Extensions and cross cultural replications', *Journal of Personality and Social Psychology*, 58, 878-891.

Shen, Y., Zhang, H., and J. Zhao (2018): 'Integrating shared autonomous vehicle in public transportation system: A supply-side simulation of the first-mile service in Singapore', *Transportation Research Part A: Policy and Practice*, 113, 125-136.

Venkatesh, V., and H. Bala (2008): 'Technology acceptance model 3 and a research agenda on interventions', *Decision Sciences*, 39(2), 273-315.

Venkatesh, V., Morris, M. G., Davis, G. B., and F.D. Davis (2003): 'User acceptance of information technology: Toward a unified view', *MIS Quarterly*, 27(3), 425-478.

Wang, K., and G. Akar (2019): 'Factors Affecting the Adoption of Autonomous Vehicles for Commute Trips: An Analysis with the 2015 and 2017 Puget Sound Travel Surveys', *Transportation Research Record*, 2673(2), 13-25.

Zhou, F., Zheng, Z., Whitehead, J., Washington, S., Perrons, R. K., and L. Page (2020): 'Preference heterogeneity in mode choice for car-sharing and shared automated vehicles', *Transportation Research Part A: Policy and Practice*, 132, 633-650.

Appendix

Table A.1. Descriptive statistics

	Mean	Std. Dev.	Min.	Max.
Socio-demographic characteristics				
Female	0.51	0.50	0	1
Age	43.78	14.31	18	70
Under 30	0.20	0.40	0	1
Between 30 and 44	0.32	0.47	0	1
Between 45 and 54	0.21	0.41	0	1
55 or over	0.27	0.44	0	1
Couple (vs. single)	0.69	0.46	0	1
Child(ren) at home	0.41	0.49	0	1
Education				
Primary and secondary	0.47	0.50	0	1
Tertiary education	0.53	0.50	0	1
Type of municipality				
Highly or mediumly-dense urban area (a major urban center or its surroundings)	0.79	0.40	0	1
Low-density urban area (an urban center or its surroundings)	0.09	0.28	0	1
Multipolar area	0.12	0.33	0	1
Attitudes and technophilia characteristics				
Perception of the future (from worse to better)	1.65	0.64	1	3
Environmental sensitivity	0.04	0.20	0	1
Urban representation ('the city is good place to')				
Study	7.22	3.07	0	10
Enjoy activities	7.21	2.82	0	10
Work	7.16	2.74	0	10
Earn a living	7.13	2.45	0	10
Shop	7.11	3.32	0	10
Fulfill your professional life	7.08	2.53	0	10
Grow	5.97	2.30	0	10
Live	5.76	2.56	0	10
Raise children	5.71	2.34	0	10
Age	5.69	2.54	0	10
Technophilia characteristics				
Has a Smartphone	0.87	0.33	0	1
Has a tablet	0.57	0.50	0	1
Mobility characteristics, travel habits and representations				
Has a driving license	0.91	0.29	0	1
Household number of cars	1.49	0.78	0	3
Main modes of transport (multiple answers were possible)				
On foot	0.31	0.46	0	1
Bicycle	0.09	0.28	0	1
Two-wheeled vehicle	0.04	0.19	0	1
Micro-mobility objects (hoverboard, skateboard, mono-wheel etc.)	0.02	0.13	0	1
Public transport	0.22	0.41	0	1
Private car (driver)	0.59	0.49	0	1
Private car (passenger)	0.23	0.42	0	1
Shared mobility (other forms) or on-demand	0.04	0.19	0	1
Daily perceived travel satisfaction	6.87	1.93	0	10
Ideal daily trip				

Different possibilities combined (car, public transport)	0.23	0.42	0	1
Exclusively public transport (bus, subway and tramway)	0.16	0.37	0	1
Exclusively car	0.29	0.45	0	1
Exclusively active modes of transport	0.32	0.47	0	1

Note: The number of observations is 3,297. 'Std. Dev.' is Standard Deviation.

Source: Chronos and L'ObSoCo 2017.