Pricing and Modal Shift

New evidences from the Lab

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Work in progress

Motivation

Transport accounts for more than a third of CO2 emissions from end use sectors

The IAE 2023 Net Zero Scenario requires transport sector emissions to fall by around a quarter by 2030, even as transport demand continues to grow

- In France, road transport accounts for 94.7% of emissions in the transport sector (Datalab 2022for 2020).
- Personal cars contribute to 53.5% of transport emissions.
- The overall increase in traffic leads to stable average CO2 emission per km-vehicule since 1990

→ **Modal shift** is key to decarbonize transport

Motivation

In the shift towards more **sustainable and efficient** transportation modes, aiming to reduce congestion and environmental impacts, two main obstacles arise :

1. Inadequate and unsuitable alternatives (infrastructure, service quality)
   - It would be necessary to triple the public transport offer to meet the challenges (Coldefy, 2022)
2. **travelers' behaviors**
   - The personal car still constitutes one of the main modes of daily transportation for 72% of the French population

- Theoretically, optimal tariff aligns fares with real transportation costs, including externalities like congestion, pollution, and social costs
- In practice, questioning the effectiveness of optimal pricing based on the assumption of individuals' rationality and cognitive bias

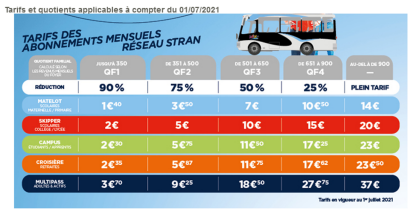
Motivation

The rational model of travel mode choice is less relevant in a repeated choice context.

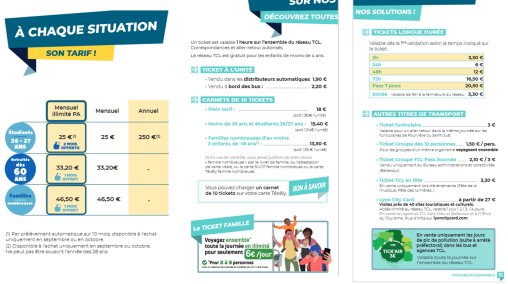
- The fully rational commuter is supposed to maximise individual utility subject to time and budget constraints
- However, habits trigger automatic reactions

Behavioral approach accounts for cognitive biases, limited rationality & psychological inertia in the mode choice

Motivation



Saint Nazaire



Lyon
https://www.tcl.fr/sites/default/files/2022-08/Guide_Tarifs_Sept2022.PDF

RQ : How does the pricing structure influence modal shift ?

Our paper

An empirical investigation on how constrained commuters react to alternative pricing structures

- **Lab evidences : contextualized discrete choice experiment based on a simple environment**
- Pricing structure that closely mirrors the real-world fare magnitudes : usual ones (Unitary price ticket, "Monthly pass") and more exploratory ones (High Peak/Low peak, Non-linear tariff)
- Participants make constrained **repeated choices** between individual car commuting and public transport & departure time
- Participants are given **feedback information** on travel costs travel conditions (congestion and incidence) to address psychological inertia and intentional motivation

We also assess the **social cost** generated by each pricing scheme.

→Contribution to the behavioral literature on transport mode choice & transport policy recommendations

Literature : mode choice

The fact that the mode choice is repeated several times has a negative impact on individuals' rationality (Gärling, 1998, Innocenti et al. 2013)

- **Habits** trigger automatic reactions to information that are not based on rational calculation (Aarts et al. 1997, Innocenti et al. 2013)
- If travellers have a strong habit,intentional motivation through pricing could make little difference to behavior (Garner, 2009)
- **Car stickiness (Gonzalez et al., 2017, Innocenti et al. 2013 ; Bamberg et al., 2003 ; Steg, 2003)**

Literature : tariff choice in transport

Some cognitive biases have been emphasized for tariff choice

- "flat rate bias" : Intrinsic user preference for a flat-rate subscription over pay-as-you-go, even if the breakeven point of the subscription is not reached (Wirtz, Vortisch, Chlond 2015) : **aversion to fixed part, convenience, risk aversion with regard to price variations**
- monthly pass may provide a sense of freedom (up to the point where it is not cost-effective) because no need to compute the cost of an additional trip (Hörcher, Hraham 2020)
- individuals do not systematically choose the optimal tariff (usage-based payment) because they cannot anticipate correctly their needs on a given period (Erramilli, Papagiannaki 2012). Risk aversion drives him to choose a suboptimal fare (the subscription) as it enables him to hedge against a potentially high bill due to possible overconsumption

Literature : tariff complexity

Another problem is aversion to complexity, leading to suboptimal choices by travelers

There are three sources of complexity (Sitzia et al., 2015) :

- Price-quantity relationship (linear vs. non-linear).
- Bundling of products : fares for a single product or two products.
- Number of different fares.

Individuals prefer simple fares with predictable prices as there is a cognitive cost in computation (Mayol and Staropoli, 2021).

- Complexity is better understood when following an "obvious" logic, such as peak/off-peak pricing (Bonsall et al., 2007).

Overview of the results

1. Users are sensitive to public transportation tariff systems.
2. Flexible tariff options for public transportation are preferred.
3. Peak/off-peak and non-linear tariff structures increase the frequency of public transportation choice compared to subscriptions and single tickets.
4. Participants' cognitive effort is higher than what a simple inertia model would predict.
5. Economic incentives for public transportation use work despite the behavioral inertia of private vehicle drivers.

Other Findings :

- Psychological inertia is a significant driver of transportation mode choices.
- Past experiences with congestion and incidents in public transportation and road networks influence decisions regarding modes of transportation.

Experimental design : treatments

- A between-subjects experiment
- 4 Treatment variables : pricing structure

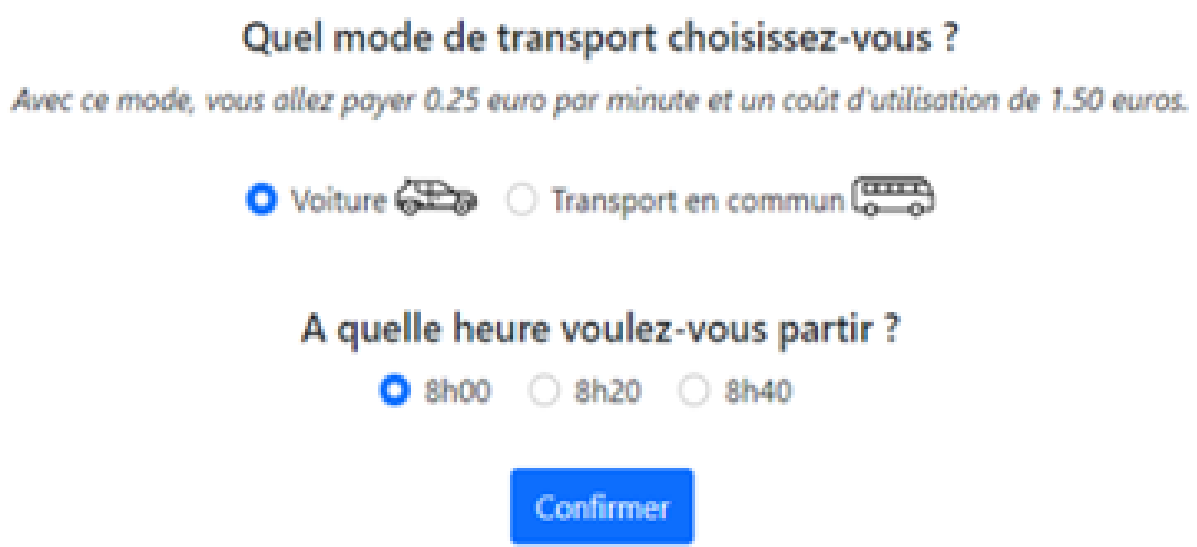
Treatment	**Type of tariff**	**Parameters**	**Cost per travel**	
1	Unitary price ticket	1.5	1.5	
2	Peak/off Peak	0.75/1.5	0.75/ 1.5	
3	Monthly pass	Fixed part = 2	If 4 PT trips	0.5
	(four periods validity)	Marginal cost = 0	3	0.67
			2	1
			1	2
4	Non-linear tariff	Fixed part = 1	If 4 PT trips	1
	(four periods validity)	Marginal cost= 0.75	3	1.08
			2	1.25
			1	1.75

Experimental design : rules

- Participants (commuters) are grouped by 10
- They are asked to arrive at 9.00 AM at a point B leaving from the same point A and using the same route
  - If they arrive **on time** they get a travel gain : 15 EUR, **early** 10 EUR and **late** 5 EUR
  - They choose the **transport mode** and the **departure time**
- The choice is **repeated 40 times**, but the final pay-off is based on a random period

Screen shot : discrete choice

	Departure		
Car	8.00AM	8.20AM	8.40AM
Public Transport	8.00AM	8.30AM	



Experimental design : non cooperative game with risk

Two events can occur :

- **Congestion** (endogeneous)
  - If 2 or more travellers choose the car at the same departure time
  - If 4 or more travellers choose the bus at the same departure time
- **Incident** (random)
  - For car : probability of an incident $= 1/5$
  - For bus : probability of an incident $= 1/20$

- They both increase the time spent in the vehicle

	Car			**Bus**	
	No cong.	*Cong.*		*No cong.*	*Cong.*
No incident	20 min	40 min	*No Incident*	30 min	45 min
Incident	30 min	50 min	*Incident*	60 min	75 min

Experimental design : costs

The travel cost depends on the travel time and the mode of transportation :

- **Cost of time spent in the vehicule** : 0,25€/min (*car*) and 0,16€/min (*Public Transport*)

	Car			**Bus**	
	No cong.	*Cong.*		*No cong.*	*Cong.*
No incident	5,00€	10,00€	*No Incident*	4,80€	7,20€
Incident	7,50€	12,50€	*Incident*	9,60€	12,00€

- **Cost of use**
  - Car = 1.5€/travel
  - Bus = Tariff (treatment variable)

Experimental design : gains

Pay-offs : 3 components

1. **Show-up fee** = 5€
2. **Mode choice**
   - Gain per period = initial endowment + gain cost of time cost of use
   - Initial endowment = 10
   - Travel gain = 10€(early), 15€(on time), 5€(late)
   - Car's cost of use = 1,5€ ; Public transport cost = Tariff
   - Final gain = drawing of lots of one gain out of fourty
3. **Lottery-choice gain** to elicit risk aversion (Hold and Laury, 2002)

Experiments

- Experiments were conducted at the LEEP (**on-site**) & **online** (LEEL platform)
- Research assistant : Victor Chapuis (PSE)
- Research engineer : Maxim Frolox (PSE, CES, Université Paris 1)
- Experiments run during the period : from 29/11/2022 to 28/03/2023
- Research project funded by **Transdev**, (french public transport operator) with the participation of Jean Coldefy, Adviser to the Transdev CEO.

	Participants	**Average pay-off / participant**
Online (S2CH-LEEL)	290	14,61€
On site (LEEP)	410	14,40€

Empirical strategy

Based on the panel database from the experiments in the lab, we use two different models :

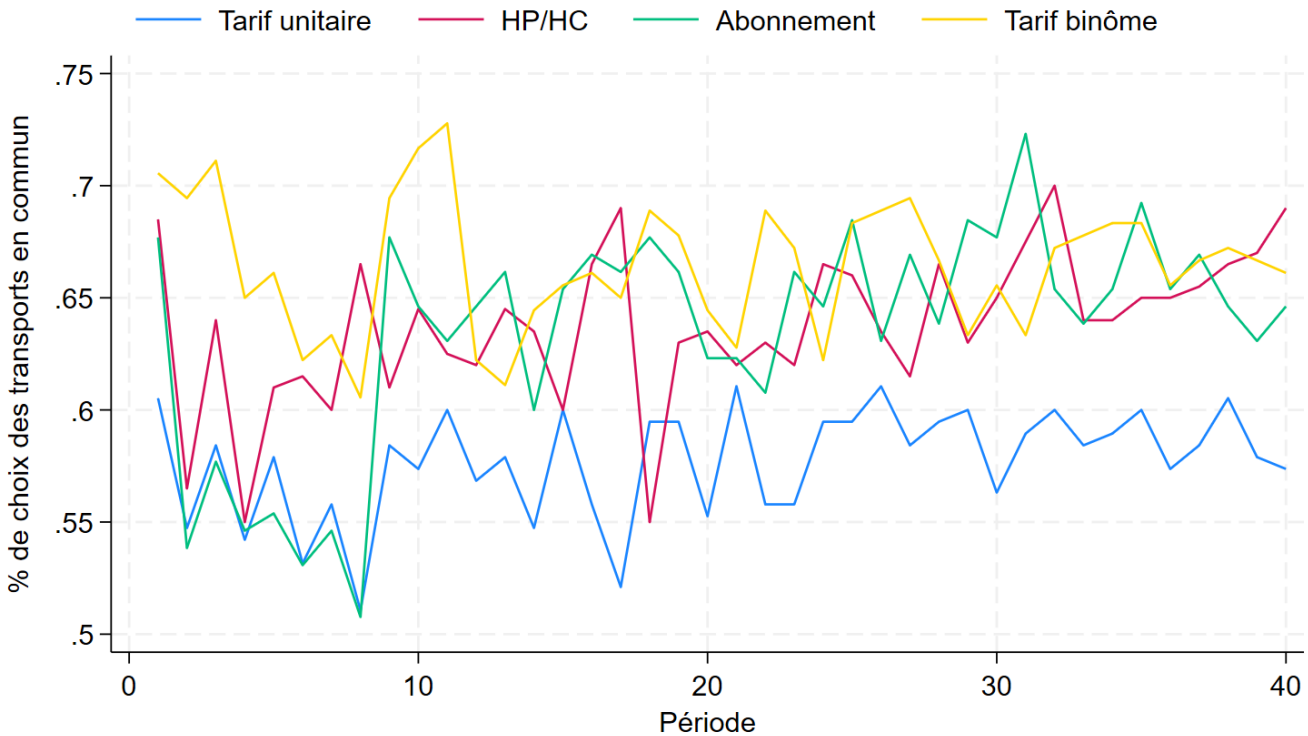
- Logit Model 1 (with RE) to explain the **PT choice** :

$$Player\_mode\_choice_{it} = 1[Player\_mode\_choice^{*}_{it} = \alpha + \beta\, treat_{it} + \gamma Controls_{it} + \delta_t + \nu_{i,t} > 0] \quad (1)$$

- Reg Model 2 (RE) to explain the **individual gain**

$$Player\_gain_{it} = \zeta + \beta_1\, treat_{it} + \beta_2\, player\_mode\_choice_i\, t + \beta_3\, treat_{it} * player\_mode\_choice_i\, t + \theta\, Control\_variables\_it + \delta_t + \varepsilon_{it} \quad (2)$$

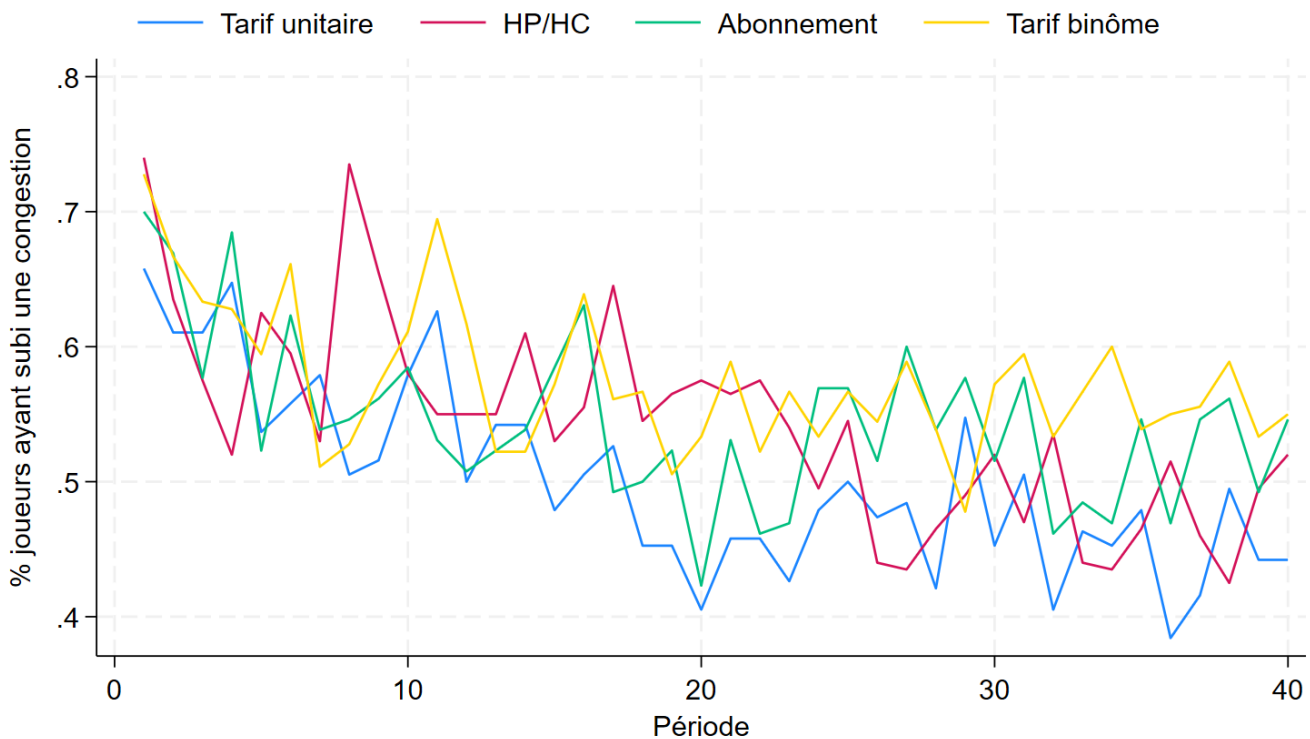
Descriptive statistics : transport mode choice



Participants consistently choose more public transport over the car

Choice of Public Transport increases over time

Descriptive statistics : Coordination



Congestion decreases : participants learn how to coordinate

Results (M1)

	(1) ChoicePT_avgt1	(2) ChoicePT_avgt4	(3) ChoicePT_lagPT	(4) ChoicePT_lagCAR
flat_rate_tariff	0	0	0	0
	(.)	(.)	(.)	(.)
offpeak_onpeak_tariff	0.658***	0.660***	0.637***	0.585***
	(4.34)	(4.53)	(4.13)	(3.83)
fixed_part_tariff	0.377	0.407	0.294	0.244
	(1.68)	(1.89)	(1.30)	(1.12)
twopart_tariff	0.853***	0.857***	0.822***	0.762***
	(4.57)	(4.69)	(4.33)	(4.17)
average_congestion_PT_t1t1	-1.507***			
	(-15.90)			
average_incident_PT_t1t1	-0.381			
	(-1.90)			
average_congestion_CAR_t1t1	1.127***			
	(8.83)			
average_incident_CAR_t1t1	0.580***			
	(5.73)			
average_PT_t1t1	3.581***			
	(18.27)			
average_congestion_PT_t4t1		-2.032***		
		(-15.72)		
average_incident_PT_t4t1		-0.619*		
		(-2.47)		
average_congestion_CAR_t4t1		1.194***		
		(7.58)		
average_incident_CAR_t4t1		0.940***		
		(6.75)		
average_PT_t4t1		4.299***		
		(17.78)		
r2				
N	27261	27261	27261	27261

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results (M1)

	(1) ChoicePT_avgt1	(2) ChoicePT_avgt4	(3) ChoicePT_lagPT	(4) ChoicePT_lagCAR
0.lag_congestion_PT1.lag_incident_PT			-0.0796	
			(-0.37)	
1.lag_congestion_PT0.lag_incident_PT			-0.911***	
			(-10.92)	
1.lag_congestion_PT1.lag_incident_PT			-1.282***	
			(-6.97)	
0.lag_congestion_CAR1.lag_incident_CAR				0.385***
				(2.91)
1.lag_congestion_CAR0.lag_incident_CAR				0.820***
				(7.53)
1.lag_congestion_CAR1.lag_incident_CAR				1.032***
				(8.25)
lag_PT			1.831***	
			(15.57)	
lag_CAR				-1.908***
				(-13.70)
subsession_round_number	0.00940***	0.00800***	0.00882***	0.0114***
	(4.37)	(3.59)	(4.35)	(5.79)
r2				
N	27261	27261	27261	27261

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Interpretation : pricing structure

Pricing structure impacts the choice of transport mode

- Off Peak/On Peak tariffs and two parts tariff incentivize participants to choose public transport
  - However, the monthly pass has little impact, contrary to predictions.
  - Interpretation : Off Peak/On Peak tariffs and two parts tariff can be considered as more flexible tariffs with no or less commitment (two parts tariff). the monthly pass. The monthly pass commits the user for the long term and restricts their ability to utilize information about traffic congestion and incidents.

Interpretation : experience

Repated choices help to analyse the role of experience to explain mode choice, congestion & incident

- Past experience with both congestions and incidents prompt a shift in transportation modes
  item The impact of road congestion has less influence on the likelihood of choosing public transportation than the effect of congestion within public transportation
- Immediate congestion experience both in public transport and in car have a positiveeffect on PT choice, less so for incidents
- Recent experiences in the immediate past (last 2 periods) exert a greater influence than more distant experiences (last 4 periods)

Interpretation : psychological inertia

Psychological inertia is the foremost determinant of modal choice among others

1. Using public transport increases the probability to choose public transport
2. Using car reduces probability to choose public transport (c̃ar stickiness)
3. The influence of previous transportation mode choices is more pronounced and has a contrary effect compared to the impact of congestion or incidents
4. Experiencing road congestion has a lesser impact on the choice of transportation mode compared to facing congestion in public transit. It confirms some king of car stickiness for drivers who are less willing to change mode despite congestion & incidents

Results (M1)

	(1) ChoicePT_avgt1	(2) ChoicePT_avgt4	(3) ChoicePT_lagPT	(4) ChoicePT_lagCAR
player_age	0.00171	0.00220	0.000970	0.000195
	(0.14)	(0.19)	(0.07)	(0.01)
male	0	0	0	0
	(.)	(.)	(.)	(.)
female	0.285*	0.272*	0.302	0.298
	(1.68)	(1.75)	(1.56)	(1.52)
gender_other	0.497	0.459	0.544	0.548
	(0.65)	(0.64)	(0.65)	(0.66)
csp_worker	0	0	0	0
	(.)	(.)	(.)	(.)
csp_internship	-1.119***	-1.009***	-1.290***	-1.308***
	(-2.66)	(-2.59)	(-2.72)	(-2.77)
csp_student	-0.145	-0.113	-0.203	-0.210
	(-0.56)	(-0.46)	(-0.70)	(-0.73)
csp_student_with_job	-0.539	-0.454	-0.660*	-0.684*
	(-1.56)	(-1.41)	(-1.68)	(-1.77)
csp_unemployment	0.407	0.375	0.468	0.459
	(1.14)	(1.13)	(1.19)	(1.16)
csp_retirement	0.365	0.340	0.426	0.419
	(0.82)	(0.82)	(0.86)	(0.84)
csp_housewife	0.627	0.611	0.662	0.675
	(1.10)	(1.16)	(1.03)	(1.05)
csp_other	0.0549	0.118	-0.0280	-0.0984
	(0.12)	(0.27)	(-0.05)	(-0.19)
r2				
N	27261	27261	27261	27261

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Results (M1)

	(1) ChoicePT_avgt1	(2) ChoicePT_avgt4	(3) ChoicePT_lagPT	(4) ChoicePT_lagCAR
never_maried	0	0	0	0
	(.)	(.)	(.)	(.)
maried	0.240	0.233	0.246	0.255
	(0.75)	(0.80)	(0.70)	(0.71)
widower	0.555	0.545	0.637	0.612
	(0.60)	(0.64)	(0.64)	(0.60)
divorced	-0.304	-0.313	-0.265	-0.273
	(-0.69)	(-0.76)	(-0.54)	(-0.55)
no_diploma	0	0	0	0
	(.)	(.)	(.)	(.)
under_bac_diploma	-0.613	-0.539	-0.695	-0.770
	(-0.44)	(-0.42)	(-0.45)	(-0.49)
bac	-1.301	-1.191	-1.413	-1.463
	(-0.97)	(-0.97)	(-0.95)	(-0.96)
bac_2	-1.157	-1.064	-1.301	-1.313
	(-0.84)	(-0.84)	(-0.85)	(-0.84)
bac_3	-0.792	-0.723	-0.868	-0.884
	(-0.58)	(-0.57)	(-0.57)	(-0.57)
bac_5	-0.623	-0.570	-0.659	-0.681
	(-0.45)	(-0.45)	(-0.43)	(-0.43)
bac_8	-1.565	-1.471	-1.690	-1.659
	(-1.03)	(-1.05)	(-1.00)	(-0.96)
house_tenant	0	0	0	0
	(.)	(.)	(.)	(.)
house_free_tenant	-0.360	-0.341	-0.398	-0.402
	(-1.33)	(-1.37)	(-1.32)	(-1.31)
house_owner	0.0655	0.0469	0.0796	0.0922
	(0.22)	(0.17)	(0.23)	(0.27)
r2				
N	27261	27261	27261	27261

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Results (M1)

	(1) ChoicePT_avgt1	(2) ChoicePT_avgt4	(3) ChoicePT_lagPT	(4) ChoicePT_lagCAR
player_n_cars	-0.109	-0.104	-0.117	-0.122
	(-0.93)	(-0.97)	(-0.88)	(-0.89)
player_freq_PT	0.116	0.0985	0.152	0.161
	(0.48)	(0.45)	(0.55)	(0.59)
PT_annual_subscri	0	0	0	0
	(.)	(.)	(.)	(.)
PT_week_subscri	-0.234	-0.203	-0.296	-0.295
	(-1.36)	(-1.29)	(-1.51)	(-1.48)
PT_month_subscri	-0.0611	-0.0101	-0.0627	-0.160
	(-0.04)	(-0.01)	(-0.04)	(-0.09)
PT_other_subscri	-0.465	-0.426	-0.569	-0.569
	(-1.34)	(-1.33)	(-1.43)	(-1.44)
PT_groupedticket	-0.459	-0.398	-0.550	-0.561
	(-1.08)	(-1.02)	(-1.13)	(-1.15)
PT_singleticket	-2.245***	-2.075***	-2.554***	-2.573***
	(-3.40)	(-3.39)	(-3.36)	(-3.35)
crt_total_score	0.128	0.120	0.140	0.144
	(1.53)	(1.54)	(1.49)	(1.51)
0.online_session1.paris	-0.368	-0.359*	-0.375	-0.345
	(-1.63)	(-1.65)	(-1.57)	(-1.43)
1.online_session0.paris	-0.0911	-0.115	-0.0687	-0.0108
	(-0.42)	(-0.54)	(-0.30)	(-0.05)
1.online_session1.paris	0	0	0	0
	(.)	(.)	(.)	(.)
r2				
N	27261	27261	27261	27261

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Preliminary conclusions

1. Pricing matters ... but won't be enough
   - The subscription is not the pricing strategy that leads to more modal shifts.
   - The single ticket is deemed too expensive.
   - More **flexible and usage-based pricing** is what increases the preference for public transportation
2. Car stickiness may pertains
3. Congestion and uncertainty deter the use of public transport

Thanks for your attention

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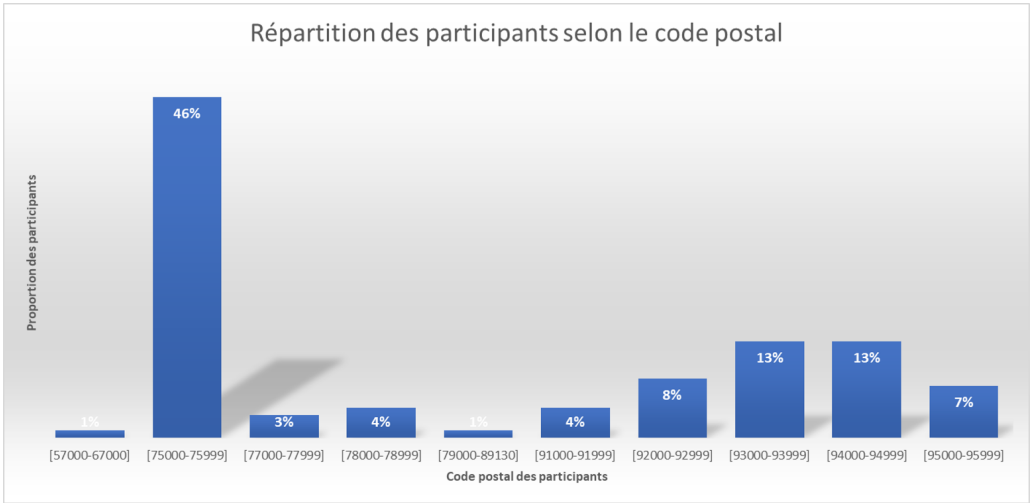
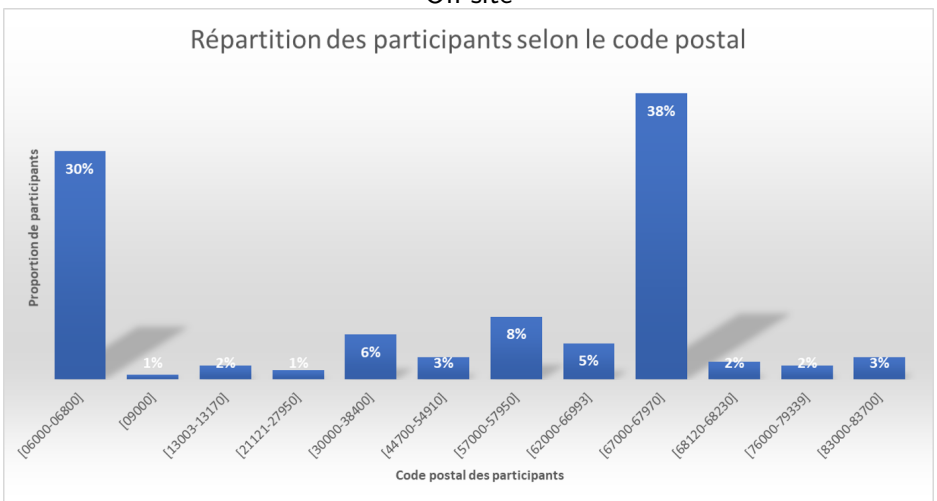
Sample statistics



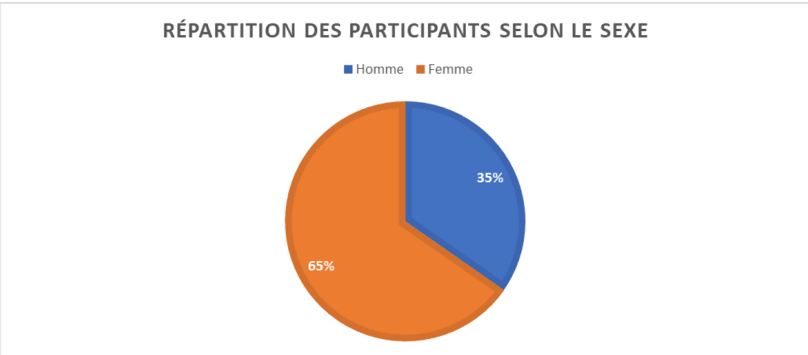
On site

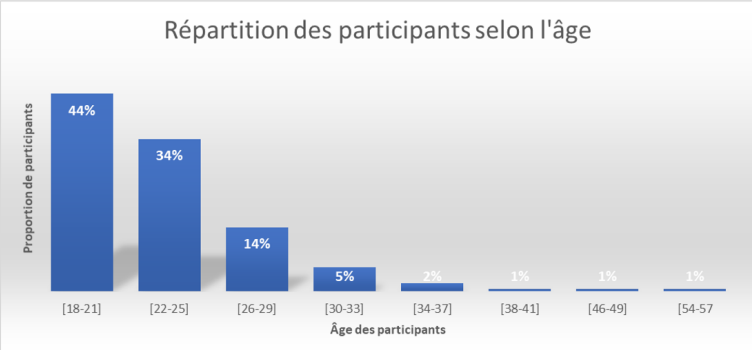


Online

Sample statistics

Online (170)





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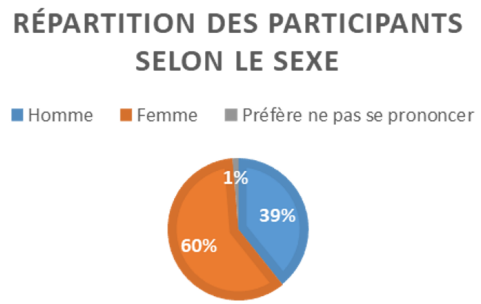

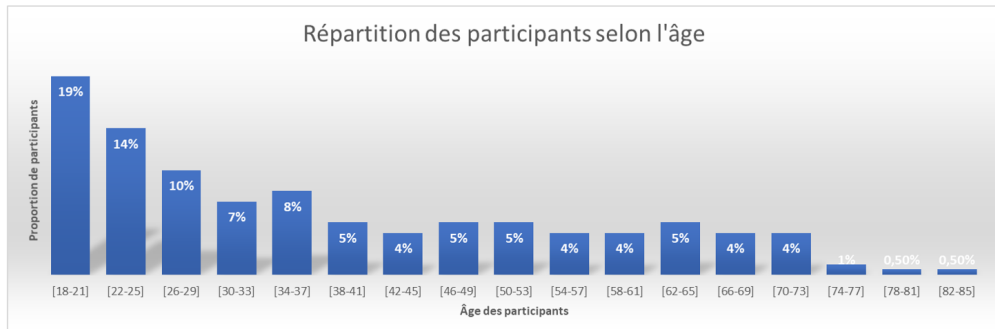

Sample statistics

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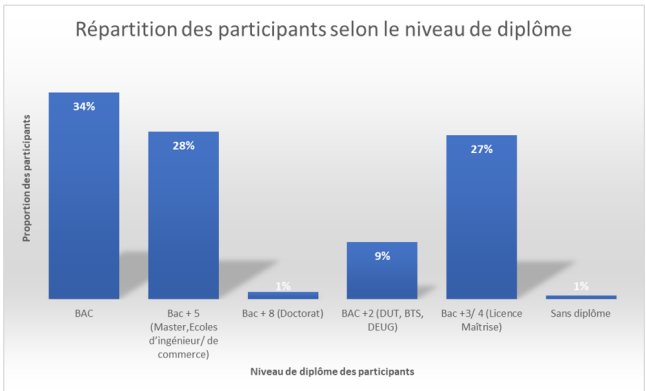
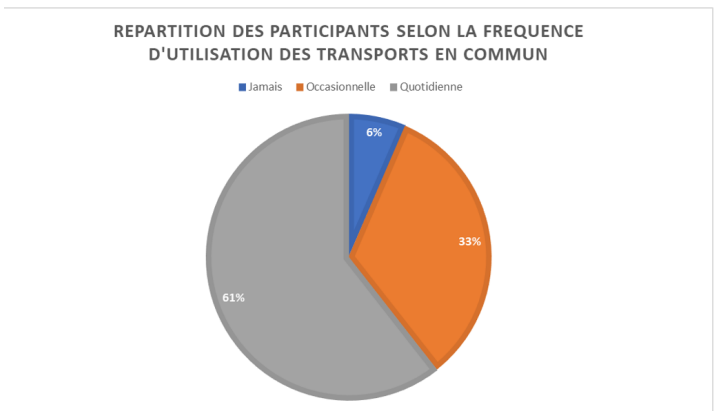
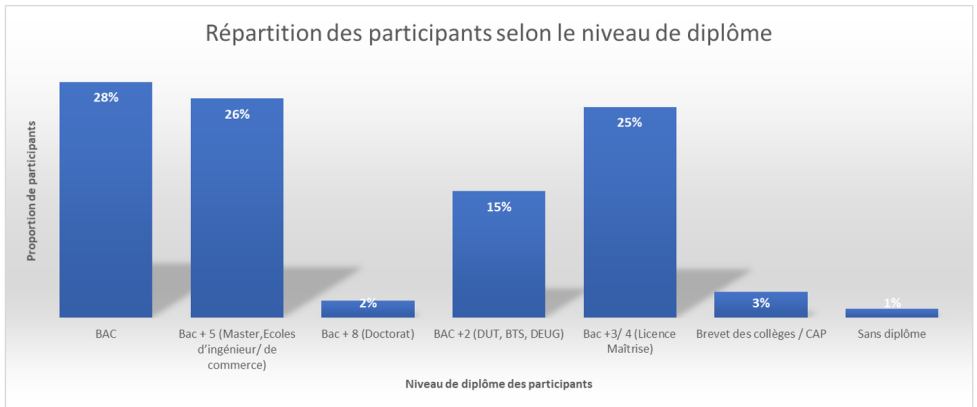
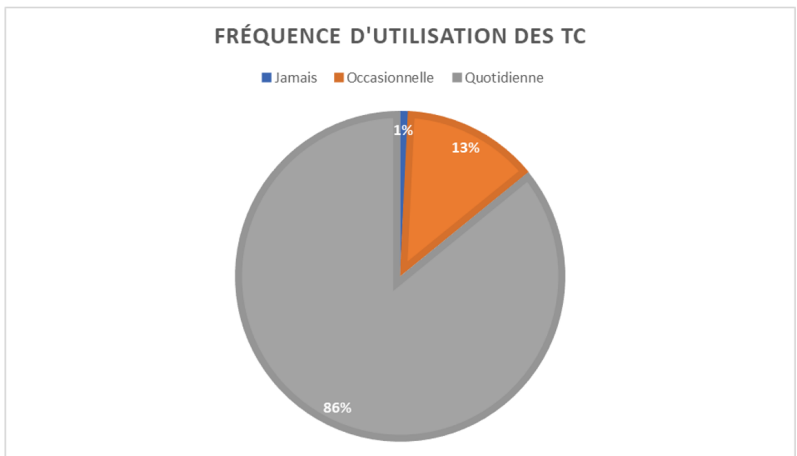




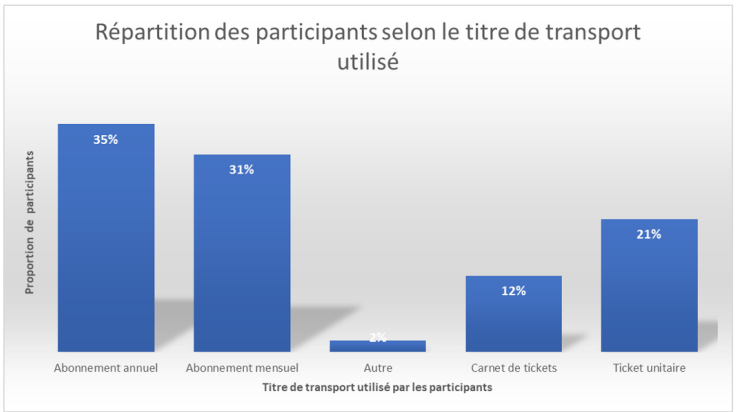
On-site (410)

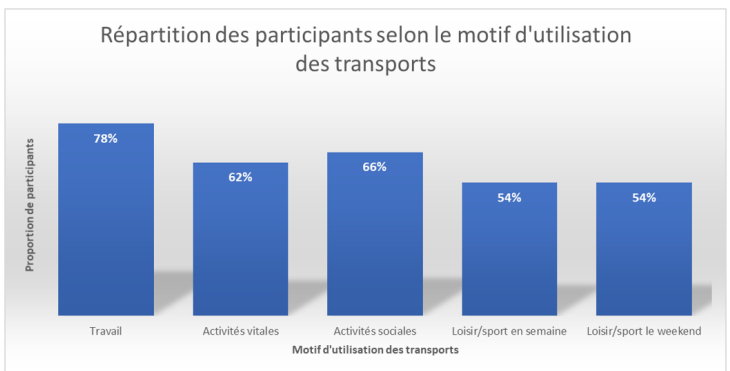




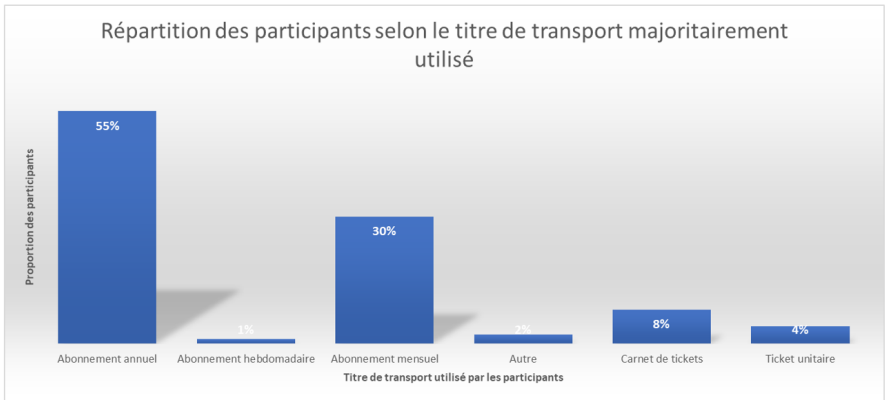
Sample statistics

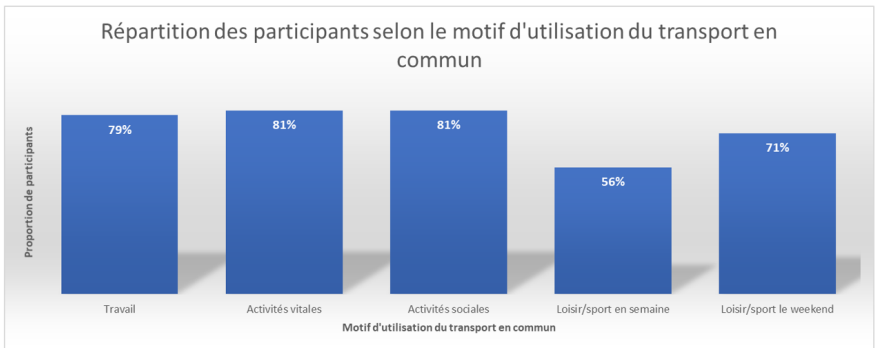
Online (170)





On-site (410)





Results (M2)

	(1) Player_Gain
PT_choice	-1.412***
	(-5.89)
offpeak_onpeak_tariff	-0.482
	(-1.90)
fixed_part_tariff	-1.070***
	(-3.61)
twopart_tariff	-0.824**
	(-3.26)
PT_choice*offpeak_onpeak_tariff	1.343***
	(4.15)
PT_choice*fixed_part_tariff	2.409***
	(6.47)
PT_choice*twopart_tariff	1.664***
	(5.16)
subsession_round_number	-0.00288
	(-1.07)
player_congestion	-6.377***
	(-76.58)
player_incident	-8.443***
	(-59.50)
player_age	-0.00662
	(-1.49)
r2	
N	27960

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results (M2)

	(1) Player_Gain
male	0
	(.)
female	-0.0788
	(-1.12)
gender_other	-0.563***
	(-4.25)
csp_worker	0
	(.)
csp_internship	-0.570***
	(-3.59)
csp_student	-0.275**
	(-2.10)
csp_student_with_job	-0.290*
	(-1.69)
csp_unemployment	0.0544
	(0.46)
csp_retirement	0.0277
	(0.18)
csp_housewife	-0.645*
	(-1.78)
csp_other	-0.302*
	(-1.76)
r2	
N	27960

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Results (M2)

	(1) Player_Gain
never_maried	0
	(.)
maried	0.200
	(1.45)
widower	0.219
	(1.22)
divorced	0.412**
	(2.46)
no_diploma	0
	(.)
under_bac_diploma	0.753***
	(2.72)
bac	0.877***
	(3.38)
bac_2	0.739***
	(2.73)
bac_3	0.988***
	(3.82)
bac_5	0.833***
	(3.01)
bac_8	0.805*
	(1.95)
house_tenant	0
	(.)
house_free_tenant	-0.0536
	(-0.43)
house_owner	0.0964
	(0.63)
r2	
N	27960

t statistics in parentheses
* p¡0.10, ** p¡0.05, *** p¡0.01

Results (M2)