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Are solo driving commuters ready to switch to carpool? Heterogeneity of preferences in Lyon's urban area

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ABSTRACT

We conduct a discrete choice experiment on 1556 solo-driving commuters in Lyon, France to estimate the values of end-to-end travel time (VoTT) of commuting trips in the presence of a HOV-lane for four modes: Solo Driver, Carpool Driver, Carpool Passenger and Public Transport. Using discrete choice models, we find a strong heterogeneity in VoTT across modes and individuals. The analysis of individual heterogeneity distinguishes four behavior patterns: reluctant to mode change (20% of our sample), preferring the three alternative modes over solo driver (35%), preferring public transport (12%) and preferring driver modes whether solo or carpool (32%). We find that current solo drivers are more likely to switch to carpooling as a driver rather than as a passenger. As suggested by our simulations aimed at marginally changing mode shares, carpool passenger will be the scarce resource if one wants to decrease car traffic by stimulating carpooling for commuting trips.

Keywords: Carpool; Commuting Trips; Discrete Choice Experiment; Values of Time

JEL codes: R41, C35

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1. INTRODUCTION

Traffic congestion is still a major issue in large cities around the world. France is no exception to this observation. According to INRIX (2019), the drivers in Paris, Marseille, Lyon and Toulouse – the four largest cities in the country – respectively lost on average 237, 140, 141 and 130 hours in road congestion in 2018. Most of this traffic congestion appears during morning and evening peak hours.

Promoting carpool is seen as a cost-effective way to moderate road congestion while avoiding costly investments in road expansion and to reduce harmful gas emissions. The current rate of car occupancy is low in France, since it amounts especially at 1.08 for commuting trips (ENTD, 2008). Similar results are found in UK (1.14, Department for Transport, 2019), USA (1.13, Santos et al., 2011) or Australia (below 1.1 in major cities, Loader, 2012). It implies that there is a large unused transport capacity during peak hours.

Local policy makers in France are currently considering different kinds of policies to promote carpool for commuting trips. The cities of Lyon and Grenoble are experimenting high occupancy vehicles (HOV)-lanes in 2021. These lanes are expected to offer shorter travel time and improved reliability for carpoolers compared to solo drivers. Despite several similar experimentations in Europe - like in Madrid, Spain or in Trondheim, Norway (Schijns & Eng, 2006) – there are few quantitative studies detailing preferences towards carpooling for commuting trips. This gap in the empirical literature motivated this research.

We address the following research question: what are the preferences of current solo drivers towards carpooling as a driver and as a passenger for a commuting trip? We especially test the presence of heterogeneity in preferences, both across modes and individuals, and measure it. By addressing these questions, we also tackle the potential behavioral responses of current solo drivers to a new carpooling supply. We answer these questions by estimating end-to-end VoTT and their distributions for commuting trips as a solo driver, a carpool driver, a carpool passenger, and a public transport passenger. To this aim, a discrete choice experiment survey was conducted on a sample of 1556 solo driving commuters in the city of Lyon. To our knowledge, we are the first to empirically measure solo driver values of time for carpool commuting trips.

A strong average preference for solo driving is identified through our results. However, the individual heterogeneity in these preferences must be considered. This heterogeneity can be described by distinguishing four behavioral patterns: reluctant to mode change, preferring the three alternative modes over solo driver, preferring public transport and preferring driver modes whether solo or carpool. The simulations performed suggest that despite travel time gains due to HOV-lane or monetary subsidies, few current solo drivers would switch to carpool as passenger.

The rest of the paper is organized as follows. Section 2 reviews the previous literature on the topic. Section 3 presents the survey design, data sampling and summary statistics. Section 4 shows the methodological framework and the empirical strategy used to estimate values of travel time. Section 5 presents the results, which are discussed in Section 6. Section 7 concludes.

2. LITERATURE REVIEW

Previous qualitative studies showed preferences toward carpooling for commuting trips are not a clear-cut case. On the one hand, individuals often consider carpooling as a risky mode (Chan & Shaheen, 2012). The desire of independency or flexibility are also reasons raised from solo drivers to stay alone in their car (Li et al., 2007). On the other hand, in a French survey (ADEME, 2015), carpoolers often cite friendliness, ecology or a reduced stress and fatigue as reasons why they choose this mode. Economic criterion is also found to be a crucial determinant of the modal choice. Indeed, the economic gain or loss is seemingly an essential attribute in the transport modal choice. Sharing the costs makes carpooling economically competitive compared to solo driving or other travel modes at least on long distances (Shaheen et al., 2017; Monchambert, 2020).

Values of travel time (VoTT) are known to differ between modes and individuals. Wardman et al. (2016) distinguished “mode used VoTT” – relative to individual characteristics – and “mode valued VoTT” – relative to mode characteristics such as comfort, privacy, security, or externalities due to environment. Previous surveys showed that travel time values are lower for public transport users – in bus and rail – than for car users (Shires & De Jong, 2009; Wardman et al., 2012; Quinet, 2013). Regarding carpooling VoTT, in a stated preferences survey in France, Blayac & Adjeroud (2018) compared VoTTs of bus and carpool users over long distances. They found that the value of time for carpool users is more than twice the one of bus users. Monchambert (2020), in a long-distance carpool survey, found that VoTTs in

carpooling are higher than those as a solo driver, bus user and train user. Concerning VoTTs for carpool commuting trips, Ciari & Axhausen (2012) measured values in Switzerland for the same four modes as the present survey, but without precision about trip purpose. They found a substantial heterogeneity between value of public transport travel time and values for other modes, with a slightly higher value for carpool modes than for solo driving.

3. SURVEY DESIGN AND DATA SAMPLING

3.1. Study context

This survey and its questionnaire were designed to observe how the inhabitants of the Lyon area (1.4M inhabitants) would react to the creation of a HOV-lane, a new infrastructure in France. Indeed, in 2021 the metropolitan authority of Lyon opened two HOV-lane sections on its main North-South axis. These lanes are 6 and 4-km long for the northern and the southern sections respectively. The survey was conducted in spring 2019 and at this time the expected time savings for carpoolers were between 5 and 15 minutes during morning rush hours.

3.2. Survey design

The questionnaire is organized in three parts. The first part aims at collecting basic socio-demographic data and the respondent's usual trip characteristics. The second part is the stated choice experiment. It is a responsive experiment in the sense that the choices tasks proposed to the respondents depend on their trip characteristics. The third part is a questionnaire on attitudes.

3.2.1. Socio-demographic and trip characteristics

In this online survey, we first collect information on respondents' socio-economics variables (gender, age, income, professional position...) and on the characteristics of their "usual trip" i.e. the most frequent trip made by car or public transport during a workweek. These characteristics are used to responsively build the choice tasks in the second step of the survey.

Our aim is to place the respondent in the context of a trip he can do with the proposed modes in the survey. We are interested in respondents for whom carpooling is a credible alternative for their usual trip. Respondents whose usual trip meets the following criteria are kept in the survey:

- a travel time between 15 and 90 minutes
- driving their car

- during rush hours (between 6 and 10 am or between 4 and 8 pm, excluding Saturday and Sunday)

On the one hand, we consider carpooling is not a credible alternative for very short distance trips (<15 minutes by car), because even a short waiting time (for the passenger) or detour time (for the driver) would proportionally lengthen the trip a lot. On the other hand, we consider long trips (>90 minutes) as outside the study scope since the time gain procured by the HOV-lane can be considered as proportionally too marginal regarding the decision to carpool. Furthermore, the average commuting time by car in Lyon area, which is around 30 minutes, is way below this threshold (SYTRAL, 2016).

As it is a new policy in France, the HOV-lane and the carpooling organization are presented to the respondents before the choice tasks through two screens.

3.2.2. Experimental Design

To make respondents state what they would do in an actual situation, alternatives are kept realistic by using the information on their usual trip collected earlier. The time attributes levels of the various alternatives vary around the initial values of this usual trip.

Since variation is needed between the exercises, a total of 60 different choice task patterns is created, split into 10 blocks. Then each respondent is allocated to a block and face six choice situations. In each of these choice screens, the respondent has the choice between four alternatives (modes), presented in columns: Solo Driver, Carpool Driver, Carpool Passenger and Public Transport (see Appendix A). Following Hensher et al. (2015) recommendations, the attribute levels of the proposed alternatives are not such that any alternative dominates the others. Furthermore, the order of columns is randomized for each screen to avoid the left right bias as recommended by Hess & Rose (2009).

For a given trip, each alternative is labelled and characterized by different types of attributes.

-Trip attributes include several time variables (in-vehicle time and in the case of alternatives to solo driver mode, waiting, detour, access, and egress time), as well as the departure and arrival times.

-The monetary aspects include two attributes. The first is the cost (resp. gain) due to the use (resp. no use) of their personal car. The second attribute is a gain or cost for providing or using carpool services or public transport. Contrary to “slugs” in the USA (Burriss et al., 2012) carpoolers in France are used to a monetary exchange between the driver and the passengers. In this survey, we approximate this cost

depending on the duration of the trip. The cost for Public Transport alternative is fixed to 0.8€ as it is the average cost for a subscriber in the city.

-In carpool alternatives, organization and matched carpooler's profile are also presented to check for other attributes who could affect mode choice such as close relationship between driver and passenger and the impact of a carpool platform. These variables will be used as controls in this survey.

The Ngene software (ChoiceMetrics, 2012) is used with a D-efficient design (see Rose et al., 2008) to build balanced choice tasks and extract as much information as possible from the trade-offs made by respondents. For that, prior information about parameters have been used from de Palma and Fontan (2000) and Quinet (2013). The mode attributes and levels used in the choice tasks are presented in Table 1.

Table 1: Trip attributes, levels in stated choice design and choice shares

Type	Attributes	Alternatives	Levels	Mean Value
Time				
Schedule early/late (in min)	Solo Driver		0, 30, 60 (earlier or later)	17 min (earlier)
				12 min (later)
End-to-end travel Time (in min)	Solo Driver		Min: $0.8 \times \text{usual_tt}$ Max: $1.9 \times \text{usual_tt}$	55 min
	Carpool Driver		Min: $0.6 \times \text{usual_tt}$ Max: $1.5 \times \text{usual_tt} + 20$	50 min
	Carpool Passenger		Min: $0.6 \times \text{usual_tt} + 10$ Max: $1.5 \times \text{usual_tt} + 50$	64 min
	Public Transport		Min: $0.6 \times \text{usual_tt} + 10$ Max: $1.5 \times \text{usual_tt} + 35$	60 min
Cost (in €)	Carpool Driver		Receives $(0, 0.02, 0.05, 0.1) \times \text{usual_tt}$	1.65 €
	Carpool Passenger		Pays $(0, 0.02, 0.05, 0.1) \times \text{usual_tt}$	2.00 €
	Public Transport		Pays 0.8	0.80 €
Carpool supply				
Carpooler matching	Carpool Driver and		With a relative, met by platform, with a hitchhiker	
Carpooler Gender	Carpool Passenger		Male, Female (not presented if relative)	
Carpooler Age			25, 45, 65 years old (not presented if relative)	

Notes: "usual_tt" is the usual travel time the respondent reports in the survey. Detailed attribute levels are provided in Appendices.

3.2.3. Attitude Questions

Finally, five questions are asked to evaluate the respondents' sensitivities to environmental consequences of the solo driving practice. Indeed, incentivizing carpooling involves psychological and social dimensions which go beyond self-interest, this latter dimension being covered through our DCE design.

The environment or the level of congestion in the city may be seen as “commons” which deserve specific behavioral adaptations.

Regarding the potential of motivational factors towards pro-environmental behavior, the literature offers two main theories. The first one is based on self-perceived cost and benefits, with the theory of planned behavior (TPB; Ajzen, 1991). TPB aims at explaining behavioral intentions (viewed as the immediate antecedent of actual behavior) by the attitudes (ATT), the perceived social pressure regarding this behavior (subjective norms, SN) and the perceived behavioral control (PBC). The other theory is based on moral and normative concerns with the norm-activation theory (NAT; Schwartz, 1977) and aims at explaining altruistic behavior. Feelings of obligation, stemming from perceived norms (PN), precede immediately behavior and are activated by the awareness of behavior consequences (AC) and beliefs about personal responsibility.

These two theories are applied and compared by Wall et al. (2007) to explain drivers' intentions to reduce or maintain their car use for commuting. The authors show that a combination of TPB and NAT constructs has a superior power of explanation when compared to the two theories separated. Following Wall et al. conclusions we build a set of five statements (presented on a Likert scale) which cover the basic constructs of both theories:

- 1: Car traffic is a major source of pollution and congestion (AC).
- 2: I am satisfied with my daily trip choices (ATT).
- 3: I can or could easily change the way I travel daily (PBC).
- 4: The opinion of people who matter to me is important for the way I travel on a daily basis (SN).
- 5: I feel personally responsible for contributing to reduce pollution and congestion (PN).

The answers to these statements have been transformed into continuous variables as follows: -2 if the respondent strongly disagreed, -1 if disagreed, +1 if agreed and +2 if strongly agreed with the statement. Neutral answers were coded as 0.

3.3. Data collection

A partnership with different motorway companies, local authorities, the University of Lyon, and a carpool company allowed us to spread a web-link of the survey to many inhabitants in the Lyon area. The call

message for the survey specified that it was about daily mobility and not specifically about carpooling to avoid strategic or selection bias.¹ There was a financial incentive to answer the survey as respondents had a chance to win a 100€ voucher. A wide part of the sample came thanks to the dissemination of the survey to electronic tolling motorway subscribers. Finally, a database containing around 3,300 respondents who fully completed the survey was collected.

In this paper our focus is on the potential change of daily commuters from solo-driving to carpooling when facing a HOV-lane. Thus, only respondents who declare a usual trip as solo drivers, at least several times a week and for work purpose are kept. This commuters' subset still represents an important part of our base sample, with 2,044 respondents.

Finally, an adhoc data filtering is applied as recommended by Hess et al. (2010). Since response times for each choice screen are available, 309 people who answered to a choice screen at least once in less than 6 seconds were excluded. This allows us to remove respondents who only came to win a voucher and answer the questionnaire as fast as they can without examining the choice sets. Also, 179 respondents who did not report income were excluded from the survey for a final sample of 1556 respondents and 9336 observations analyzed. Descriptive statistics of this final sample are presented in Table 2. A comparison between socio-demographic characteristics of our sample and the targeted population (population in the first rows of Table 2) shows a fairly good representativeness of our sample.

¹ The call message for the survey was: "We are interested in your daily journeys! Help researchers at the University of Lyon to better understand your travels! Take this online survey in 15 minutes and try to win vouchers!"

Table 2: Sample characteristics

	Sample		Commuting Population in the area**		
	Mean	Sd	Mean	sd	
Individual					
Male	54.7%		54.8%		
Age (years)	44.6	10.4	41.1	11.6	
Income per month (€)*	2378	901			
Occupation					
Self-employed	3.9%		7.3%		
Senior Management/Professional	47.9%		18.5%		
Middle Management	12.1%		29.1%		
Clerical Staff	32.3%		22.8%		
Laborers	3.0%		21.7%		
Students	0.7%		Farmers	0.5%	
Reference trip					
Length (min.)	39.1	16.7			
Attitude statements (in the sample)					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
S1 (“car traffic major source”)	2.1%	5.0%	8.5%	34.4%	50.0%
S2 (“satisfied with my choices”)	8.6%	25.1%	19.4%	30.9%	16.0%
S3 (“could change easily”)	19.5%	28.1%	16.3%	28.6%	7.5%
S4 (“opinion matter”)	25.8%	17.2%	31.2%	19.3%	6.6%
S5 (“personally responsible”)	5.5%	7.9%	22.8%	44.0%	19.8%
Choices					
	Solo Driver	Carpool Driver	Carpool Passenger	Public Transport	
	31%	38%	15%	16%	
Nb of individuals		1556			

*income variable is collected as categorical. Mean and standard deviation are calculated using the center of the classes selected by respondents. Income is not available in the census.

** source: MOBPRO, a national census that aim to survey the professional mobility over territories (INSEE, 2019), solo driver data from départements of Ain, Isère, Loire and Rhône which intersect the Lyon urban area.

4. METHODOLOGY

4.1. Econometric Models

Three model types are used to analyze the discrete choice data: a multinomial logit (MNL) which is the usual base model, a mixed logit (MXL) and a latent class logit (LCL). These two last models provide two different functional forms of heterogeneity in preferences for some attributes, which relieve the IIA assumption (McFadden & Train, 2000) and consider the panel structure of the data (Lancsar et al., 2017). The MXL model considers and analyzes heterogeneity through “random parameters” estimates. These

estimates then vary following a parametric distribution. Contrary to the MXL, the LCL model does not need any assumption on distribution of preferences in the population. It builds a typology of preferences, considering as many types of behavior as latent classes. However, the number of classes is chosen by the analyst, which is in a way another assumption. We retain the number of classes whose model has the lowest AIC (Louviere et al. 2000, chap.10).

Concerning the parametrization of individual heterogeneity, we let intercepts and time estimates vary across respondents. Preferences can thus vary according to time spent in the mode, reflecting for example perceived comfort (time estimates), or a pure preference for the mode, due for instance to past experiences (intercepts). Other estimates remain fixed across all classes just like in the MNL model.

Furthermore, the analyst can define latent class parameters to explain the class allocation probability of individuals (see Hess & Palma, 2020). Hence, we tried to use respondents' socio-economic characteristics and the attitude statements answers as explanators of the classes.

4.2. Utility Specifications

A willingness to pay (WTP) space utility specification is used (Train & Weeks, 2005; Daly et al, 2012). This expression of the utility is a re-parametrization obtained by multiplying the cost coefficient estimate by time coefficients. It allows for a direct interpretation of time estimates as values of time.

Utilities for the four alternatives are presented below.

$$\begin{aligned}
V_{sd} &= \beta_{cost}(Cost_{sd} + \beta_{TTsd}TT_{sd} + \beta_{early}SchedEarly + \beta_{late}SchedLate) + \beta_{Zsd}Z \\
V_{cpd} &= \beta_{cost}(Cost_{cpd} + \beta_{TTcpd}TT_{cpd}) + \beta_{Zcpd}Z + \beta_{Xcpd}X_{cpd} \\
V_{cpp} &= \beta_{cost}(Cost_{cpp} + \beta_{TTcpp}TT_{cpp}) + \beta_{Zcpp}Z + \beta_{Xcpp}X_{cpp} \\
V_{pt} &= \beta_{cost}(Cost_{pt} + \beta_{TTpt}TT_{pt}) + \beta_{Zpt}Z
\end{aligned} \tag{1}$$

β_{0k} is the Alternative Specific Constants (ASCs) associated with mode k , with β_{0sd} normalized to zero (solo driver chosen as the reference alternative), β_{cost} is the cost coefficient, β_{tk} the Value of Travel Time (VoTT) of mode k , Z the respondent individual variables and X the carpool organization variables.

β_Z and β_X are vectors of estimates for Z and X respectively. β_{0ds} and β_{Zds} are fixed to 0 as references. At this point, let's recall that we expect heterogeneity across individuals, but that we also expect individual

preferences to vary across modes, due for example to differences in comfort or safety. Therefore, one ASC and one VoTT coefficient per mode are estimated.

Focusing on the Solo Driver cost function, leaving earlier or later is considered as an option to avoid road congestion. Considering the HOV-lane will reduce congestion for other modes, schedule delay is only considered for Solo Driver. The idea is to observe if respondents are ready to delay their trip rather than switching to carpool modes or public transport. *SchedEarly* and *SchedLate* are schedule delay time variables. β_{early} and β_{late} are their respective estimates. The *Cost* variable is measured as the difference between the cost of the alternative and the cost of the Solo Driver situation (reference).

In the MXL, travel time random parameters are defined as follows for mode k :

$$\beta_{ttk} = \exp(\mu_{\beta_{TTk}} + \sigma_{\beta_{TTk}} * \zeta_{\beta_{TTk}}) \quad (2)$$

where μ and σ are the estimated parameters of the lognormal distribution and ζ follow standard normal distribution across individuals.

Correlations are introduced between travel time random parameters, particularly because VoTT is correlated with unobserved respondent idiosyncrasies (see Appendix B). The VoTTs of an individual are hence expected to be correlated with each other.

5. RESULTS

5.1. MNL and MXL estimates

Coefficients in Equations (1) have been estimated with the *Apollo* package built by Hess & Palma (2019) for the R software. Full estimation results are displayed in the Appendices while an extract is shown in Table 3. The MXL models has been estimated with 2,000 Modified Latin Hypercube Sampling (MLHS) draws (Halton draws are not advised for more than five random coefficients, see Bhat, 2003). In these models, the alternative-specific constants are assumed to be normally distributed. It is assumed that VoTTs are positive and correlated with the distribution of incomes, which justifies the choice of lognormal distributions.

Table 3: Estimations results of MNL and MXL models

Attribute	Alternative	MNL1	MNL2	MXL1	MXL2	MXL3
Alternative-Specific	Carpool Driv.	-0.483***	0.240*	-1.038***	-0.845**	-0.015
Constants (ASCs) (Reference: Solo Driver)	Carpool Pass.	-0.638***	0.025	-1.082***	-1.079**	-0.295
	Pub. Transport	-1.054***	-0.286*	-2.186***	-0.917*	-0.886*
ASCs	Carpool Driv.			2.350***	1.413***	1.508***
Standard deviation (σ_{ASC})	Carpool Pass.			2.494***	0.092	0.686***
	Pub. Transport			2.864***	1.503***	2.122***
Travel time ($\mu_{\beta_{tt}}$ in MXL)	Solo Driver		0.336***		-0.630***	-0.777***
	Carpool Driv.		0.502***		-0.730***	-0.666***
	Carpool Pass.	0.576***	0.462***	-1.095***	-0.841***	-0.732***
	Pub. Transport		0.481***		-0.548***	-0.588***
Travel time Standard deviation ($\sigma_{\beta_{tt}}$)	Solo Driver				0.891***	1.254***
	Carpool Driv.				0.260***	0.674***
	Carpool Pass.			0.776***	0.233***	0.004
	Pub. Transport				0.275***	0.019
Schedule early	Solo Driver	0.299***	0.190***	0.175***	0.170***	0.166***
Schedule late	Solo Driver	0.072***	0.052***	0.050***	0.056***	0.033*
Cost	All	-0.072***	-0.100***	-0.199***	-0.163***	-0.167***
Carpool organization controls (Z)		Yes	Yes	Yes	Yes	Yes
Respondent indiv. charact. controls (X)		Yes	Yes	Yes	Yes	Yes
Correlation between random parameters		/	/	No	No	Yes
Nb of individuals		1556	1556	1556	1556	1556
Nb of observations		9336	9336	9336	9336	9336
Nb of parameters		24	27	28	34	40
LL (final)		-11004.1	-10917.5	-9137.3	-8808.2	-8625.2
Adj.Rho-squared (0)		0.148	0.154	0.292	0.317	0.331
AIC		22056	21889	18331	17684	17330
BIC		22228	22082	18531	17927	17616

Notes: Values for MXLs are the “ μ ” parameters of normal and lognormal functions. See detailed results in appendices.

P-values: 1 () 0.1 (‘) 0.05 (*) 0.01 (**) 0.001 (***) 0.

5.1.1. General comments on models

The MNL1 and MXL1 suppose no difference between VoTTs of the four modes. The MNL2, MXL2 and MXL3, which consider “mode-valued” heterogeneity, outperform these models with higher Rho-squared and lower AIC and BIC. It shows with consistency across models that time is valued differently in solo driver compared to its alternatives. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) confirm that using random coefficients produces a better goodness of fit, indicating with consistency over the three MXL the presence of individual heterogeneity. The best fit is found for MXL3,

indicating correlations between time parameters estimated.

5.1.2. Constants

A positive (resp. negative) mode k ASC implies a relative preference (resp. depreciation) for mode k over the solo driver mode (reference alternative). The Public Transport ASCs are significantly negative in every model which means that all other variables equaling zero, there is on average a preference for Solo Driver mode over Public Transport.

Despite the means of ASC for Carpool Driver and Carpool Passenger are zero in the MXL3 model, there is a strong heterogeneity in “pure” preferences for modes across individuals. Indeed, the standard deviations of the ASC are high, 1.51 for Carpool Driver, 0.69 for Carpool Passenger and even 2.12 for Public Transport.

5.1.3. Values of time

The MNL2 results show directly VoTTs in €/minute, that can be multiplied by 60 to give results in €/h. Solo Driver, Carpool Driver, Carpool Passenger and Public Transport VoTTs are respectively equal to 20€/h, 30€/h, 28€/h and 29€/h. In the MXL3, due to specificities of the lognormal distribution, $\exp(\mu)$ is the median of the lognormal distribution. Consequently, MXL3 gives median VoTTs for Solo Driver, Carpool Driver, Carpool Passenger and Public Transport respectively equal to 28€/h, 31€/h, 29€/h and 33€/h.

Table 4 below displays the VoTT for all modes estimated through MNL2 and MXL3. The lower Solo Driver VoTT given by the MNL2 suggest a preference for this mode. The three alternatives to this mode show VoTTs between 40% and 50% higher than solo driver VoTT. Since the respondents are currently solo drivers, this is not surprising to find Solo Driver VoTT as the lowest.

Table 4: Values of Time in MNL and MXL models

Mode	Model	
	MNL2	MXL3 Med [1Q;3Q]
Solo Driver	20	28 [12 ; 64]
Carpool Driver	30	31 [18 ; 60]
Carpool Passenger	28	29 [14 ; 59]
PubT	29	33 [19 ; 59]

5.1.4. Schedule delay

Schedule delay is presented only with solo driving mode in the survey. In all models, the cost of arriving at destination one minute earlier than the preferred arrival time (0.19€/minute in MNL2, 0.17€/minute in MXL3) is found to be higher than the cost of arriving one minute later (0.05€/minute in MNL2, 0.03€/minute in MXL3). This is an unexpected result discussed in the next section. Our results also suggest that the value of the schedule delay early is around 36% of the Solo Driver VoTT.²

5.1.5. Cost

As expected, the cost coefficient sign is negative in both specifications. The value of the estimated coefficient in MXL3 implies that all other things being equal, a one euro increase in the price of a mode decreases the odds of choosing this mode over other modes by 15.4%.³

5.2. LCL model

We also estimate coefficients in Equations (1) with a LCL model. The LCL model with the lowest AIC, presented here in Table 5, has four classes. We use the five “attitude statements” as latent class membership covariates. We also tested individual socio-economic variables (gender, age, and income) as latent class membership covariates, but the goodness-of-fit was lower (see Appendices).

The adjusted Rho-squared of the LCL is 0.33. The LCL model outperforms the MNL with lower information criterions (AIC and BIC). Since their structures are not nested, MXL and LCL are not directly comparable. However, they present similar goodness of fit.

² $0.166 / \exp(-0.777) = 0.361$

³ $\exp(-0.167) - 1 = -0.154$

Table 5: Estimations results of LCL model

Attribute	Alternative	LCL			
		Class A	Class B	Class C	Class D
Alternative Specific Constants (Reference: Solo Driver)	CpDriver	-3.042 ***	2.103 ***	-2.659 ***	1.100 ***
	CpPassger	-5.531 ***	2.554 ***	-1.832 **	-1.068 **
	PubTrsprt	-4.396 ***	2.507 ***	0.997 **	-1.659 **
Travel Time	SDriver	0.280 ***	0.454 ***	0.443 ***	0.208 ***
	CpDriver	0.432 ***	0.719 ***	0.290 ***	0.313 ***
	CpPassger	0.113	0.620 ***	0.278 ***	0.185 ***
	PubTrsprt	0.237 **	0.714 ***	0.400 ***	0.293 ***
Scheduled early	SDriver		0.193 ***		
Scheduled late	SDriver		-0.017		
Cost	All		-0.132 ***		
Latent Class Allocation Variables					
	Average Latent Class Allocation Probability	0.20	0.35	0.12	0.32
	S1 (“car traffic major source”)	0	0.263 **	0.353 **	0.161 .
	S2 (“satisfied with my choices”)	0	-0.679 ***	-0.966 ***	-0.285 ***
	S3 (“could change easily”)	0	0.661 ***	0.891 ***	0.499 ***
	S4 (“opinion matter”)	0	0.091	-0.116	0.138 *
	S5 (“personally responsible”)	0	0.206 *	0.045	0.155 .
Carpool organization controls (Z)			Yes		
Respondent Individual characteristics controls (X)			Yes		
Nb of individuals			1556		
Nb of observations			9336		
Nb of parameters			66		
LL(final)			-8560		
Adj.Rho-square			0.334		
AIC			17252		
BIC			17723		

Notes: This table reports LCL estimates of coefficients in Equations (1).

P-values: 1 () 0.1 (‘) 0.05 (*) 0.01 (**) 0.001 (***) 0. See Appendices for more detailed results.

5.2.1. Latent class probability and covariates

The sample average probability of belonging to Class A is 20%, 35% for Class B, 12% for Class C and 32% for Class D. We find that individuals who agree with the statements S2 (“I am satisfied with my daily trip choices”) and disagree with statement S3 (“I can or could easily change the way I travel on a daily basis”) have a higher probability of belonging to Class A. On the contrary, individuals who disagree with S2 and agree with S3 are more likely to belong to Class B and even more to class C. Individuals who agree with S4 (“The opinion of people who matter to me is important for the way I travel on a daily basis”)

are more likely to be in Class D. Finally, we can observe a tendency for class B (and more slightly for class D) to declare more often they feel personally responsible to reduce traffic, and that it is a major source of pollution (Statements 1 and 5).

5.2.2. Mode preferences

To understand how mode preferences differ between the classes, it is important to consider both ASCs and VoTTs. Therefore, we build up in Table 6 generalized costs for a 40-minute trip which is the average length of respondents' current trip (see Table 2).

Class A preferences are clearly drive by the ASC with high negative values that prevent any switching from the solo driver mode. On the contrary, class B has positive ASCs, indicating an interest for alternative modes but the difference between the generalized costs of the different modes is smaller. The VoTTs of all modes are quite high compared to other classes, suggesting this class has a higher opportunity cost of time. Class C clearly rejects carpool alternatives, with a preference for Public Transport and finally, class D prefers driving modes.

Table 6 : Generalized costs for a 40-minute trip in each mode and class in LCL

	Class A	Class B	Class C	Class D
Solo Driver	11€	18€	18€	8€
Carpool Driver	40€	13€	32€	4€
Carpool Passenger	47€	6€	25€	15€
Public Transport	43€	10€	8€	24€

Notes: the generalized cost is obtained dividing the ASC by the cost estimate and adding the mode-specific value of 40 minutes for each mode.

5.3. Elasticities

We compute direct modal share elasticities to travel time by using Hensher et al.'s (2015) formula. The elasticity of the probability to choose alternative j with respect to a marginal change in attribute k in the alternative j is:

$$E_{X_{jk}}^{P_j} = \frac{\partial V_j}{\partial X_{jk}} X_{jk} (1 - P_j)$$

Note that the elasticity is then sensitive to modal share, P_j and to end-to-end travel time X_{jk} .

Results are presented in Table 7 below. In all models, time elasticity is the lowest for the Solo Driver

mode, then increasing for Carpool Driver, Carpool Passenger and finally Public Transport. The direct elasticities ranking is the same across models, showing some robustness. Moreover, elasticities are calculated locally and are therefore sensitive to the modal shares and travel times of our sample (see Table 1 and Table 2). This strengthens the validity of the elasticity ranking as Carpool Driver has a higher modal share and lower end-to-end travel time than Solo Driver and still has a higher elasticity.

Table 7: Direct share elasticities to end-to-end travel time

Alternative	MNL2	MXL3	LCL
Solo Driver	-1.15	-0.86	-0.78
Carpool Driver	-1.34	-1.30	-1.16
Carpool Passenger	-1.72	-1.88	-1.59
Public Transport	-2.06	-2.17	-2.01

Notes: These elasticities are calculated on the survey data. They can be interpreted as follows: an increase of 1% solo driver travel time would decrease the probability to choose the solo driver mode by 0.78% according to LCL results.

6. DISCUSSION

6.1. Main results

6.1.1. Heterogeneity of preferences

In our study, MXL3 and LCL models clearly outperforms the MNL2, the pseudo-R-squared being more than twice larger than the MNL2 one. This proves that the heterogeneity of individual preferences is meaningful. Moreover, in the MXL3 model, the combination of the standard deviation and correlation estimates that are statistically significant shows that both the ASC and the VoTT are highly distributed across the population. This heterogeneity in preferences towards transport modes may recover several aspects. It can be related to mode-specific features (like service quality or comfort), to individual characteristics (age, income, gender), or to personal attitudes (environmental concerns, social norms). A sharpened public policy should consequently consider this high heterogeneity.

The LCL model allows a different approach to estimate preferences heterogeneity, distinguishing as many preferences profiles in the sample as the number of classes. We consider simultaneously VoTTs and ASCs to understand mode preferences of each class. As an example, in Class A, the Carpool Passenger's VoTT is not significant, but the Carpool Passenger constant is very high with a negative impact on the

alternative. This reveals a strong aversion for this mode in Class A. The four following profiles are identified with the same logic:

- Reluctant to change from solo driving (Class A, 20% of the sample)
- Preferring the three alternative modes over solo driver (Class B, 35%)
- Preferring public transport (Class C, 12%)
- Preferring driver modes whether solo or carpool (Class D, 32%)

The ranking of elasticities found in Table 7 – with higher elasticities for alternatives to solo driver – implies that the modal shift towards carpooling and public transport will be greater if one reduces the (end-to-end) travel times of these modes rather than increasing the solo driver's travel time.

6.1.2. Values of time

The VoTT ratios go from 40% to 50% higher VoTTs for carpool modes compared to the solo driver VoTT. They are slightly higher than those Ciari & Axhausen (2012) found with Swiss data (their ratios are between 20% and 30% higher for carpool modes VoTTs). It could be explained by differences between the two samples. Ours is composed of current commuting solo drivers, expected to have a stronger preference for solo driving over other modes compared to a whole population representative sample, as in Ciari & Axhausen (2012). Consequently, they could proportionally value lower the Solo Driver travel time compared to a sample including other mode users.

VoTTs estimated in this survey are higher than what Wardman et al. (2016) and Shires & De Jong (2009) reported for commuting by car in France, respectively 11.8€₂₀₁₉/h and 15.4€₂₀₁₉/h. Several reasons may explain this. First, our sample is composed only of currently solo drivers, who may have higher incomes than the whole population and hence higher values of time. Another explanation could be that the values we find can be considered from a willingness to accept (WTA) perspective since the exercises challenge what solo drivers are willing to accept to switch to another mode (see also Monchambert, 2020). In the VoTT field, De Borger & Fosgerau (2008) found an important gap between WTP and WTA with a 1 to 4 factor.

When analyzing the distributions of MXL3-derived VoTTs, we see that the interquartile ranges are overlapping. This is an unexpected result since our sample contains only solo drivers. One would have

expected the distribution of the solo driver VoTT to be at lower ranges. This suggests that the current choice of solo driving by some respondents is constrained by the weak quality of alternative supplies because with equivalent travel times, they would choose alternative modes more often.

The schedule late delay is valued lower than schedule early delay. This result is unexpected and opposite to what is found in the literature. It could be due to the way we introduced schedule delay in the survey, that may have been unclear. Respondents could have only observed that their departure time was later than usual and hence thought their total travel time was lower, thinking all the alternatives were arriving on time. Respondents may also have a lot of flexibility and no time constraints they cannot override. However, the scheduled early value is found around 36% of the Solo Driver VoTT. This result is consistent with what was found in de Palma & Fontan (2000) in Paris, around 35%.

6.2. Policy implications

6.2.1. Carpool passenger is the scarce resource

The analysis of preferences allows to predict properly modal shares and the impact of new measures on demand. This is an opportunity to test the effects of a HOV-lane and a subsidy for carpooling passengers. Therefore, modal shares need to be estimated on a reference situation. This reference situation is calibrated to give modal shares close to those observed (in France, the car occupancy rate for commuting trips is 1.08, ADEME, 2015). Thus, the transport supply of the four modes is calibrated based on the current travel time of the respondent. The solo driving alternative has an end-to-end travel time equal to the respondent's current situation. A few minutes are added to the carpool trips as a driver and as a passenger to represent the potential time lost to find or wait for the carpooler. Public transport trips are assumed to be 50% longer than the solo driver trip. Modal shares obtained in this situation are displayed in the first lines of Table 8 below. Two levels for each measure have been tested. A 5-minute and a 15-minute time gain with the HOV-lane, a 1.5€ and a 3€ subsidy.

Table 8: Market shares with the implementation of new measures

Measure	Alternative	MNL2	MXL3	LCL
<i>(i) Reference situation</i>	Solo Driver	76%	65%	73%
	Carpool Driver	16%	23%	19%
	Carpool Passenger	5%	8%	6%
	Public Transport	3%	4%	2%
<i>(ii) HOV-Lane</i> <i>5 min time savings</i>	Solo Driver	-5pp	-3pp	-5pp
	Carpool Driver	+3pp	+3pp	+4pp
	Carpool Passenger	+1pp	+0pp	+1pp
	Public Transport	+1pp	+0pp	+1pp
<i>(iii) HOV-Lane</i> <i>15 min time savings</i>	Solo Driver	-15pp	-11pp	-17pp
	Carpool Driver	+10pp	+9pp	+12pp
	Carpool Passenger	+3pp	+1pp	+3pp
	Public Transport	+2pp	+1pp	+2pp
<i>(iv) Subsidy</i> <i>1.5€ subsidy for Carpool Passenger</i>	Solo Driver	-1pp	-1pp	-1pp
	Carpool Driver	-0pp	-1pp	-0pp
	Carpool Passenger	+1pp	+1pp	+1pp
	Public Transport	-0pp	-0pp	-0pp
<i>(v) Subsidy</i> <i>3€ subsidy for Carpool Passenger</i>	Solo Driver	-1pp	-1pp	-2pp
	Carpool Driver	-0pp	-1pp	-1pp
	Carpool Passenger	+2pp	+3pp	+3pp
	Public Transport	-0pp	-0pp	-0pp

Notes: values in the reference situation are the initial modal shares. Values in HOV-lane and subsidy scenarios indicates gains or losses in percentage points compared to the reference situation

The reference situation (*i*) modal shares are slightly different between the models. However, these shares are of the same order of magnitude and reflect the current situation on the routes potentially affected by a HOV-lane. In the reference situation, the scarce resource for carpooling is the passenger. Indeed, even if carpool drivers would like to carpool, they are limited by the low number of potential passengers. According to the MXL3, out of 100 current drivers, only one-third (8/23) of drivers willing to carpool can find a carpool passenger. Furthermore, 96% of people choose to commute by car (solo driver +

carpool modes modal shares) and only 8% will be able to do it as carpool passengers. Hence, the vehicle occupation rate would be 1.09 (on 100 individuals 96 are commuting in $96 - 8 = 88$ cars, thus an occupation rate of $96/88 = 1.09$), very close to what is observed today.

The estimation of modal shares varies across the models. Indeed, the MXL3 model estimates a lower modal share for the solo driver. It is also less sensitive to time savings and more sensitive to subsidies than other models. The important result of these predictions is that the modal share of the Carpool Passenger remains very low despite the implementation of measures to increase this share.

We study the effects of a HOV-lane, which allows a time saving of 5 (*ii*) or 15 minutes (*iii*) for carpooling and public transport modes. Scenario (*ii*) implies a potential decrease in the solo driver modal share of between 3 and 5 percentage points. However, the variation in the effective share of carpoolers is marginal because few switchers go towards the scarce resource, carpool passenger.

Scenario (*iii*) is hardly more successful. Indeed, according to the MXL3 (and LCL), of the solo drivers leaving this mode, 82% (71%)⁴ become potential carpool drivers and only 9% (18%) become carpool passenger. The time saving does not seem to overcome the scarcity of the carpool passenger resource.

Scenarios (*iv*) and (*v*) consist of the allocation of a subsidy of €1.5 and €3 respectively to carpool passengers.⁵ These subsidies result in a slight increase in the modal share of carpool and passenger (+1 pp in scenario (*iv*) and between +2 and +3 pp in scenario (*v*)). The 3€ subsidy is expected to decrease the total share of drivers (solo and carpool) from 88 to 85%. As the drivers' average distance travelled in Lyon's area is around 26km (SYTRAL, 2016), it implies that the subsidy would cost 0.4€ per veh.km saved.⁶ This is way higher than the average external cost of a car, estimated at around 0.12€/veh.km by Van Essen et al. (2019). The main reason for this inefficiency is that around 70% of subsidized passengers would have chosen to be passengers even in the absence of subsidy (8% in reference situation, +3pp with the 3€ subsidy).

These simulations show that the measures tested do not seem to be effective solutions to the scarcity of carpool passengers. This result should be qualified because our sample only contains solo drivers. Carpool

⁴ 9 out of 11 (82%) people who leave solo driver mode choose the carpool driver mode.

⁵ As a comparison, in 2018, public transport in Lyon was subsidized at around €1.30 per trip (Crozet et al., 2019).

⁶ A rough back-of the envelope calculation gives 3 drivers less, each travelling on average 26km. Considering a scenario in which 11 passengers are paid 3€, we obtained a marginal cost of veh.km saved of $(3 \times 11) / (3 \times 26) \approx 0.4$.

passengers may come from other modes (public transport, bicycle) or from the induced demand. However, in this case, the implementation of the carpool lane would not cause a decrease of vehicular traffic. Our recommendation to the public authorities is to be cautious about the modal origin of carpool passengers, who are the scarce resource of the system. There are several potential rebound effects on modal shift or trip distance that could mitigate positive effects of carpooling on traffic and pollution reductions (Coulombel et al., 2019).

6.2.2. *Latent class attitudes*

Following the results and typology identified with the LCL model, we find that attitudes are better correlates of carpool behavior than socio-demographics. These attitudes could be a tool to identify and target the profiles of individuals likely to switch to carpooling.

Respondents the most likely to switch to Carpool Driver are those associated with class D, which represent an important part of the sample (32%, see Table 5). This class values the opinions of others more highly. As shown in Table 6, the two driver alternatives generalized costs remains very close since end-to-end travel times are similar (8 € for solo driving, 4 € for carpool driving). This means the HOV-lane time gain should at least compensate the Carpool Driver time loss due, for example to a possible detour, in order to keep end-to-end travel durations equal.

If one wants to promote carpooling to reduce car traffic, some drivers will have to switch to passengers. It is even more crucial given the results obtained from simulations, indicating passengers will be the scarce resource. Following the typology obtained from the LCL, individuals most likely to switch to Passenger Carpool are those associated with class B, which represents 35% of the sample. Linking the classes to the attitudes is consistent since these classes contain more respondents thinking car traffic is a major source of pollution and unsatisfied with their current journey choice (i.e. solo driving). It appears more useful to target this class with the message that carpooling makes people pollute less. This class has similar generalized costs for all alternatives. It seems difficult to guarantee a shorter end-to-end travel time when carpooling as a passenger than as a driver. However, it is necessary to guarantee quality and reliability of service to encourage them to switch to carpool passengers. Since the financial incentive on its own seems of limited effectiveness, the combination of several incentives or other incentives should be explored. The potential of nudging or psychological interventions combined to monetary incentives

looks promising (Hilton et al, 2014; Raux et al, 2020).

6.3. Limitations of the study

6.3.1. Difficulty in considering a new supply

The first limitation of the survey comes from the limitations of the stated choice method. It is assumed that the hypothetical choice of respondents and their choice in a real situation would be the same. The difficulty of projecting oneself into the future and face this new HOV-lane could also bias the results. This hypothetical bias tends to lead to higher WTP.

6.3.2. External validity

As we only surveyed solo drivers, this sample does not reflect the entire population of a territory that could use carpooling to commute. In our case, it could be that some current public transport users switch to carpooling after the introduction of a HOV-lane.

Another limitation is the focus on end-to-end travel time values. This choice has been made to ensure comparability with VoTTs found in the literature. Nonetheless, it does not consider the various components that are part of a carpool trip. As Wardman et al. (2016) shows for public transport, access, waiting and detour times could be valued differently than in-vehicle time. Assessing these components could provide a more accurate understanding of individual preferences.

Furthermore, this sample is not representative of the whole French population. It remains more representative of solo driving commuters even if some of the occupations are under- (laborers) or over-represented (senior management). However, HOV-lanes are mainly installed on the outskirts of dense urban areas. The populations that can benefit from these infrastructures may also be different from all commuting solo drivers of the city. It will therefore be necessary to pay attention to the target population before generalizing the results of this study.

7. CONCLUSION

This paper has estimated preferences for four different modes for commuting trips in a context of prioritizing carpool through HOV-lanes: solo driver, public transport and carpool as a driver and as a passenger. A stated choice survey conducted on a 1556-respondent sample allowed us to understand modal choices through different types of models measuring heterogeneity in preferences across modes

and individuals.

Our results suggest an average preference for the solo driving mode compared to carpool or public transport among solo drivers. Nonetheless, the respondents react heterogeneously in their mode choice behavior. The latent-class analysis reveals these heterogeneities are explained better by the attitude statements than by socio-economic variables. Besides, it also allows a typology of currently commuting solo drivers that identifies four behavioral patterns: individuals reluctant to mode change, those preferring the three alternative modes over solo driver, the ones preferring public transport and the last preferring driver modes whether solo or in carpool. This typology could be used to target profiles likely to switch to carpooling as a driver and as a passenger. Moreover, knowing the preferences for carpooling provides a basis for calculating benefits in cost-benefits analysis. It could also be valuable for future studies on shared autonomous vehicles.

Moreover, our results clearly indicate that if one wants to decrease cars traffic by stimulating carpooling for commuting trips, the passengers will be the scarce resource. Indeed, the behavioral pattern most likely to switch to carpool passenger is also appealed by other alternative modes. Incentives will therefore have to be targeted on car commuters ready to switch and strengthened to make the passenger mode as attractive as possible.

Finally, we know carpool organization and individual social interactions may impact carpool choices. This raises the question of how impactful matching between individuals can be on the decision to carpool or not. Moreover, the different stages that compose end-to-end travel time can be valued differently, such as access to carpool meeting or waiting times. These effects on commuting mode choice will be explored through further research.

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







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APPENDICES

Appendix A: An example of choice screen for a driver respondent with a 8:30 preferred arrival time

Mode	Driver Alone	Driver in a Carpool	Passenger in a Carpool	Public Transport
Trip Characteristics	Start : 7:20  Drive Alone: Between 30 and 40 min Arrival: Between 7:50 and 8:00	Start : 7:30 Join the station: no detour Wait:  5 min  Carpool : Between 25 and 40 min Join your destination:  5 min walk Arrival : Between 8:15 and 8:30	Start : 7:35 Join the station:  5 min walk Wait:  5 min  Carpool : Between 30 and 40 min Join your destination:  5 min walk Arrival : Between 8:20 and 8:30	Start : 7:30 Join the station:  10 min by car Wait:  5 min  Public Transport: Between 25 and 40 min Join your destination:  5 min walk Arrival : Between 8:15 and 8:30
Monetary aspects	You pay your usual transportation costs	You pay your usual transportation costs Carpooling makes you earn 1€	You save on your usual transportation costs Carpooling costs you 1€	You save on your usual transportation costs Public Transport costs you 0,80€
Carpooler's profile		Your passenger:  45 years old, Hitchhiker	Your driver:  25 years old, Referenced on the carpool platform	
Which mode do you choose ?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix B: Correlation estimates

The β_{ttk} estimates are assumed log-normally distributed with the following correlations:

$$\begin{aligned} \beta_{ttsd} &= \exp(\mu_{\beta_{ttsd}} + \sigma_{\beta_{ttsd}} * \xi_{\beta_{ttsd}}) \\ \beta_{ttcpd} &= \exp(\mu_{\beta_{ttcpd}} + \sigma_{\beta_{ttcpd}} * \xi_{\beta_{ttcpd}} \\ &\quad + \theta_{cpdsd} * \xi_{\beta_{ttsd}}) \\ \beta_{ttcpp} &= \exp(\mu_{\beta_{ttcpp}} + \sigma_{\beta_{ttcpp}} * \xi_{\beta_{ttcpp}} \\ &\quad + \theta_{cpps d} * \xi_{\beta_{ttsd}} \\ &\quad + \theta_{cppcpd} * \xi_{\beta_{ttcpd}}) \\ \beta_{ttpt} &= \exp(\mu_{\beta_{ttpt}} + \sigma_{\beta_{ttpt}} * \xi_{\beta_{ttpt}} \\ &\quad + \theta_{ptsd} * \xi_{\beta_{ttsd}} \\ &\quad + \theta_{ptcpd} * \xi_{\beta_{ttcpd}} \\ &\quad + \theta_{ptcpp} * \xi_{\beta_{ttcpp}}) \end{aligned}$$

The θ parameters allow us to capture correlations between VoTT of the 4 modes. As an example, the parameter θ_{dcps} (used in the expression of β_{ttcp}) is multiplied by $\xi_{\beta_{ttsd}}$, already used in the expression of β_{ttsd} .

Appendix C: LCL models tested with attitudes vs socio-economics

Class allocation variables	Attitudes	Socio-Economics
#parameters	66	51
LL	-8560	-8741
R ² -adj	0.334	0.321
AIC	17252	17584
BIC	17723	17948

Appendix D: Trip attributes and levels in stated choice design

Attributes	Alternatives	Levels
Time variables		
Schedule early/late	Solo Driver	0, 30, 60 minutes (earlier or later)
Access time	Passenger modes*	5 minutes walking (ref), 10 minutes by car, 20 minutes by car
Detour time	Carpool Driver	0, 5, 10 minutes
Waiting time	Passenger modes and Driver in Spontaneous Carpool	0, 5, 10 minutes
In-vehicle travel time	All	Solo Driver: (0.8, 1.1, 1.5) * usual_tt Other modes: (0.6, 0.9, 1.2) *usual_tt
Travel time variability	All	(0.1, 0.3, 0.5) * In-vehicle travel time
Egress time	Passenger modes	Carpool passenger: 5 min walking (ref), 10/20 min by Public Transport Public transport: 5 min walking
Cost (in €)	Carpool modes* and Public Transport	Carpool Driver: receives (0, 0.02, 0.05, 0.1) * usual_tt Carpool Passenger: pays (0, 0.02, 0.05, 0.1) * usual_tt Public transport: pays 0.8
Carpooler profile		
Carpooler matching	Carpool modes	Planned (with a relative or by platform), Spontaneous (with a hitchhiker or by platform)
Carpooler Gender		Male, Female (not presented if relative)
Carpooler Age		25, 45, 65 years old (not presented if relative)

Notes: Passenger modes: Carpool Passenger and Public Transport. Carpool modes: Carpool Driver and Carpool Passenger. "usual_tt" is the usual travel time the respondent reports in the survey

Appendix E: Full estimation results of MNL and MXL models

Attribute	Alternative	MNL1	MNL2	MXL1	MXL2	MXL3
Alternative-Specific	Carpool Driv.	-0.483***	0.240*	-1.038***	-0.845**	-0.015
Constants (ASCs) (Reference: Solo Driver)	Carpool Pass.	-0.638***	0.025	-1.082***	-1.079**	-0.295
	Pub. Transport	-1.054***	-0.286*	-2.186***	-0.917*	-0.886*
ASCs	Carpool Driv.			2.350***	1.413***	1.508***
Standard deviation (σ_{ASC})	Carpool Pass.			2.494***	0.092	0.686***
	Pub. Transport			2.864***	1.503***	2.122***
Travel time ($\mu_{\beta_{tt}}$ in MXLs)	Solo Driver		0.336***		-0.630***	-0.777***
	Carpool Driv.		0.502***		-0.730***	-0.666***
	Carpool Pass.	0.576***	0.462***	-1.095***	-0.841***	-0.732***
	Pub. Transport		0.481***		-0.548***	-0.588***
Travel time Standard deviation ($\sigma_{\beta_{tt}}$)	Solo Driver				0.891***	1.254***
	Carpool Driv.				0.260***	0.674***
	Carpool Pass.			0.776***	0.233***	0.004
	Pub. Transport				0.275***	0.019
Travel time Correlation estimates (θ in MXL3)	Solo Driver / Carpool Driver					0.738***
	Solo Driver / Carpool Passenger					0.694***
	Solo Driver / Public Transport					0.629***
	Carpool Driver / Carpool Passenger					0.786***
	Carpool Driver / Public Transport					0.578***
	Carpool Passenger / Public Transport					-0.048
Schedule early	Solo Driver	0.299***	0.190***	0.175***	0.170***	0.166***
Schedule late	Solo Driver	0.072***	0.052***	0.050***	0.056***	0.033*
Cost	All	-0.072***	-0.100***	-0.199***	-0.163***	-0.167***
Male	Carpool Driv.	-0.239***	-0.213***	-0.367*	-0.525**	-0.362*
	Carpool Pass.	-0.412***	-0.391***	-0.625***	-0.694***	-0.596**
	Pub. Transport	-0.296***	-0.273***	-0.543**	-0.618**	-0.464*
Age46+	Carpool Driv.	-0.438***	-0.459***	-0.744***	-0.907***	-0.700***
	Carpool Pass.	-0.492***	-0.502***	-0.719***	-0.841***	-0.598**
	Pub. Transport	-0.222**	-0.273***	-0.269	-0.507*	-0.218
Income	Carpool Driv.	0.158***	0.185***	0.225**	0.261*	0.225‘
	Carpool Pass.	0.070‘	0.087*	0.018	0.101	0.058
	Pub. Transport	0.192***	0.213***	0.251*	0.318**	0.253‘
Platform	Carpool Driv.	0.067	0.109*	0.166*	0.179**	0.204**
	Carpool Pass.	0.240***	0.233***	0.306**	0.324***	0.281**
Spontaneous	Carpool Driv.	0.023	0.041	0.054	0.124	0.152
	Carpool Pass.	-0.135*	-0.132‘	-0.359‘	-0.120	-0.159
CarpoolerMale	Carpool Driv.	-0.230***	-0.218***	-0.448***	-0.400***	-0.427***
	Carpool Pass.	-0.243***	-0.260***	-0.403***	-0.389***	-0.387***
CarpoolerAge	Carpool Driv.	0.023	0.003	0.062	0.063	0.030
	Carpool Pass.	-0.026	-0.033	-0.040	-0.037	-0.012
Nb of individuals		1556	1556	1556	1556	1556
Nb of observations		9336	9336	9336	9336	9336

Nb of parameters	24	27	28	34	40
LL (final)	-11004.1	-10917.5	-9137.3	-8808.2	-8625.2
Adj.Rho-squared (0)	0.148	0.154	0.292	0.317	0.331
AIC	22056	21889	18331	17684	17330
BIC	22228	22082	18531	17927	17616

Notes: Values for MXLs are the “ μ ” parameters of normal (for ASCs) and lognormal (for time) functions.

P-values: 1 () 0.1 (‘) 0.05 () 0.01 (**) 0.001 (***) 0.*

Appendix F: Estimations results of LCL model

Attribute	Alternative	LCL			
		Class A	Class B	Class C	Class D
Alternative Specific Constants	CpDriver	-3.042 ***	2.103 ***	-2.659 ***	1.100 ***
	CpPassger	-5.531 ***	2.554 ***	-1.832 **	-1.068 **
	PubTrsprt	-4.396 ***	2.507 ***	0.997 **	-1.659 **
Travel Time	SDriver	0.280 ***	0.454 ***	0.443 ***	0.208 ***
	CpDriver	0.432 ***	0.719 ***	0.290 ***	0.313 ***
	CpPassger	0.113	0.620 ***	0.278 ***	0.185 ***
	PubTrsprt	0.237 **	0.714 ***	0.400 ***	0.293 ***
Scheduled early	SDriver		0.193 ***		
Scheduled late	SDriver		-0.017		
Cost	All		-0.132 ***		
Male	CpDriver		0.134		
	CpPassger		0.042		
	PubTrsprt		0.115		
Age46+	CpDriver		-0.135		
	CpPassger		-0.049		
	PubTrsprt		0.095		
Income	CpDriver		0.047		
	CpPassger		-0.134 ‘		
	PubTrsprt		0.095		
Platform	CpDriver		0.175 **		
	CpPassger		0.296 ***		
Spontaneous	CpDriver		0.170 ‘		
	CpPassger		0.083 ‘		
CarpoolerMale	CpDriver		-0.351 ***		
	CpPassger		-0.350 ***		
Carpooler25yo	CpDriver		0.018		
	CpPassger		-0.071		
Latent Class Allocation Variables					
Average Latent Class Allocation					
Probability		0.20	0.35	0.12	0.32
S1 (“car traffic major source”)		0	0.263 **	0.353 **	0.161 .
S2 (“satisfied with my choices”)		0	-0.679 ***	-0.966 ***	-0.285 ***
S3 (“could change easily”)		0	0.661 ***	0.891 ***	0.499 ***
S4 (“opinion matter”)		0	0.091	-0.116	0.138 *
S5 (“personally responsible”)		0	0.206 *	0.045	0.155 .
Nb of individuals				1556	
Nb of observations				9336	
Nb of parameters				66	
LL(final)				-8560	
Adj.Rho-square				0.334	
AIC				17252	
BIC				17723	

*Notes: P-values: 1 () 0.1 (') 0.05 (*) 0.01 (**) 0.001 (***) 0.*