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# Why do (or don't) people carpool for long distance trips?

## A discrete choice experiment in France

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### Abstract

Long-distance carpooling is an emerging mode in France and Europe, but little is known about monetary values of this mode attributes in transport economics. We conducted a discrete choice experiment to identify and measure the values of attributes of long-distance transport modes for a trip as a driver and as a passenger, with a special focus on carpooling. Around 1.700 French individuals have been surveyed. We use discrete mixed logit models to estimate the probability of mode choice. We find that the value of travel time for a driver who carpools is on average 13% higher than the value of travel time when driving alone in his/her car. The average value of travel time for a carpool trip as passenger is around 26 euros per hour, 60% higher than for a train trip and 20% higher than for a bus trip. Moreover, our study confirms a strong preference for driving solo over taking carpoolers in one's car. We also show that individuals traveling as carpool passenger incur a "discomfort" cost of on average 4.5 euros per extra passenger in the same vehicle. Finally, we identify robust socio-economic effects affecting the probability of carpooling, especially gender effects. When they drive a car, females are less likely to carpool than male, but they prefer to carpool two passengers over only one passenger.

**JEL Codes:** R41; C35

**Keywords:** Value of time; Long-distance; Carpooling; Discrete choice experiment

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# 1. Introduction

Every month in France, more than one million people use the leading carpooling platform (Blablacar.com) to carpool for a long-distance trip.<sup>2</sup> According to CGDD (2016), long-distance carpoolers travelled 6 billion kilometers in 2015, which is 2.72% of the long-distance kilometers made by travelers in France. This trend is not France-specific: BlaBlaCar has now expanded to 22 countries across Europe, Asia, and Latin America and the platform claims more than 40 million users at the beginning of 2017 (Barrat, 2017) and 65 million at the end of 2018 (White, 2018). The success met by carpooling after 2010 is related to two factors: the sharing economy and emergence of online platforms (Montero, 2019).

However, Wagner (2016) suggests that there is no evidence that this development allows to decrease road traffic, because on the one hand most carpool passengers come from transit and not from private cars, and on the other hand, some carpool drivers (16% according to Wagner's study) would have not make the trip without monetary reward due to carpool. Using existing European data, Finger et al. (2017) reveal that the raise of carpooling is explained by a migration of substantial number of passengers from traditional long-distance public transport services. This is one of the reasons why Wang (2011) suggests to not award carpoolers with public resources such as free parking or high-occupancy lanes in China.

There is a need for new empirical evidence to better understand attitudes towards long-distance carpool and improve public policies. Despite the significant long-distance carpool raise, little is known about this successful but not new (see Teal, 1987) transport mode. Neoh et al. (2017) propose a meta-analysis of 22 studies evaluating factors of carpooling. They find that factors such as “number of employees”, “partner matching programs”, “female” and “fixed work schedule” have strong effects on carpooling decision (see also Charles & Kline (2006), Buliung et al. (2010), and De Luca & Di Pace (2015) for studies on the determinants of short-distance carpooling).

However, most of these studies look at short distance trips, especially commute to work and characteristics of daily commuting trips differ from those of occasional long-distance trips (Dargay &

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<sup>2</sup> The carpool trip distance average is around 360km (ADEME 2015).

Clark, 2012). Few studies address long-distance carpooling specificities. Delhomme & Gheorghiu (2016) study characteristics and motivational factors upon which carpoolers and non-carpoolers differ. They find that carpoolers are more likely to be women and have children. They also have positive attitude towards public transport and tend to be more environmentally aware. Shaheen et al. (2017) use an online survey of 618 BlaBlaCar members in France to show that carpoolers are on average younger than the French population, and respondents with high income level carpool more often as driver whereas low income respondents are more often carpool passengers. Farajallah et al. (2019) observe how price and demand are determined on BlaBlaCar platform. Controlling for price, they observe that the fraction of seats sold is three percentage points higher for female drivers than for males. In an extensive qualitative survey carried out by the French Environment and Energy Management Agency (ADEME, 2015), interviewed carpoolers state they carpool because this transport mode is, in order of importance, convivial, cheap, flexible, environmentally friendly and comfortable. These statements are to be tested through theoretical and empirical studies.

This paper focuses on the determinants of carpool choice for long-distance trips (100-700 km). As in Delhomme & Gheorghiu (2016), we define carpool as an arrangement where two or more people, not belonging to the same household, share the use of privately owned<sup>3</sup> car for a trip, and the passengers contribute to the driver's expenses.<sup>4</sup> In this framework, we address the following research questions: what are the determinants of carpool choice for long-distance trips?

We respond to these questions by measuring carpool Value of Travel Time (VoTT) for a trip as a driver and as a passenger, comparing them with other modes VoTT, and by measuring the value of an extra passenger from a driver and a passenger perspective. We also observe and measure channels by which individuals' socio-economic characteristics affect these elements. To this aim, a stated choices experiment survey was conducted in France.

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<sup>3</sup> Private property is an important carpooling feature because it distinguishes it from car-sharing, where the same vehicle is owned by several persons.

<sup>4</sup> Carpooling is known as ridesharing in North America.

To our knowledge, we are the first to empirically measure and value the attributes of long-distance carpooling, especially the VoTT and the effect of the number of passengers. This paper also contributes to the literature estimating mode-specific VoTT. We show that carpool VoTT is greater than competing modes VoTT, and that additional passenger in the vehicle is perceived as a cost by individuals, both as driver and as passenger. The econometric analysis also reveals strong and mode-dependent gender effects.

In this study, we do not investigate the choice between being a driver or a passenger. Indeed, this choice rests on a multitude of variables difficult to implement in a discrete choice experiment survey, such that the need of a car at destination. Consequently, we investigate separately the choice of mode for drivers on the one hand, and for passengers on the other hand.

The rest of the paper is organized as follows. Section 2 presents the theoretical framework and the empirical strategy used to measure VoTT and the effect of extra carpool passenger. Section 3 presents the survey design used to elicit preferences and summary statistics. Section 4 presents results. Section 5 concludes.

## **2. Theoretical framework**

We use a stated choices experiment survey to (i) test the validity of our hypothesis, and (ii) value the attributes of carpooling.

### **2.1. Utility functions**

Most of the journey positive attributes stated by carpoolers are not included in traditional utility functions. Therefore we need to define new utility functions which take into account these attributes. We distinguish utility of a trip as a driver and as a passenger, and we define one utility function per mode.

Travel time and monetary cost (or gain) are the traditional attributes of transport modes used in mode choice modelling (see for example Truong & Hensher, 1985). The trade-off between these two attributes is conceptualized through the VoTT defined in subsection 2.2 below. These attributes are to be included in the utility functions to test if carpool choice implies a lower, equal or high VoTT than other transport

modes. A specific attribute of carpool is the number of individuals in the car, which should also be considered in the carpool utility function. This attribute is somehow related to the occupancy rate in public transport, which may strongly deteriorate individual perceptions of trips (Haywood et al., 2017).

One of the purposes of the paper is to identify the ways individual socio-economics characteristics may have an effect on the mode choice probabilities. We want to test if these individual characteristics may explain the inter-individual differences in the VoTT and in the perception of the number of individuals in the car. Moreover, we especially want to test if the inter-modes variations in VoTT can be explained by socio-economics variables. For that, we use *interaction effects* between socio-economics variables and modes attributes of interest.

We consider three main socio-economics characteristics: age, gender and income. These variables have been identified as some of the determinants of the distribution of VoTT (Fosgerau, 2006, Small, 2012).

The utility of a trip as a driver ( $D$ ) who is alone (i.e. *solo* or  $s$ ) in his/her car,  $U_s^D$ , is usual and defined by:

$$U_s^D = \beta_{0;s} + \beta_{1;s}tt_s + \sum_i (\gamma_{i;s}X_i + \delta_{i;s}X_i tt_s) + \sum_k (\gamma_{k;s}X_k) + \varepsilon_s \quad (1)$$

where  $tt_s$  is the travel time solo,  $X_i$  is a set of socio-economic characteristics from which we test the interaction with travel time (age, gender and income), and  $X_k$  is a set of other individual characteristics.

A driver who chooses to carpool experiences a different utility, mainly because he/she is not alone in his/her car and because he/she receives a monetary payment. Therefore, his/her utility for a trip as a carpooling driver (i.e. *carpool as a driver* or  $cpd$ ),  $U_{cpd}^D$ , is described by

$$\begin{aligned} U_{cpd}^D = & \beta_{0;cpd} + \beta_{1;cpd}tt_{cpd} + \beta_{2;cpd}\tau + \beta_{3;cpd}NbExtPass \\ & + \beta_{4;cpd}NbExtPass tt_{cpd} \\ & + \sum_i (\gamma_{i;cpd}X_i + \delta_{i;cpd}X_i tt_{cpd} + \theta_{i;cpd}X_i NbExtPass) \\ & + \sum_k (\gamma_{k;cpd}X_k) + \varepsilon_{cpd} \end{aligned} \quad (2)$$

where  $\tau$  is the (gross) monetary gain received by the carpool driver, and  $NbExtPass$  is the number of *extra* carpooled passengers in the car. The effect of the number of passengers has to be disentangled from the *pure* effect of carpool. Carpool is characterized by at least one passenger. Therefore, the variable Number of extra passengers contains the total number of carpooled passengers minus 1.

Making a trip as a passenger differ from a trip as driver because a passenger may use different modes: carpool as passenger ( $cpp$ ), bus ( $b$ ) or train ( $t$ ). These modes being characterized by exogenous and discrete departure time and arrival time at destination, passengers have to choose within a finite set of possible arrival times. If the effective arrival time does not coincide with the preferred arrival time, the traveler incurs schedule delay costs, which can be early if he/she arrives before his/her preferred arrival time, or late if he/she arrives after (see Tseng & Verhoef, 2008). The utility of a carpool passenger,  $U_{cpp}^P$ , is:

$$\begin{aligned}
U_{cpp}^P = & \beta_{0;cpp} + \beta_{1;cpp}tt_{cpp} + \beta_{2;p}r + \beta_{3;cpp}NbOthPass + \beta_{4;cpp}NbOthPass tt_{cpp} \\
& + \sum_i (\gamma_{i;cpp}X_i + \delta_{i;cpp}X_i tt_{cpp} + \theta_{i;cpp}X_i NbOthPass) \\
& + \sum_k (\gamma_{k;cpp}X_k) + \alpha_1 SchedEarly + \alpha_2 SchedLate + \varepsilon_{cpp},
\end{aligned} \tag{3}$$

where  $r$  is the monetary price paid by passengers,  $NbOthPass$  is the number of other passengers in the car (excluding the driver),  $SchedEarly$  and  $SchedLate$  are schedule delay time variables. Early (respectively late) schedule delay time is positive and equals the time between preferred and effective arrival times if the effective arrival time occurs before (resp. after) the preferred arrival, and equals zero if not.

A passenger choosing to travel by bus (i.e.  $b$ ) or train (i.e.  $t$ ) experiences the following utility:

$$\begin{aligned}
U_j^P = & \beta_{0;j} + \beta_{1;j}tt_j + \beta_{2;p}r + \sum_i (\gamma_{i;j}X_i + \delta_{i;j}X_i tt_j) + \sum_k (\gamma_{k;j}X_k) \\
& + \alpha_1 SchedEarly + \alpha_2 SchedLate + \varepsilon_j, \quad j = b, t.
\end{aligned} \tag{4}$$

## 2.2. Values of travel time and of other passengers in the car

The Value of Travel Time (denoted VoTT) is the marginal rate of substitution between travel time and money (DeSerpa, 1971). Formally, it can be defined as (Lam & Small, 2001):

$$VoT_m \equiv \frac{\frac{\partial U_m}{\partial tt_m}}{\frac{\partial U_m}{\partial p_m}}, \quad (5)$$

where  $U_m$  is the utility associated to a trip with mode  $m$ ,  $tt_m$  is the travel time in mode  $m$  and  $p_m$  is a measure of monetary cost (or benefit) when using mode  $m$ . Consequently, the Value of Travel Time (VoTT) for each of the five modes we study can be written:<sup>5</sup>

$$\begin{aligned} VoTT_s &= \frac{\beta_{1;s} + \sum_i \delta_{i;s} X_i}{\beta_{2;d}}, \\ VoTT_{cpd} &= \frac{\beta_{1;cpd} + \beta_{4;cpd} NbExtPass + \sum_i \delta_{i;cpd} X_i}{\beta_{2;d}}, \\ VoTT_{cpp} &= \frac{\beta_{1;cpp} + \beta_{4;cpp} NbOthPass + \sum_i \delta_{i;cpp} X_i}{\beta_{2;p}}, \\ VoTT_j &= \frac{\beta_{1;j} + \sum_i \delta_{i;j} X_i}{\beta_{2;p}}, \quad j = b, t. \end{aligned} \quad (6)$$

The coefficients associated with the interaction terms,  $\delta_i$ , allow to measure how VoTT reacts to changes in individuals characteristics ( $\frac{\partial VoT_n}{\partial X_i} = \frac{\delta_{i;n}}{\beta_2}$ ).

At this point, it might be useful to recall that we expect VoTT to vary across individuals, but that we also expect VoTT of one individual to vary across modes. These variations are due to differences in comfort, noise, safety... More generally, the conditions of travel have an impact on the marginal utility of time. Wardman (2004) refer to these differences as *User Type* variation and *Mode Valued* variation in VoTT.

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<sup>5</sup> There is no monetary value in the utility function of a driver solo (Equation (1)). Therefore we use the coefficient  $\beta_{2;p}$  present in Equation (2). There is no normalization problem as coefficients from Equations (1) and (2) will be simultaneously estimated in a binomial logit model.



The other coefficients of interest to understand attitudes towards carpooling are related to the number of people in the car. In the same vein as VoTT, we define the Value of an Extra Passenger (*VoEP*) for carpool driver and the Value of an Other Passenger (*VoOP*) for carpool passenger:

$$\begin{aligned} VoEP_{cpd} &= \frac{\beta_{3;cpd} + \beta_{4;cpd}tt_{cpd} + \sum_i \theta_{i;cpd}X_i}{\beta_{2;d}}, \\ VoOP_{cpp} &= \frac{\beta_{3;cpp} + \beta_{4;cpp}tt_{cpp} + \sum_i \theta_{i;cpd}X_i}{\beta_{2;p}}. \end{aligned} \quad (7)$$

If VoEP and VoOP are positive, then people value the fact to travel with additional individuals in the car. This is the expected result according to declarative surveys made in France (ADEME, 2015).

### 2.3. Mixed logit

We estimate coefficients in Equations (1), (2), (3) and (4) in a logit framework (McFadden 1974). Utility functions in Equations (1), (2), (3) and (4) can be re-written:

$$\begin{aligned} U_m^D &= V_m^D + \varepsilon_m, & m = cpd, s, \\ U_m^P &= V_m^P + \varepsilon_m, & m = cpp, b, t. \end{aligned} \quad (8)$$

$V_m$  is the deterministic part of the utility, and  $\varepsilon_m$  the stochastic part. In this study, drivers have to choose between two transport modes: travelling alone or carpooling. Passengers may choose to travel by bus, train, or to carpool.

We use a mixed logit model (Hensher & Greene, 2003) to take into account the panel structure of our data. Each individual in our sample face a number of exercises or choice sets. Consequently, the choices made by one individual are not independent. We control this dependency by considering that the intercept in utility function ( $\beta_{0,m}$ ) are normally distributed across individuals.

In a context of a number  $T$  of choice situations and assuming that the errors terms  $\varepsilon_m$  are identically and independently extreme value distributed over individual, alternatives, and choice situations, Train (2009) shows that the probability of an individual selecting mode  $m$  is given by

$$P_m^D = \int \prod_{t=1}^T \left[ \frac{1}{1 + e^{V_m^D - V_{-m}^D}} \right] f(\beta_0) d\beta_0, \quad m = cpd, s, \quad (9)$$

$$P_m^P = \int \prod_{t=1}^T \left[ \frac{e^{V_m^P}}{\sum_k e^{V_k^D}} \right] f(\beta_0) d\beta_0, \quad m = cpp, b, t.$$

### 3. Survey design, sampling and data structure

#### 3.1. The sample

A stated choice experiment was used to collect data to examine the trade-off between travel time, price (or gain) of the trip and number of passengers in the car for trips both as driver and as passenger. An internet-based survey instrument was used. The data were collected in March and April 2017 involving respondents residing in France. Around 1 700 participants were selected by an internet panel provider. The sample is representative of the French population over 18 years old according to the quota method (gender, age, income and occupation).

We implement two distinct sub-experiments in this survey, one for trip as “driver” and the other for trip as “passenger”. The reason is that many factors affecting the choice of being a driver or a passenger cannot be implemented in a discrete choice experiment in a satisfactory way. An example of these factors is the need of having a car at destination. One respondent participated to the *driver sub-experiment* or to the *passenger sub-experiment*, but not both. The sub-experiments sampling has been made according to car ownership and driving license criteria. Individual without car or with driving license were not considered as potential drivers, so they went to the passenger sub-experiment. Among individuals with a car and a driving license, 225 were randomly chosen to go to the driver sub-experiment, whereas others respondents with a car and a driving license took part in the passenger sub-experiment. The driver sub-sample (225 individuals) is much smaller than the passenger sub-sample (1 476 individuals) because the driver model needs a smaller amount of data to be calibrated.

The characteristics of the samples are displayed in Table 1. Individuals in the driver sample are on average richer, have more qualified jobs, live closer to rail station but make less interurban trips than individuals from the passenger sample.

The statistics on the number of long-distance trips are biased by surprising statements from few individuals in the passenger sample who stated several thousand interurban trips in the last year.

	<b>Driver</b>		<b>Passenger</b>		<b>Pooled</b>	
	Mean	sd	Mean	sd	Mean	sd
Gender (1=woman)	40.9%		51.4%		50.0%	
Age (years)	46.64	15.72	45.61	14.92	45.75	15.03
Income (categorical) (€/month)	2302.22	1186.70	2029.81	1108.35	2065.84	1122.46
Occupation						
Higher managerial and prof. occupations	15.1%		10.0%		10.7%	
Intermediate occupations	13.3%		14.6%		14.5%	
Employees	22.7%		31.4%		30.2%	
Routine occupations	8.9%		6.0%		6.3%	
Retired	24.4%		19.9%		20.5%	
Unemployed	11.6%		13.3%		13.1%	
Students	4.0%		4.8%		4.7%	
Access time (min.) to the closest rail station	21.19	18.00	26.85	52.30	26.10	15.15
Is it a High speed rail station? (1=Yes)	58.2%		63.5%		62.8%	
Car in the household (1=Yes)	100%		91%		92%	
Car but no driving license (1=yes)	0.0%		3.4%		2.9%	
Mode-specific experience for interurban trips (at least one trip in the last year)						
train (1=Yes)	36.9%		42.5%		41.8%	
bus (1=Yes)	19.6%		20.1%		20.0%	
carpooling as driver (1=Yes)	38.7%		29.0%		30.3%	
carpooling as passenger (1=Yes)	29.8%		33.9%		33.4%	
Number of interurban trips made						
during the last year	11.56	18.54	72.01	1438.27	64.01	1339.88
by train during the last year	1.48	4.95	3.13	52.30	2.91	48.75
by bus during the last year	1.31	10.39	19.53	655.33	17.12	610.46
by carpooling as driver	3.46	9.67	5.55	50.65	5.27	47.32
by carpooling as passenger	1.51	4.68	3.41	16.14	3.16	15.15
<b>Sample size</b>	<b>225</b>		<b>1476</b>		<b>1701</b>	

*Notes: Income variable is categorical, the mean and standard deviation have been computed by using the centers of the classes. The sum of interurban trips made by different modes during last year does not exactly matches the stated total of interurban trips made during last year, due to divergence between respondents' statements.*

Table 1: Characteristics of the samples

### 3.2. The stated choice experiments

Respondents were first asked to fill in some socioeconomic characteristics and then take part in the driver sub-experiment or in the passenger sub-experiment, as described in subsection 3.1.

Each respondent faced two sets of 8 successive choice situations, and for each of these  $8 \times 2 = 16$  situations he/she was asked to make a choice. The two sets of choice situations faced by the individual differ in the length of trips, because we wanted to test if our results depend on the distance of the trip.

The length of the trips were 100km, 300km, 500km and 700km. For example, an individual first faced 8 mode choice situations for a 300km trip, than 8 mode choice situations for a 700km trip.

From the analysis perspective, it is important that the attribute levels of the proposed modes are not such that the preference for one mode dominates the preferences for the other modes present (Hensher & Rose, 2007). If a dominant alternative exists, respondents are unlikely to make a trade-off. We used the software Ngene<sup>6</sup> and an efficient design to build choice tasks described below. For each of the four possible trip distances (100, 300, 500 and 700km) and for the two sub-experiments (driver and passenger), we built 100 choice situations. For each respondent, 8 choice situations were randomly chosen among the set of 100 choice situations for one distance, and 8 choice situations were randomly chosen among the set of 100 choice situations for another distance.

Figure 1 presents examples of choice screens submitted to respondents.

For a 100km trip, you have the choice between travelling alone or carrying one passenger or more, according to the following conditions:

	Alone	Carpool
Travel time	1 hour	1:25 hour
Carpool revenue		30 euros
Nb of carpooled passengers		3

What do you choose ?

Travel alone
Carpool

Figure 1a: Example of choice situation screen submitted to respondent taking the driver survey

<sup>6</sup> See [www.choice-metrics.com](http://www.choice-metrics.com) .

For a 100km trip, you have the choice between 4 transport modes whose characteristics are the following:

	Train	Bus	Carpool A	Carpool B
Travel time	1:10 hour	1:25 hour	1:05 hour	1:10 hour
Difference between the scheduled arrival time and your preferred arrival time	No	1 hour later	5 min later	15 min earlier
Price	15 euros	13 euros	5 euros	6 euros
Nb of other individuals in the car			3	2

Which transport mode do you choose ?

Train

Bus

Carpool A

Carpool B

Figure 1b: Example of choice situation screen submitted to respondent taking the passenger survey

We proposed two carpooling alternatives to make the transport supply more realistic. The observation of internet multimodal journey planners reveals the carpool supply is more complete along the day in the sense that it offers more possible departure times. For a specific trip with a specific desired arrival time, a passenger will likely find one well-fitting bus or train option, but several well-fitting carpooling options. Carpools allows more flexibility in the departure time choice than train or bus whose frequency is much lower.

### 3.2.1. Drivers' survey

Respondents reviewed two hypothetical alternatives, driving alone (solo) or driving with one or more passengers (carpool). The alternatives in each choice situation were described by three attributes: travel time, monetary gain (null if solo, positive in carpool), and number of carpooled people (null if solo, positive in carpool). The characteristics of the attributes levels in the choice situations submitted to respondents as well as the respondents' choices frequency are displayed in Table 2.

Distance	Attributes	Mean	sd	Min	Max
100 km	Travel time alone (min.)	74,68	10,23	60	90
	Travel time carpool (min.)	74,87	10,29	60	90
	Carpool revenue (€)	25,46	13,87	5	50
	Nb of carpool passengers	1,98	0,80	1	3
	Mode choice: carpool	47%			
	Nb of choice situations proposed	896			
300 km	Travel time alone	198,53	33,67	150	250
	Travel time carpool	199,00	34,28	150	250
	Carpool revenue	57,34	27,94	10	100
	Nb of carpool passengers	1,98	0,83	1	3
	Mode choice: carpool	53%			
	Nb of choice situations proposed	896			
500 km	Travel time alone	341,58	51,45	270	420
	Travel time carpool	345,96	50,88	270	420
	Carpool revenue	84,48	39,38	20	150
	Nb of carpool passengers	1,98	0,81	1	3
	Mode choice: carpool	53%			
	Nb of choice situations proposed	904			
700 km	Travel time alone	474,54	50,23	400	550
	Travel time carpool	474,57	51,41	400	550
	Carpool revenue	78,78	34,18	30	180
	Nb of carpool passengers	1,99			
	Mode choice: carpool	51%			
	Nb of choice situations proposed	904			

Table 2: Characteristics of the drivers' choice situations submitted to respondents

### 3.2.2. Passengers' survey

Respondents review four hypothetical alternatives: bus, train, carpool A or carpool B. Each alternative is described by at least four attributes: Travel time, Early arrival, Late arrival and Price (€). For the carpooling alternatives, the number of other individuals in the car is added as attribute. The 100km choice situations are described in Table 3. Other distance choice situations descriptions are relegated to the appendices (see Tables 9, 10, 11 and 12).

Mode	Variable	Mean	sd	Min	Max
Train	Travel time (min.)	60,19	14,14	40	80
	Early arrival (min.)	31,71	42,98	0	120
	Late arrival (min.)	21,41	28,82	0	90
	Price (€)	12,45	5,63	5	20
Bus	Travel time	74,92	10,12	60	90
	Early arrival	25,24	37,08	0	120
	Late arrival	14,86	21,69	0	75
	Price	8,33	4,10	2	15
Carpool A	Travel time	74,76	10,06	60	90
	Early arrival	7,55	11,27	0	30
	Late arrival	5,71	9,13	0	30
	Price	7,48	1,71	5	10
	Nb of other ind.	1,99	0,82	1	3
Carpool B	Travel time	74,65	10,02	60	90
	Early arrival	7,02	10,69	0	30
	Late arrival	5,72	9,40	0	30
	Price	7,49	1,72	5	10
	Nb of other ind.	2,00	0,82	1	3
Mode choice: train		28%			
Mode choice: bus		21%			
Mode choice: carpool A		29%			
Mode choice: carpool B		22%			
Nb of choice situations proposed		5908			

Table 3: Characteristics of the 100km passengers' choice situations submitted to respondent

## 4. Results

Results are split in two subsections. Subsection 4.1 focuses on drivers' results and 4.2 on passengers' results.

We use mixed logit models to take into account the panel structure of our data. Therefore the intercepts  $\beta_{0,m}$  in Equations (1), (2), (3) and (4) are assumed to be normally distributed.<sup>7</sup> We focus on the socio-economic variables affecting VoTT and value of an extra passenger, and not on the computation of VoTT to perform cost-benefit analysis. Consequently, following Hess et al. (2005), we do not estimate random parameters for travel time or other variables.

The models have been estimated with the *mlogit* package built by Croissant (2012) for the R software.

<sup>7</sup> We tested other distributions such that uniform, triangular or lognormal. The normal distribution always produces the best goodness of fit.

#### 4.1. Drivers' results

Table 4 shows results of binomial mixed logit estimations of a model combining Equations (1) and (2) and described in Equation (9).<sup>8</sup> The reference mode is driving solo. We estimate four different specifications. In the first one (col. (1) in Table 4), we estimate an “average” cost of time for a trip as driver by assuming there is no difference between parameters associated with travel time solo and with travel time carpool as a driver ( $\beta_{1;s} = \beta_{1;cpd}$ ). In the second one (col. (2)), we introduce individual effects (age, gender, income, access time to the closest rail station) and interaction effects between travel time, the number of extra passengers and three socio-economic variables: age, gender and income. We repeat the exercise in specifications (3) and (4) but we differentiate the effect of travel time on utility depending if the trip is made as a solo driver or as a carpool driver ( $\beta_{1;s} \neq \beta_{1;cpd}$ ). The reference mode is “solo”, so generally a negative (resp. positive) coefficient implies a negative (resp. positive) marginal effect of the variable on the probability of choosing carpool over solo. The interpretation of the travel time coefficients is different because they are mode-specific, so a negative (resp. positive) coefficient implies a negative (resp. positive) marginal effect of the variable on the probability of choosing this specific mode over the other.

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<sup>8</sup> For ease of exposition, standard errors are not reported. The full results table is available in the appendices (see Table 13).



	(1)	(2)	(3)	(4)
Intercept - mean	-1.160***	0.216	-0.969***	1.354***
Intercept - sd	3.776***	3.640***	3.807***	3.714***
Gain from carpooling (euros)	0.016***	0.019***	0.021***	0.021***
<b>Travel time effects</b>				
Travel time (hours)	-0.859***	-1.253***		
Trav. Time x Age		0.016***		
Trav. Time x Gender		0.022		
Trav. Time x Income		-0.137***		
<b>Travel time solo effects</b>				
Travel Time solo (hours)			-0.815***	-1.069***
TT solo x Age				0.012***
TT solo x Gender				0.007
TT solo x Income				-0.140***
<b>Travel time carpool effects</b>				
Travel Time carpool (hours)			-0.923***	-1.445***
TT carpool x Age				0.018***
TT carpool x Gender				0.049
TT carpool x Income				-0.139***
<b>Number of extra passengers effects</b>				
Nb of extra pass.	-0.198***	0.425*	-0.190***	0.216
Nb of extra pass. x TT		-0.072***		-0.034
Nb of extra pass. x Age		-0.006		-0.005
Nb of extra pass. x Gender		0.468***		0.470***
Nb of extra pass. x Income		-0.095		-0.090
<b>Individual effects</b>				
Age (years)		-0.023***		-0.044***
Gender (0=M;1=F)		-1.262***		-1.644***
Income (k euros)		0.354***		0.548***
Access time to closest rail station (min.)		-0.028***		-0.030***
AIC	2957.585	2916.555	2941.750	2902.061
Log Likelihood	-1473.792	-1442.277	-1464.875	-1431.031
McFadden R2	0.409	0.422	0.423	0.426
Num. obs.	3600	3600	3600	3600
Sample size	225	225	225	225

Notes. This table reports binomial mixed logit estimations of Eq. (1) and (2) where the intercepts  $\beta_0 \sim \mathcal{N}(\mu, \sigma)$ ,  $\beta_{1;s} = \beta_{1;cpd}$  (columns (1) and (2)),  $\gamma_i = 0$  (columns (1) and (3)) and  $\delta_i = \theta_i = 0$  (columns (1), (2), and (3)). The dependent variable is the mode choice between “solo” and “carpool”. The reference alternative is “solo”. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.

Table 4: Empirical results from the drivers’ model

The Akaike Information Criterion (AIC) confirms that using interaction effects and differentiated travel time coefficients in specification (4) produces the best goodness of fit.<sup>9</sup>

The intercept mean in the first specification is negative and shows that other thing being equal, on average, respondents have a strong preference for driving solo over carpooling. The average monetary

<sup>9</sup> This is confirmed by the LR Tests and Wald Tests we conducted.

benefit from carpooling needed to compensate this aversion for carpooling is 72.5 euros ( $-1.160/0.016 = -72.5$ ).

As expected, the Gain from carpooling coefficient sign is positive in all specifications. The values of the estimated coefficients mean that other things being equal, a 1 euro increase in the gain from carpooling raises the odds of carpooling over driving solo by around 2%.<sup>10</sup>

We find that travel time decreases utility of a trip as a driver, even when carpooling, because all the estimated coefficients associated with travel time are negative in all specifications. The coefficient associated with travel time alone is always less negative than the one associated with carpool travel time.<sup>11</sup> This implies that on average carpool travel time decreases more driver's utility than alone travel time. On the opposite of carpoolers' statements from previous French survey (ADEME, 2015), we find that on average individuals prefer driving solo to taking passengers. Coefficients associated with the interactions effects between travel time and age on the one hand, and income on the other hand are respectively positive and negative. The utility of a trip whether solo or carpool decreases faster with travel time if the driver is younger and richer.

The individual effects in Table 4 reveal that preferences for carpool also depend on socio-economic variables. Other things being equal, older and poorer drivers have a lower probability to choose to carpool.

We introduced the access time to the closest rail station as an explanatory variable because rail stations are often multimodal platforms that are also used as carpooling meeting or exiting points. Individuals living further away from rail station have a lower probability to carpool, which is confirmed by the estimated coefficients.

The effect of the number of carpooled passengers is tricky. Whereas specifications (1) and (3) suggest a negative effect of the number of extra passengers, specifications (2) and (4) show that a strong gender

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<sup>10</sup>  $\exp(0.016) = 1.016$ , and  $\exp(0.21) = 1.021$ .

<sup>11</sup> We test the difference between the coefficients with a Wald test. The Chi-squared statistics equals 17.9 in specification (3) and 21.9 in specification (4). The difference between coefficients  $\beta_{1,s}$  and  $\beta_{1,cpd}$  is statistically significant in the two specifications.

effect is playing. This effect is illustrated in Table 5. This table displays carpool choice probability of the representative<sup>12</sup> driver as a function of gender, number of carpooled passenger and travel time, in a situation of an 80€ carpool monetary gain.<sup>13</sup> The gender effect is twofold: females have a greater dislike for carpooling than males (the difference in carpool choice probability is always larger than 20 percentage points), however, they prefer conveying two passengers to conveying one passenger, whereas it is the opposite for males. The first effect has been documented in the literature (de Luca & Pace, 2015, Becker et al., 2017), but the second one is, at the best of our knowledge, new.

Travel time	Nb of passenger	Gender	
		Male	Female
2 hours	1 passenger	76%	39%
	2 passengers	70%	43%
5 hours	1 passenger	51%	17%
	2 passengers	41%	18%

*Notes. This table reports carpool choice probability of the representative driver having the choice between driving solo or carpooling with a monetary gain of 80€.*

Table 5: Carpool choice probability of the representative driver as a function of the gender,  
number of carpooled passenger and travel time

We use the coefficient associated with the Gain from carpooling to compute monetary values of travel time (VoTT) and values of an extra passenger (VoEP), as defined in Equations (6) and (7). These figures are exposed in Table 6.

<sup>12</sup> The representative driver is someone who has all the characteristics of the driver sample average.

<sup>13</sup> The amount of 80€ has been chosen such that the carpool probability is significantly larger than 0.

Specification	(1)	(2)	(3)	(4)
<b>VoTT (euros/hour)</b>	53.25	42.45		
Marginal effect of Age (years) on VoTT (euros/h)		-0.81		
Marginal effect of Income (k euros) on VoTT (euros/h)		7.05		
<b>Solo VoTT (euros/hour)</b>			39.48	38.3
Marginal effect of Age (years) on alone VoTT (euros/h)				-0.58
Marginal effect of Income (k euros) on alone VoTT (euros/h)				6.56
<b>Carpool VoTT (euros/hour)</b>			44.71	43.1
Marginal effect of Age (years) on carpool VoTT (euros/h)				-0.86
Marginal effect of Income (k euros) on carpool VoTT (euros/h)				6.51
<b>Carpool VoTT / Solo VoTT</b>			113%	113%
<b>Value of extra passenger (euros)</b>	-12.26	-10.44	-9.22	-9.64
Marginal effect of Travel time (min.) on value of extra pass. (euros)		-0.06		
Marginal effect of gender (0=M;1=F) on value of extra pass. (euros)		24.03		22.03

*Notes. This table reports VoTT and VoEP described in Equations (6) and (7). The values have been computed by applying specifications displayed in Table 4. To take into account the interaction effects used in specifications (2) and (4), the representative driver making the representative trip is used.*

Table 6: Drivers' values of travel time and of extra passenger

Computed VoTT are high compared to the literature. Small (2012) relates that commuting VoTT typically averages one half of the gross wage rate.<sup>14</sup> Quinet (2013) gives an “official” VoTT for long distance trips in France of 15.7€ per hour.<sup>15</sup> Several reasons might explain these gaps of at least 20 euros between our values and those from the literature. First, our experiment has a willingness-to-accept structure, because drivers are willing to accept an amount of money to put up with something negative for them, carpooling. This is rather unusual in the VoTT literature, where studies mostly used willingness-to-pay methods. Horowitz & McConnell (2002) showed that willingness to accept is substantially higher than willingness to pay. In the specific field of VoTT valuation, De Borger & Fosgerau (2008) show that the gap is a factor of four. Second, the difference might be due to the fact that individual in our driver sample are chosen among the individuals owning a car and then a high income on average. Third, another limit comes from the design of the stated survey experiment. We did not propose a null alternative (i.e. no trip) and respondents were “forced” to make the trip.

For these reasons, we prefer to interpret carpool VoTT as a percentage of alone VoTT than as an absolute value. When taking into account the individual effects and the number of extra passenger in the car, we

<sup>14</sup> According to INSEE (2018), the average gross wage rate in France in 2014 was 17.3€.

<sup>15</sup> The official value of travel time for long-distance trips in France given by Quinet (2013) is 14.4 €2010/hours, which transforms into 15.7 €2018/hour by taking into account the inflation.

find carpool increases the VoTT by 13% with respect to solo VoTT. This percentage only reflects the difference in the cost of time, but does not include perceptions of carpooling which are not related to travel time.

We also find that the effect of income on VoTT is of same magnitude for carpool and driving alone (+6.5 €/h when the income increases by 1 000 euros), whereas the effect of age on VoTT is lower for driving alone than for carpooling (-0.58 euro/hour per year vs -0.86 euro/hour per year). We find that on average extra passenger lowers the utility of driver by around 10 euros. However, one has to be cautious with this result as it is very gender-dependent as shown by the marginal effect of gender and results from Table 5. An extra passenger increases the utility of a trip by more than 20€ for a female driver.

#### 4.2. Passengers' results

In each of the 16 choice situations they faced, individuals in the passenger experiment were asked to make a choice between 4 modes (train, bus, carpool A and carpool B). Our passenger discrete choice experiment contains two alternatives describing the same mode, carpool. In theory, estimated corresponding coefficients should be equal for these two alternatives. Therefore we constrained the model calibration to estimate equal coefficients for these two alternatives.

Table 6 displays results of mixed multinomial logit estimations of a model combining Equations (3) and (4) described in Equation (9).<sup>16</sup> Four different specifications are estimated. The strategy is very similar to the one used for the drivers model. In the first specification (col. (1) in Table 4), we estimate an “average” cost of time for passengers ( $\beta_{1;cpp} = \beta_{1;b} = \beta_{1;t}$ ). In the second one (col. (2)), we introduce individual effects and we consider the interaction effects between travel time, the number of extra passengers, and three socio-economic variables: gender, age and income. We repeat the exercise in specifications (3) and (4) but we differentiate the effect of travel time on utility depending on the transport mode ( $\beta_{1;cpp} \neq \beta_{1;b} \neq \beta_{1;t}$ ). The reference mode is “train”, so generally a negative (resp. positive) coefficient associated with another mode (“bus” or “carpool”) implies a negative (resp.

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<sup>16</sup> Again, for ease of exposition, standard errors are not reported. The full results table is available in the appendices (see Table 14).

positive) marginal effect of the variable on the probability of choosing this mode over train. Let us recall that the interpretation of the price and travel time coefficients is different because they are mode-specific. A negative (resp. positive) coefficient implies a negative (resp. positive) marginal effect of the variable on the probability of choosing this specific mode over the others.

	(1)	(2)	(3)	(4)
Price (euros)	-0.027***	-0.027***	-0.028***	-0.029***
<b>Travel time effects</b>				
Travel time (hours)	-0.695***	-0.668***		
TT x Age		0.003***		
TT x Gender		-0.121***		
TT x Income		-0.030***		
<b>Travel time train effects</b>				
Travel time train			-0.473***	-0.535***
TT train x Age				0.003*
TT train x Gender				-0.107**
TT train x Income				-0.009
<b>Travel time carpool effects</b>				
Travel time carpool			-0.736***	-0.728***
TT carpool x Age				0.003***
TT carpool x Gender				-0.134***
TT carpool x Income				-0.027**
<b>Travel time bus effects</b>				
Travel time bus			-0.587***	-0.629***
TT bus x Age				0.003***
TT bus x Gender				-0.093***
TT bus x Income				-0.018
<b>Number of carpool passengers effects</b>				
Nb of other pass.	-0.122***	0.015	-0.124***	-0.183***
Nb of pass. x TT		-0.051***		-0.003
Nb of pass. x Age		0.001		0.001
Nb of pass. x Gender		0.019		0.023
Nb of pass. x Income		0.005		0.005
<b>Individual effects - carpool</b>				
Intercept carpool - mean	-0.406***	-0.173	0.275***	0.323*
Intercept carpool - sd	2.736***	2.764***	2.824***	2.837***
Age - carpool (years)		-0.011***		-0.010***
Gender - carpool (0=M;1=F)		0.524***		0.633***
Income - carpool (k euros)		0.060**		0.119***
Access time to clos. rail st. - carpool (min)		-0.000**		-0.000**
High speed station - carpool (0=N;1=Y)		-0.235***		-0.212***
<b>Individual effects - bus</b>				
Intercept bus - mean	-0.318***	-0.515***	-0.245***	-0.364*
Intercept bus - sd	2.221***	2.166***	2.211***	2.171***
Age - bus (years)		0.010***		0.010***
Gender - bus (0=M;1=F)		-0.104*		-0.179*
Income - bus (k euros)		-0.083***		-0.065
Access time to clos. rail st. - bus (min.)		-0.005***		-0.005***
High speed station - bus (0=N;1=Y)		-0.001		-0.013
<b>Schedule delay effects</b>				
Early schedule delay (hours)	0.101***	0.088***	0.058***	0.058***
Late schedule delay (hours)	-0.360***	-0.372***	-0.414***	-0.417***
AIC	49328.623	49126.464	48873.065	48805.539
Log Likelihood	-24655.311	-24537.232	-24425.532	-24368.769
McFadden R2	0.231	0.235	0.238	0.240
Num. obs.	23616	23616	23616	23616
Sample size	1476	1476	1476	1476

Notes. This table reports mixed multinomial logit estimations of Eq. (3) and (4) where the intercepts  $\beta_0 \sim \mathcal{N}(\mu, \sigma)$ ,  $\beta_{1;cpv} = \beta_{1;b} = \beta_{1;t}$  (columns (1) and (3)), and  $\gamma_i = \delta_i = \theta_i = 0$  (columns (1) and (3)). The dependent variable is the mode choice between “bus”, “train”, “carpool A”, and “carpool B”. The reference alternative is “train”. Standard errors in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.

Table 7: Empirical results from the passengers’ model

AIC reveals that specification (4) produces the best goodness of fit. The AIC ranking between models has been confirmed by LR Tests and Wald Tests we conducted.

The sign of the carpool intercept mean is negative in specification (1) and positive in specification (3). We cannot conclude for preference or aversion for carpool over train. However, the bus intercept mean is always negative. Other things being equal, passengers on average prefer train over bus.

As expected, the sign of the coefficient associated with the price coefficient is negative. It implies that other things being equal, a 1 euro increase in the price of a mode decreases the odds of choosing this mode over other modes by 2.76% ( $\exp(-0.028) - 1 = -0.0276$ ).

All coefficients associated with travel time are negative: whatever the mode, an increase in travel time decreases the probability of the mode to be chosen, other things being equal. Results of specifications (2) and (4) show that this negative effect of travel time on utility is on average higher for female, younger and wealthier individuals. When differentiating the effect of travel time by mode in specifications (3) and (4), we show that the negative effect of an extra minute of travel time on the mode choice probability is larger for carpool than for bus, and larger for bus than for train.<sup>17</sup> This is a mode-specific variation which might be related to the comfort or to the use of time during a trip. However, coefficients estimated in specification (4) associated with the interaction between time and socio-economic variables are not statistically different from one mode to another.

Table 7 reveals that there is a clear other passenger effect: when carpooling, passengers prefer travelling alone with the driver than with another passenger. This effect is robust to all specifications except specification (2), however we cannot conclude on potential interaction effects with socio-economics variables.

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<sup>17</sup> We compared the coefficients with Wald tests. The Chi-squared statistics for a test  $\beta_{1,cpp} = \beta_{1,b}$  equals 294 in specification (3) and 10 in specification (4), and for a test  $\beta_{1,t} = \beta_{1,b}$  it equals 45.3 in specification (3) and 2.4 in specification (4). The differences between coefficients  $\gamma$  to carpool than male, but they prefer to carpool two passengers over only one passenger. 2323232323 are statistically significant at a 0.1% threshold, except the difference between  $\beta_{1,t}$  and  $\beta_{1,b}$  which is only significant at a 12% threshold.



The analysis of individual effects shows that age, gender and income effects are also drivers of the probability of choosing carpool over train. Specifications (2) and (4) reveal that older individuals, females and wealthier individuals have a higher preference for carpool over train.

Coefficients associated with schedule delay are not easy to interpret. As expected, individuals prefer to arrive at destination earlier than later. However, they also prefer to arrive earlier than on time. They seem to set up a buffer time to anticipate potential unreliability of travel times.

Table 8 reports monetary value of the attributes of passenger transport modes as defined in Equation (6) and (7). Train VoTT are close from previous results in the literature: Abrantes & Wardman (2011) found a rail VoTT of 13€/hour for 200 miles trips.<sup>18</sup> The VoTT to be used in CBA analysis in France is 15.7 €/hour, independently of the mode (Quinet, 2013). We find that the VoTT is lower for passengers in any mode than for drivers. A potential explanation is that the drivers VoTT have been estimated through willingness to accept method whereas passengers VoTT have been estimated through willingness to pay survey.

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<sup>18</sup> They find a value of in-vehicle time of 19 pence/minute in Q4 2008 prices for 200 miles trips.

Specification	(1)	(3)	(4)	(6)
<b>VoTT (euros/hour)</b>	25.9	26.5		
Marginal effect of Gender (0=M;1=F) on VoTT (euros/h)		4.48		
Marginal effect of Age (years) on VoTT (euros/h)		-0.1		
Marginal effect of Income (k euros) on VoTT (euros/h)		1.1		
<b>Carpool VoTT (euros/hour)</b>			25.99	26.7
Marginal effect of Gender (0=M;1=F) on carpool VoTT (euros/h)				4.69
Marginal effect of Age (years) on carpool VoTT (euros/h)				-0.09
Marginal effect of Income (k euros) on carpool VoTT (euros/h)				0.94
<b>Train VoTT (euros/hour)</b>			16.7	16.6
Marginal effect of Gender (0=M;1=F) on train VoTT (euros/h)				3.75
<b>Bus VoTT (euros/hour)</b>			20.73	20.68
Marginal effect of Gender (0=M;1=F) on bus VoTT (euros/h)				3.24
Marginal effect of Age (years) on bus VoTT (euros/h)				-0.1
<b>Value of other passenger (euros)</b>	-4.56	-5.14	-4.37	-4.39
Marginal effect of Travel time (hours) on cost of other pass. (euros)		-1.88		

*Notes. This table reports VoTT and VoOP described in Equations (6) and (7). The values have been computed by applying specification displayed in Table 7. To take into account the interaction effects used in specifications (2) and (4), the representative passenger making the representative trip is used.*

Table 8: Passengers' values of travel time and of extra passenger

Carpool as a passenger VoTT is around 26 euros per hour and 60% higher than train VoTT and 20% higher than bus VoTT. This is constant across specifications and seems robust. The differences in VoTT can be explained by differences in transport experiences. Other things being equal, individuals making a trip as passenger are willing to pay more to decrease their carpool travel time than their train travel time.

Specification (4) in Tables 7 and 8 reveals a strong gender effect in the carpool as passenger VoTT. Females' carpool VoTT is 4.69 euros higher than males'. The same gender effect, although smaller, is present for the train and bus VoTT. We also find a positive effect of income (+0.94 euros/h per 1000 k euros) and a negative effect of age (-0.09 euros/h per year) on carpool as passenger VoTT. These socio-economic drivers are specific to carpool. The amplitude of *User Type* variations in VoTT as passenger is lower than the amplitude of *Mode type* variations.

The value of an extra passenger is around -4.5 euros per passenger. The effect is of same magnitude across specifications. The presence of another carpooled passenger (besides the driver) is clearly perceived as an inconvenience. We do not find any socio-economic drivers to this effect.

## 5. Conclusion and discussion

This paper has used a discrete choice experiment survey to identify, measure and value the attributes of long-distance transport modes (bus, train, and car) for a trip as driver and as passenger, with a special focus on an emerging mode, carpooling. We estimate values of travel time for these modes of transport, and we reveal robust mode type variations in VoTT.

Our main conclusions can be summarized as follows: First, our study reveals a strong preference for driving solo over taking carpoolers in one's car. Second, we show that the VoTT for a driver who carpools is on average 13% higher than the VoTT when driving alone in his/her car and that the VoTT for a carpool trip as passenger is on average 60% higher than train VoTT and 20% higher than bus VoTT. Third, we find that individuals traveling as carpool passenger incur a "discomfort" cost of on average 4.5 euros per extra passenger in the same vehicle. Finally, we also identify strong socio-economic effects. The gender, the age and the income clearly drives the probability of carpooling. These variables play through three different channels: a pure effect on the probability of carpool choice, and mitigations of the carpool VoTT and of the cost of an extra passenger (this heterogeneity is captured with interaction terms). When they drive a car, females are less likely to carpool than male, but they prefer to carpool two passengers over only one passenger.

This paper contributes to the transport economics literature in several aspects. We add new values of travel time to a literature that has mostly focused on short distance trips made in car, whereas we focus on long-distance trips made by train, and more originally, by bus and carpool. In addition, our analysis includes original empirical evidences on an emerging long-distance trip mode, the carpool. We identify clear socio-economic drivers of preference or aversion for carpooling. Finally, we introduce and measure the effect of the number of other individuals in the car, that turns out to be an important attribute of a carpool trip. This attribute is related to the crowding effect identified in public transport.

Our results help to understand the relatively low mode shares of carpool for long-distance trips despite the recent trends. Carpool turns to be a relatively uncomfortable transport mode as other things being equal, one minute carpooling decreases more the utility of a trip than one minute in competing transport

modes (car solo, bus or train). This suggests that the monetary price (for passengers) and gain (for drivers) of carpooling are the main tools available to increase carpool use.

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## Appendices

Mode	Variable	Mean	sd	Min	Max
Train	Travel time (min.)	60,19	14,14	40	80
	Early arrival (min.)	31,71	42,98	0	120
	Late arrival (min.)	21,41	28,82	0	90
	Price (€)	12,45	5,63	5	20
Bus	Travel time	74,92	10,12	60	90
	Early arrival	25,24	37,08	0	120
	Late arrival	14,86	21,69	0	75
	Price	8,33	4,10	2	15
Carpool A	Travel time	74,76	10,06	60	90
	Early arrival	7,55	11,27	0	30
	Late arrival	5,71	9,13	0	30
	Price	7,48	1,71	5	10
	Nb of other ind.	1,99	0,82	1	3
Carpool B	Travel time	74,65	10,02	60	90
	Early arrival	7,02	10,69	0	30
	Late arrival	5,72	9,40	0	30
	Price	7,49	1,72	5	10
	Nb of other ind.	2,00	0,82	1	3
Mode choice: train		28%			
Mode choice: bus		21%			
Mode choice: carpool A		29%			
Mode choice: carpool B		22%			
Nb of choice situations proposed		5908			

Table 9: Characteristics of the 100km passengers' tasks submitted to respondents

Mode	Variable	Mean	sd	Min	Max
Train	Travel time (min.)	164,40	51,32	90	240
	Early arrival (min.)	28,88	42,26	0	120
	Late arrival (min.)	32,48	44,06	0	120
	Price (€)	39,46	20,12	10	70
Bus	Travel time	193,91	30,34	150	240
	Early arrival	23,82	36,34	0	120
	Late arrival	18,75	30,82	0	120
	Price	17,22	8,48	5	30
Carpool A	Travel time	199,33	34,02	150	250
	Early arrival	6,37	9,88	0	30
	Late arrival	5,13	8,85	0	30
	Price	20,00	7,10	10	30
	Nb of other ind.	1,98	0,82	1	3
Carpool B	Travel time	199,35	34,25	150	250
	Early arrival	6,31	10,09	0	30
	Late arrival	5,54	9,38	0	30
	Price	19,98	7,04	10	30
	Nb of other ind.	1,98	0,82	1	3
Mode choice: train		28%			
Mode choice: bus		28%			
Mode choice: carpool A		24%			
Mode choice: carpool B		20%			
Nb of choice situations proposed		5908			

Table 10: Characteristics of the 300km passengers' tasks submitted to respondents

Mode	Variable	Mean	sd	Min	Max
Train	Travel time (min.)	193,19	51,05	120	270
	Early arrival (min.)	24,46	37,81	0	120
	Late arrival (min.)	34,56	45,18	0	120
	Price (€)	77,70	42,51	10	150
Bus	Travel time	343,51	50,78	270	420
	Early arrival	26,91	40,61	0	120
	Late arrival	27,79	39,34	0	120
	Price	22,14	11,44	5	40
Carpool A	Travel time	342,85	51,05	270	420
	Early arrival	11,75	18,88	0	60
	Late arrival	13,04	20,01	0	60
	Price	32,22	8,45	20	45
	Nb of other ind.	1,99	0,82	1	3
Carpool B	Travel time	343,33	50,72	270	420
	Early arrival	10,46	17,26	0	60
	Late arrival	12,45	19,07	0	60
	Price	32,19	8,52	20	45
	Nb of other ind.	1,99	0,82	1	3
Mode choice: train		38%			
Mode choice: bus		27%			
Mode choice: carpool A		19%			
Mode choice: carpool B		16%			
Nb of choice situations proposed		5900			

Table 11: Characteristics of the 500km passengers' tasks submitted to respondents

Mode	Variable	Mean	sd	Min	Max
Train	Travel time (min.)	253,98	50,75	180	330
	Early arrival (min.)	41,01	58,92	0	180
	Late arrival (min.)	46,06	62,41	0	180
	Price (€)	102,14	46,71	30	180
Bus	Travel time	474,81	50,88	400	550
	Early arrival	41,74	57,37	0	180
	Late arrival	36,41	53,83	0	180
	Price	29,98	12,85	10	50
Carpool A	Travel time	474,59	51,25	400	550
	Early arrival	13,81	21,37	0	60
	Late arrival	13,23	20,64	0	60
	Price	44,95	10,06	30	60
	Nb of other ind.	2,00	0,81	1	3
Carpool B	Travel time	473,00	50,52	400	550
	Early arrival	12,91	19,32	0	60
	Late arrival	11,38	17,78	0	60
	Price	44,91	10,03	30	60
	Nb of other ind.	1,98	0,82	1	3
Mode choice: train		43%			
Mode choice: bus		27%			
Mode choice: carpool A		17%			
Mode choice: carpool B		13%			
Nb of choice situations proposed		5900			

Table 12: Characteristics of the 700km passengers' tasks submitted to respondents

	(1)	(2)	(3)	(4)
Intercept - mean	-1.160*** (0.132)	0.216 (0.324)	-0.969*** (0.139)	1.354*** (0.479)
Intercept - sd	3.776*** (0.189)	3.640*** (0.183)	3.807*** (0.190)	3.714*** (0.187)
<b>Gain from carpooling (euros)</b>	0.016*** (0.002)	0.019*** (0.002)	0.021*** (0.002)	0.021*** (0.002)
Travel time effects				
Travel time (hours)	-0.859*** (0.053)	-1.253*** (0.180)		
Trav. Time x Age		0.016*** (0.003)		
Trav. Time x Gender		0.022 (0.105)		
Trav. Time x Income		-0.137*** (0.047)		
<b>Travel time solo effects</b>				
Travel Time solo (hours)			-0.815*** (0.054)	-1.069*** (0.184)
TT solo x Age				0.012*** (0.004)
TT solo x Gender				0.007 (0.108)
TT solo x Income				-0.140*** (0.049)
<b>Travel time carpool effects</b>				
Travel Time carpool (hours)			-0.923*** (0.056)	-1.445*** (0.190)
TT carpool x Age				0.018*** (0.004)
TT carpool x Gender				0.049 (0.107)
TT carpool x Income				-0.139*** (0.047)
<b>Number of extra passengers effects</b>				
Nb of extra pass.	-0.198*** (0.065)	0.425* (0.251)	-0.190*** (0.065)	0.216 (0.267)
Nb of extra pass. x TT		-0.072*** (0.018)		-0.034 (0.024)
Nb of extra pass. x Age		-0.006 (0.005)		-0.005 (0.005)
Nb of extra pass. x Gender		0.468*** (0.140)		0.470*** (0.141)
Nb of extra pass. x Income		-0.095 (0.064)		-0.090 (0.064)
<b>Individual effects</b>				
Age (years)		-0.023*** (0.006)		-0.044*** (0.009)
Gender (0=M;1=F)		-1.262*** (0.184)		-1.644*** (0.274)
Income (k euros)		0.354*** (0.085)		0.548*** (0.119)
Access time to closest rail station (min.)		-0.028*** (0.004)		-0.030*** (0.004)
AIC	2957.585	2916.555	2941.750	2902.061
Log Likelihood	-1473.792	-1442.277	-1464.875	-1431.031
McFadden R2	0.409	0.422	0.423	0.426
Num. obs.	3600	3600	3600	3600
Panel size	225	225	225	225

Notes. This table reports binomial mixed logit estimations of Eq. (1) and (2) where the intercept  $\beta_0 \sim \mathcal{N}(\mu, \sigma)$ ,  $\beta_{1;s} = \beta_{1;cpd}$  (columns (1) and (2)),  $\gamma_i = 0$  (columns (1) and (3)) and  $\delta_i = \theta_i = 0$  (columns (1), (2), and (3)). The dependent variable is the mode choice between “solo” and “carpool”. The reference alternative is “solo”. Standard errors in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.

Table 13: Empirical results from the drivers’ model

	(1)	(2)	(3)	(4)
Price (euros)	-0.027*** (0.001)	-0.027*** (0.001)	-0.028*** (0.001)	-0.029*** (0.001)
<b>Travel time effects</b>				
Travel time (hours)	-0.695*** (0.012)	-0.668*** (0.038)		
TT x Age		0.003*** (0.001)		
TT x Gender		-0.121*** (0.021)		
TT x Income		-0.030*** (0.010)		
<b>Travel time train effects</b>				
Travel time train			-0.473*** (0.022)	-0.535*** (0.082)
TT train x Age				0.003* (0.002)
TT train x Gender				-0.107** (0.046)
TT train x Income				-0.009 (0.021)
<b>Travel time carpool effects</b>				
Travel time carpool			-0.736*** (0.013)	-0.728*** (0.044)
TT carpool x Age				0.003*** (0.001)
TT carpool x Gender				-0.134*** (0.025)
TT carpool x Income				-0.027** (0.011)
<b>Travel time bus effects</b>				
Travel time bus			-0.587*** (0.013)	-0.629*** (0.044)
TT bus x Age				0.003*** (0.001)
TT bus x Gender				-0.093*** (0.025)
TT bus x Income				-0.018 (0.012)
<b>Number of carpool passengers effects</b>				
Nb of other pass.	-0.122*** (0.013)	0.015 (0.052)	-0.124*** (0.013)	-0.183*** (0.053)
Nb of pass. x TT		-0.051*** (0.005)		-0.003 (0.005)
Nb of pass. x Age		0.001 (0.001)		0.001 (0.001)
Nb of pass. x Gender		0.019 (0.026)		0.023 (0.026)
Nb of pass. x Income		0.005 (0.012)		0.005 (0.012)
<b>Individual effects - carpool</b>				
Intercept carpool - mean	-0.406*** (0.036)	-0.173 (0.118)	0.275*** (0.049)	0.323* (0.181)

Intercept carpool - sd	2.736*** (0.043)	2.764*** (0.044)	2.824*** (0.044)	2.837*** (0.044)
Age - carpool (years)		-0.011*** (0.002)		-0.010*** (0.003)
Gender - carpool (0=M;1=F)		0.524*** (0.062)		0.633*** (0.099)
Income - carpool (k euros)		0.060** (0.028)		0.119*** (0.045)
Access time to clos. rail st. - carpool (min)		-0.000** (0.000)		-0.000** (0.000)
High speed station - carpool (0=N;1=Y)		-0.235*** (0.046)		-0.212*** (0.047)
<b>Individual effects - bus</b>				
Intercept bus - mean	-0.318*** (0.033)	-0.515*** (0.115)	-0.245*** (0.051)	-0.364* (0.189)
Intercept bus - sd	2.221*** (0.037)	2.166*** (0.036)	2.211*** (0.037)	2.171*** (0.036)
Age - bus (years)		0.010*** (0.002)		0.010*** (0.003)
Gender - bus (0=M;1=F)		-0.104* (0.060)		-0.179* (0.103)
Income - bus (k euros)		-0.083*** (0.028)		-0.065 (0.048)
Access time to clos. rail st. - bus (min.)		-0.005*** (0.001)		-0.005*** (0.001)
High speed station - bus (0=N;1=Y)		-0.001 (0.048)		-0.013 (0.048)
<b>Schedule delay effects</b>				
Early schedule delay (hours)	0.101*** (0.019)	0.088*** (0.019)	0.058*** (0.019)	0.058*** (0.019)
Late schedule delay (hours)	-0.360*** (0.020)	-0.372*** (0.021)	-0.414*** (0.021)	-0.417*** (0.021)
AIC	49328.623	49126.464	48873.065	48805.539
Log Likelihood	-24655.311	-24537.232	-24425.532	-24368.769
McFadden R2	0.231	0.235	0.238	0.240
Num. obs.	23616	23616	23616	23616
Sample size	1476	1476	1476	1476

Notes. This table reports mixed multinomial logit estimations of Eq. (3) and (4) when the intercepts  $\beta_0 \sim \mathcal{N}(\mu, \sigma)$ ,  $\beta_{1;cpp} = \beta_{1;b} = \beta_{1;t}$  (columns (1) and (3)), and  $\gamma_i = \delta_i = \theta_i = 0$  (columns (1) and (3)). The dependent variable is the mode choice between “bus”, “train”, “carpool A”, and “carpool B”. The reference alternative is “train”. Standard errors in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.

Table 14: Empirical results from the passengers’ model