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Bicycle use in the university community: Empirical analysis using MobiCampus-UdL data (Lyon, France)

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Abstract: Promoting sustainable mobility systems by encouraging the use of the bicycle as a transport mode is now a public policy objective. This political will is also pursued in France where the modal share of cycling is relatively low. However, young people and those with a high level of human capital, such as members of the university community, are observed to be more advanced in their adoption of cycling. An understanding of how cycling is used by university students and staff would therefore help to inform public decision-making and support more efficient targeted policies to develop this mode of transport. Using original data from the MobiCampus-UdL project, the aim of this article is to analyze the determinants of bicycle use by the university community at the University of Lyon, France. Two multivariate logistic regression models are estimated on the subsamples of students and staff: one explaining the probability of using the bicycle as an exclusive mode of transport to get to the campus and the other explaining the probability of using the bicycle in combination with other modes. Our results suggest that while socio-demographic characteristics have little influence within our two relatively homogeneous subsamples, access to mobility resources and the spatial characteristics of the campus and place of residence are crucial. We also find that access to bicycles is an important determinant of the utilization of cycling. Given that the adoption of cycling is still very low, our findings justify policies to increase the availability of bicycles and subsidize their purchase. More specifically, our results suggest that access to a shared bike station on campus encourages the exclusive use of bicycles by students and staff but has no effect when used in combination with other modes. On the other hand, good accessibility to public transport, whether from home or from campus, does not reduce the use of bicycles by either sub-population, either exclusively or in combination. Furthermore, while living far from the city center is an obstacle to the exclusive use of the bicycles, especially for staff, it does not in any way prevent their use in combination with other modes, such as the train. These results open up new avenues for anticipating the development of intermodality between public transport and cycling.

Keywords: Home-campus mobility, combined modes, public transport accessibility, bike-sharing accessibility, students, university staff

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1 Introduction

In recent decades, policy makers in developed countries have increasingly recognized the importance of biking, not only as an efficient means of transport, but also as an important component of urban planning, public health and environmental quality. In particular, compared to the private car, cycling offers environmental and social benefits, such as reduced energy consumption, air and noise pollution (Neves & Brand, 2019), and improved quality of life for city dwellers by reducing congestion and boosting local businesses (Martens, 2004). Relatively speaking, cycling is the most economical form of mechanized transport as infrastructure is cheaper to build (Handy et al., 2014; Heinen et al., 2010). Cycling is also an essential form of active transport with sufficient intensity to meet the World Health Organization's Health-Enhancing Physical Activity (HEPA) criteria (Oja et al., 1998; Rabl & de Nazelle, 2012), thereby reducing the burden of non-communicable diseases (Prince et al., 2021). For example, a Danish study (Andersen et al., 2000) estimates that cycling to work reduces the risk of mortality by 28%, after taking into account major measured confounding factors (age, type of employment, smoking, physical activity, etc.). Other international studies suggest that cycling to work is associated with higher individual productivity, a reduction in sickness absence of up to 15% (Hendriksen et al., 2010), a reduction in the risk of cancer by a factor of two (Celis-Morales et al., 2017), and a 15% lower risk of type 2 diabetes and depression.[1] Moreover, these health benefits would far outweigh the risks cyclists face, such as accidents and higher exposure to pollution in urban areas (Praznocky, 2012). As a result, the number of policy initiatives to promote cycling has increased significantly as part of the search for more sustainable transport solutions (Heinen et al., 2010; Martens, 2004; Pucher et al., 2010).

In France, public investment in facilities and services for cyclists began in the 1970s, as cycling was seen as a solution to reduce the number of road deaths, partly linked to the massive use of cars, and to limit energy dependency, the negative effects of which were highlighted by the 1973 oil crisis. The first bike sharing system was introduced during this period in the mid-sized city of La Rochelle (Huré & Pasalacqua, 2017) long before the Vélo'v system in Lyon in 2005 and Vélib system in Paris in 2007. However, these pro-cycling policies were not sustained over time; the second oil crisis brought these national initiatives to a halt in favor of investment in public transit, thanks to the "transport payment" tax paid by companies. They finally regained momentum with the launch of the National Plan for Active Mobility in 2014, which set the target of tripling the proportion of daily journeys made by bicycle by 2024. Indeed, the bicycle use in France is low compared to the European average: only 5% of daily trips are made by bike, compared to more than double that at European level and around 43% in the Netherlands.[2] Moreover, this political will has been reaffirmed by the 2018 National Cycling Plan, accompanied by a 350-million-euro fund to address the insufficiency and discontinuities of safe cycle paths, and by the recent Cycling and Walking Plan 2023-2027, which aims to make these two modes of transport an attractive alternative to private car for short journeys and combined with public transport for longer journeys. These initiatives show that there is a growing awareness of the benefits of transport

[1] https://www.c40.org/news/climate-action-green-healthy-streets-paris/

[2] https://www.entreprises.gouv.fr/files/files/en-pratique/etudes-et-statistiques/dossiers-de-la-DGE/impact-economique-et-potentiel-developpement-velo-en-france.pdf

modes increasingly towards integrated approaches that address the whole transport system.

In many countries, the motivation to integrate cycling into public transport has been justified by the fact that cycling can help to solve the weakness of public transport: accessibility (Martens, 2004). The main argument is that cycling as a mode of transport feeder to public transport can reduce the total journey time from door to door, as cycling is faster than walking (Martens, 2004) and offers a wider accessibility and flexibility in combining sub-modes (Kager et al., 2016). However, as the French public transport network is often recognized for its good performance and accessibility, the use of the bicycle as a connecting pre-mode for the use of public transport may be less relevant and may partly explain the low level of cycling.

In this context, a better understanding of the current exclusive and combined use of bicycles in France is essential for the implementation of effective, sustainable and pro-cycling policies. Our article focuses on the bicycle use for work and school trips by staff and students of the university community in the Lyon metropolitan area. We chose this target population because the university community, and students in particular, are deemed to adopt more sustainable commuting modes and travel behaviors than the rest of the population (Balsas, 2003; Van den Berg & Russo, 2017). University students belong to the group of users who are more likely to use bicycles, mainly due to their age and associated dynamism, lower economic conditions and higher environmental awareness. Furthermore, university campuses are a major source of travel demand on local transport networks (Klomp, 2022; Romanowska et al., 2019; Shannon et al., 2006): they contribute to the saturation of road infrastructures and public transport networks, especially during rush hours. The mobility of university communities is therefore a major issue in the transport policies of large cities such as Lyon, and universities are privileged places to promote sustainability and to contribute to the transformation of society's transportation patterns. Like other studies (Heinen et al., 2010; Kroesen & Handy, 2014), we focus on bicycle commuting: these regular trip data may be better and more relevant for policy making than information available on trips for other purposes. Indeed, commuting trips are more related to habits than other non-regular trips, and the importance of the habits, the frequency of bicycle use and familiarity with cycling has already been pointed out (Rondinella, 2015).

For our study, we conducted a travel survey (2017-2019) under the project title MobiCampus-UdL, among staff and students from around twenty university campuses and institutions grouped under the academic label "University of Lyon" (UdL). We examined the extent of cycling in this university community for regular commuting trips, distinguishing between exclusive cycling and combined cycling, and also between the use of a personal bicycle and the use of the shared bicycle network. In addition, we proposed binary choice models to identify and compare the factors associated with a higher likelihood of exclusive and combined cycling in the student and staff populations. Our study thus complements the few existing quantitative works on the determinants of bicycle use in France (Héran, 2015; Jensen et al., 2010; Papon, 2003; Raux et al., 2017). Moreover, with regard to increasing intermodality in urban areas, the aim of this analysis is to include all trips made by bicycle to reach the campus, and not just those where the bicycle is the exclusive or the main mode of transport. The analysis will therefore encompass all uses of the bicycle, whether exclusively or combined with another mode of transport, whether owned or used through the Vélo'v shared bicycle system.

The remainder of the paper is structured as follows. Section 2 presents the design of MobiCampus-UdL travel surveys and the statistical methods and regression models used to explain the probability of exclusive use and combined use of the bicycle, the latter being statistically considered as a "rare event." Section 3 presents the data analysis and discusses the main results. Section 4 concludes the paper with policy and research implications.

2 Material and methods

2.1 Study context and area

Lyon, the capital of the Auvergne-Rhône Alpes region, has 60,000 inhabitants in the urban core formed by the municipalities of Lyon and Villeurbanne, and a total of 1.4 million inhabitants in the Greater Lyon area (Metropole de Lyon). The University of Lyon (UdL), an academic community that brings together 26 institutions dedicated to education (4 universities and 22 business and engineering schools called "Grandes Ecoles"[3]), is the second cluster of excellence in education and research in France and has an international academic reputation. The UdL has 140,000 students, 7,000 researchers and 3,000 administrative and technical staff spread over 21 campuses and university sites (Figure 1). However, to maintain its national and international attractiveness, the UdL needs a sufficient supply and quality of housing, transport and urban amenities to cope with the flow of students and researchers and the economic activities they generate.

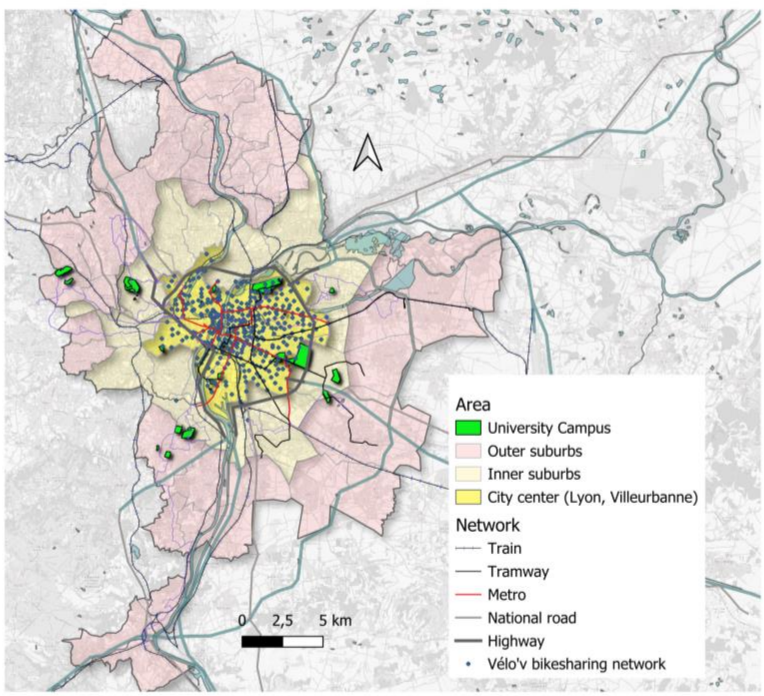

Figure 1. Campuses of the University of Lyon (UdL) and public transport lines and self-service bike stations in Lyon agglomeration.

[3] Business and engineering schools (Grandes Ecoles) are prestigious higher-education institutions with competitive entrance exams.

The UdL authorities have therefore launched a series of in-depth discussions on how to improve the access to local services and the quality of life for students on all campuses. In particular, the issue of travel for the university community has become a major concern. One of the main objectives of the UdL Mobility Plan, in addition to improving the accessibility of the campuses and university sites, is to reduce the use of the car, which is more polluting and takes up more space, in favor of alternative modes of transport. A recent UdL assessment showed that, on average, home-to-work travel accounts for 14% of the carbon footprint of its institutions (Université de Lyon, 2022).

In this context, the Labex IMU - Intelligence of Urban Worlds Laboratory of Excellence - decided to fund the MobiCampus-UdL project, carried out by the Transport Urban Planning Economics Laboratory with the support of the University of Lyon and the Lyon Urban Community. Its aim is to understand the daily travel behavior of the university community in Lyon in order to help campus managers to plan coherent mobility management policies.

2.2 The MobiCampus-UdL travel survey

Our study uses data from the web-based MobiCampus-UdL travel survey conducted in March-April 2017, 2018, or 2019, depending on the institution. Of the 26 UdL institutions, 17 participated in the survey, representing a total survey population of 89,144 students and 11,952 staff. The questionnaires were sent via institutional email addresses to their students and staff and included several categories of questions: i) *their affiliation to the academic institution and their status* (student/staff, department/faculty, degree and level of study for students; type of job for staff; usual patterns and timetables of study/work); ii) *usual mode(s) of travel to and from the campus and transport membership and ownership* (bicycle/car ownership, public transport membership, bike-sharing membership, practice of car-sharing or car-pooling); iii) *general socio-economic and demographic characteristics* such as age, gender, and place of residence.

The information collected for students and staff is not exactly the same. For example, students were specifically asked whether they were still lived with their parents, in a student residence or in a private accommodation; whether or not they had a student job during the academic year; whether they were scholarship student; or whether they alternated between courses and work placements periods in the academic year. University staff for whom these questions were not relevant, were asked about their marital status (couple or not, with or without children), their occupation (lecturer-researcher vs. administrative and technical staff), their income class, and whether or not they teleworked. Part A of Table 1 describes the survey variables for the two sub-populations. In addition, as the respondents precisely located their main place of activity on the campus and their place of residence on interactive maps (Google maps), it was possible not only to calculate the distance from home to the campus, but also to construct individual measures of accessibility to different modes of transport, based on infrastructure network information, for their place of residence and campus. The Lyon agglomeration has more than 120 bus lines, 4 metro lines (32 km), 7 tramway lines (66 km), 2 funiculars, 6 railway stations and more than 400 bike-sharing stations (the Vélo'v network) with around 5,000 bicycles in operation. However, the level of public transport is uneven across the 21 campuses and study areas, with most bike and public transport stations located in the city center (Figure 1). We therefore constructed dichotomies indicating whether the respondent's home (respectively for the campus) was less than one kilometer from a train station, close to a public transport station (i.e., less than 500 meters from a metro station, less than 400 meters from a tram stop, less than 300 meters from a bus stop), and less than 300 meters from a bike-share station. These thresholds for defining accessibility have been chosen in line with previous studies (Poelman et al., 2020; Dalton et al., 2013; Millward et al., 2013; McConville et al., 2011). For public transport accessibility measures based on distances to the nearest stations, thresholds between 300m and 1km are usually retained to reflect the distances people are willing to walk to a bus or train station. For example, Millward et al. (2013) found a peak in walking to bus stops at distances between 200m and 400m, and most walking to a number of destinations was within 1km. Furthermore, it is generally accepted that people are willing to walk a little further to get to a metro station, and even further to get to a train station, than to a bus or tram stop (Poelman et al., 2020). Part B of Table 1 describes the home location and accessibility variables used, which are identical for our two sub-populations.

2.3 Sample characteristics

12,995 people from the 17 participating institutions (9,325 students and 3,670 staff) completed the questionnaire, giving a response rate of around 13% (10.4% for students and 30.7% for staff). Table 1 presents the main sample characteristics.

Table 1. Sample characteristics

Students			**Staff**
Part A			
Socio-economic factors			
Gender		**Gender**	
Men	46.5%	Men	52.8%
Women	53.5%	Women	47.2%
Age		**Age**	
18 to19 years old	23.0%	under 35 years old	19.3%
20 to 21 years old	29.9%	35 to 44 years old	28.3%
22 to 24 years old	26.2%	45 to 54 years old	32.2%
25 to 34 years old	17.1%	55 years old and over	20.2%
35 years and over	3.8%	**Marital status**	
Scholarship student	29.2%	Couple with children	50.4%
Dwelling type		Couple without children	23.6%
Living at the parents' home	22.3%	Single	19.3%
Living in a public student residence (Crous)	6.1%	Single with children	6.7%
Living in a private student residence	13.8%		
Other	57.8%	**Household income per month**	
Student job during the academic year		Less than 2,000 euros	15.6%
None	76.1%	[2,000 , 3,000[euros	18.6%
Weekends only	6.7%	[3,000 , 4,000[euros	19.0%
Weekdays or weekdays + weekends	17.2%	[4,000 , 6,000[euros	26.4%
		6,000 euros and above	11.1%
Type of institutions		**Type of institutions**	
University	72.1%	University	48.6%
"Grandes Ecoles"	27.9%	"Grandes Ecoles"	51.5%
Alternating periods between courses and work placements	13.9%		

Memberships and means of transport			
Driving license and car ownership		**Driving license and car ownership**	
No driving license	27.3%	No driving license	6.0%
Driving license and car unavailable	40.7%	Driving license and car unavailable	17.9%
Driving license and car available	32.0%	Driving license and car available	76.1%
Own a bike	16.7%	**Own a bike**	28.6%
Bike sharing membership	23.7%	**Bike sharing membership**	11.4%
Public transport membership	60.3%	**Public transport membership**	37.2%
Practicing car-sharing	2.4%	**Practicing car-sharing**	1.9%
Practicing car-pooling	43.0%	**Practicing car-pooling**	19.6%
Usual schedules		***Usual schedules***	
Usual arrival time (campus)		**Usual arrival time (campus)**	
Before 7.30 am	4.2%	Before 7.30 am	12.2%
Between 7.30 and 8.00 am	41.6%	Between 7.30 and 8.00 am	21.4%
Between 8.00 and 8.30 am	21.5%	Between 8.00 and 8.30 am	20.5%
Between 8.30 and 9.00 am	12.0%	Between 8.30 and 9.00 am	26.6%
Between 9.00 and 9.30 am	8.1%	Between 9.00 and 9.30 am	13.7%
Between 9.30 and 10.0 am	5.7%	Between 9.30 and 10.0 am	3.2%
After 10.0 am	6.9%	After 10.0 am	2.4%
Usual departure time (campus)		**Usual departure time (campus)**	
Before 5.00 pm	11.7%	Before 5.00 pm	16.4%
Between 5.00 and 5.30 pm	19.0%	Between 5.00 and 5.30 pm	19.9%
Between 5.30 and 6.00 pm	19.9%	Between 5.30 and 6.00 pm	20.7%
Between 6.00 and 6.30 pm	21.4%	Between 6.00 and 6.30 pm	19.3%
After 6.30 pm	28.1%	After 6.30 pm	23.7%
Part B			
Home location		***Home location***	
City Center (Lyon, Villeurbanne)	69.6%	City Center (Lyon, Villeurbanne)	47.1%
Inner suburbs	12.9%	Inner suburbs	13.7%
Outer suburbs	6.1%	Outer suburbs	11.4%
Outside the agglomeration	11.4%	Outside the agglomeration	27.7%
Home-campus distance		**Home-campus distance**	
Less than 1 km	11.3%	Less than 1 km	2.9%
1 to 3 km	27.6%	1 to 3 km	12.4%
3 to 5 km	17.0%	3 to 5 km	14.2%
5 to 15 km	30.2%	5 to 15 km	38.5%
15 to 30 km	8.0%	15 to 30 km	16.6%
30 to 50 km	3.5%	30 to 50 km	8.0%
50 km and more	2.5%	50 km and more	7.4%
Indicators of accessibility			
Accessibility to self-service bicycle station (residence)	62.1%	**Accessibility to self-service bicycle station (residence)**	44.4%
Accessibility to public transport station (residence)	86.6%	**Accessibility to public transport station (residence)**	70.6%
Accessibility to train station (residence)	28.7%	**Accessibility to train station (residence)**	28.1%
Accessibility to self-service bicycle station (campus)	75.3%	**Accessibility to self-service bicycle station (campus)**	69.6%
Accessibility to public transport station (campus)	94.8%	**Accessibility to public transport station (campus)**	91.6%
Accessibility to train station (campus)	13.1%	**Accessibility to train station (campus)**	13.0%
Number of observations	9,325		3,670

Compared to the student population, the respondent population of university staff, half of whom are researchers and half of whom are administrative and technical staff, is much less likely to live in the city center (47% versus 70% for students) and much more likely to live outside the agglomeration (27.7% versus 11.4%). On average, their distance from home to work is greater: only 29.5% of them live less than 5 km from their place of work and only 44% have a self-service bicycle station within 300m of their home. On the other hand, a much higher proportion of them (76%) have a driving license and a car, and only 37% have a season ticket for public transport.

2.4 Statistical analyses and econometric specifications

Our analysis of cycling behavior in the university community of Lyon is mainly based on two questions from the MobiCampus-UdL Travel Survey on home-study/work trips, namely: i) whether the respondent usually used a single mode of transport for the same trip (*exclusive mode*) or several modes of transport consecutively (*combined mode*), and ii) if several modes of transport were used, the precise description of each mode used in turn. For combined modes, walking is only counted as a separate mode of transport if it takes more than 5 minutes.

Descriptive statistics were used to quantify the extent of cycling (by own bike or self-service bike) in our two sub-populations, students and staff, and in particular the extent of combined use with cycling. Weighting was used to ensure that the results were representative of the UdL participating institutions. For each sub-population we also estimated multivariate logistic regressions to explore and compare the determinants of cycling as an exclusive mode and cycling as a combined mode for commuting to university campuses and sites:

$$Bike_{ij} = \begin{cases} 1 & if\ B^*_{ij} = X_i\alpha + u_i > 0 \\ 0 & otherwise \end{cases}, j = \{e, c\} \quad (1)$$

where $Bike_{ie}$ is the binary variable indicating whether individual *i* uses only the bicycle for commuting (j=e); $Bike_{ic}$ is the binary variable indicating whether individual *i* uses a combination of transport modes (j=c), including the bicycle, for commuting between home and work/study; B^*_{ij} are the latent variables; X_i is the covariate vector, and u_i is a random term iid distributed by the standard logistic distribution. $Bike_{ie}$ and $Bike_{ic}$ are defined for all observations of our samples. In other words, $Bike_{ie} = 0$ for individuals who use combined commuting modes, including cycling, and $Bike_{ie} = 0$ for individuals who use only the bicycle for commuting, as we want to understand these two specific travel choices compared to all the usage options available to them.

In the model explaining the probability of using only the bicycle, the coefficients associated with the covariates are estimated by maximizing the following standard likelihood:

$$L_e(\alpha|X_i) = \prod_{i=1}^{N} \left[\frac{exp(X_i\alpha)}{1+exp(X_i\alpha)}\right]^{Bike_{ie}} . \left[1 - \frac{exp(X_i\alpha)}{1+exp(X_i\alpha)}\right]^{(1-Bike_{ie})} \quad (2)$$

For the model explaining the use of cycling in combination with other modes, the standard maximum likelihood estimators may be biased because this mode has a very low frequency in our samples (see Results section). In the presence of "rare events," the degree of bias is strongly dependent on the number of cases in the less frequent modality of the binary dependent variable under investigation (King & Zeng, 2001). Therefore, following the literature, we applied Firth's (1993) corrections for rare events in the logistic regressions (Leitgöb, 2013; Woo et al., 2022). Specifically, we used a penalized method, which consists of obtaining the $\hat{\alpha}$ coefficients by maximising the penalized log-likelihood $ln[L_c(\alpha|X_i)] - pen(\alpha)$, where $pen(\alpha)$ is the "penalty term" and $L_c(\alpha|X_i)$ has the same form as $L_e(\alpha|X_i)$ in Equation 2. To remove the first-order bias in the MLEs of the regression coefficients, Firth (1993) suggested using the penalty term $\frac{1}{2} trace[I(\alpha)^{-1}\, \delta I(\alpha)/\delta\alpha_k]$, where $I(\alpha)^{-1}$ is the inverse of the information matrix evaluated at α. The corresponding penalized log-likelihood is then written as:

$$ln[L_c(\alpha|X_i)] + \frac{1}{2}\ log|I(\alpha)|, \quad (3)$$

where the penalty term used is known as the Jeffreys invariant prior[4].

With our econometric models, we tested the relative influence of socio-economic variables (age, gender, household income, type of housing, etc.), spatial characteristics (area of residence, distance from home to campus), individual modal availability (driving license, access to a private car, bicycle ownership, possession of a public transport season ticket or bike-sharing membership, and practice of car-sharing or car-pooling), and indicators of the accessibility of train, public transport and bike-sharing stations (at home and at work/study) on cycling behavior.

3 Results

3.1 Descriptive statistics of bicycle use in the university community

Students and staff in the UdL community do not use the same means of transport to get to campus and university sites (Table 2). Among students, almost 36% use public transport (bus, tram, metro) exclusively, 23% walk exclusively and 11% combine walking and public transport. Exclusive use of bicycles comes 4th in this ranking with 9%. Among university staff, exclusive use of a private car as a driver is the most common (36% of respondents), followed by exclusive use of public transport (19%) and, in third place, exclusive use of a bicycle (12.5%). Our results are in line with the modal shares observed for the student population in French cities of more than 300,000 inhabitants (excluding the Paris region), based on the *Living Conditions of Students 2020 Survey*[5].

Table 2. Ranking of the top 5 modes or combinations of modes used by students and staff to get to campus

	Students			Staff	
Rank		***Freq.***	***Rank***		***Freq.***
1	Exclusive use of public transport	35.6%	1	Exclusive use of a private car as driver	35.7%
2	Exclusive Walking	22.8%	2	Exclusive use of public transport	18.9%
3	Combined use of walking and public transport	10.9%	3	Exclusive use of bicycle	12.4%
4	Exclusive use of bicycle	9.0%	4	Exclusive Walking	6.9%
5	Exclusive use of a private car as driver	8.0%	5	Combined use of walking and public transport	6.8%

Focusing on cycling behavior, Figure 2 shows that almost 11% of students and 15.5% of employees use a bicycle to travel to study/work. In our two sub-samples, this use of the bicycle is overwhelmingly exclusive and not combined with one or more other modes. When it comes to exclusive cycling, members of the university community use their own bike more than they use the shared bike network (70% versus 30% for students and even 90% versus 10% for staff). Among commute cyclists, combined use is much

[4] The McFadden R^2 for the Firth's logit models are computed with the Stata module of Staudt (2020).
[5] https://www.ove-national.education.fr/wp-content/uploads/2022/11/Fiche-CDV2020-Transports-et-deplacements.pdf

more common among staff than among students. What's more, when it comes to combined cycling, over 95% of students use shared bikes, while staff are almost evenly split between private and shared use. Cases where cyclists use both a private bike and a shared bike for the same trip do exist, but are very rare (Figure 2). The few employees in this situation usually start their journey with their own bike, then take public transport or the train and finish with a bike from the Vélo'v network (Figure A in the appendix). For students, there is more of a chronological sequence between private and shared bikes before ending up with public transport (Figure A in the appendix). The fact of changing the type of bike could be linked to fears of theft or problems of parking private bikes near public transport stations.

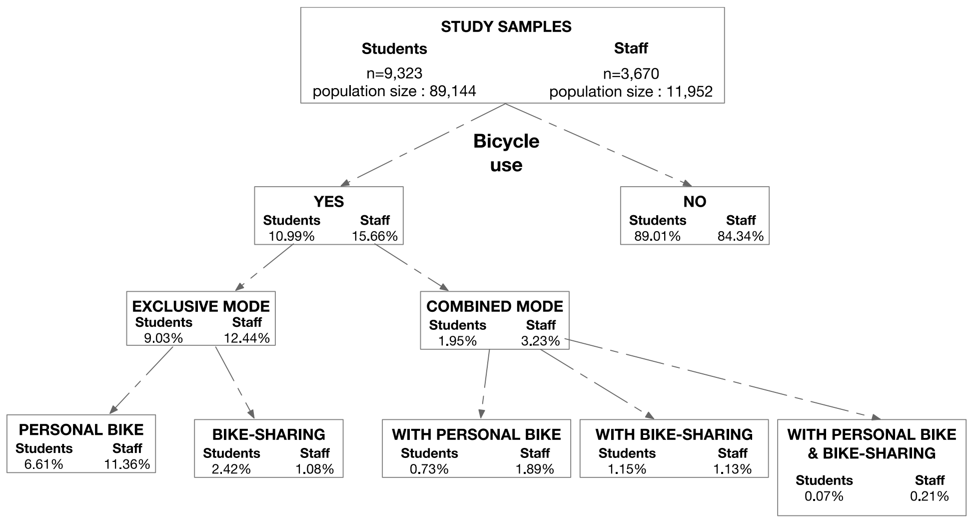

Figure 2. Use of bicycle to travel from home to campus

Figure 3 shows the order of the modes used to travel to campus in combination with cycling, distinguishing between those using their own bike (Figure 3a) and those using a shared bike. For combinations involving the use of a private bicycle (Figure 3a), the bicycle is often used as the first mode of transport when leaving home. For the student population the private bicycle is mainly used as a connecting pre-mode to public transport (bus, tram, metro), but it is very rarely used at the end of the trip. In the case of employees, the private bicycle is used much more frequently both at the beginning and at the end of the trip, with a significant proportion using the train in the middle. Only employees combine private car and private bicycle for their home/work commute.

An analysis of the combinations that include the use of a shared bike (Figure 3b) shows that this mode is also often a connecting pre-mode to public transport for the student population. However, for a number of students it is not the first mode used: to use it they have to go to a Vélo'v station that is more than 5 minutes away on foot. In addition, there is a third profile of student cyclists: those who use a shared bike at the end of their journey to complement their initial use of public transport. For students and staff, the shared bike is almost never used at the beginning and end of the same trip. UdL staff are again more likely to use the train and combine it with the shared bike, even if it means using the car to get to the train station.

Figure 3. Chronological order of combined modes of transport a) for people who used their own bike and b) for people who used a shared bike (each row represents the travel order of an individual)

3.2 Determinants of the exclusive and combined use of bicycle

Tables 3 and 4 present the estimation results of the logistic regressions exploring the determinants of cycling as an exclusive and combined mode of commuting in the student and staff populations, respectively.

3.2.1 Differences in socio-economic determinants between exclusive and combined cycling

In our two sub-samples of the Lyon university community - which are relatively homogeneous compared to studies of the general population - not only few socio-economic characteristics are statistically significant, but also varying effects of such variables on exclusive and combined cycling are estimated. For example, among students, living with parents or in university halls of residence is associated with less exclusive cycling than living in private rented accommodation, but this housing factor is not significant for combined cycling. Conversely, having a student job on weekdays during the academic year increases the likelihood of combined cycling, but not that of exclusive cycling.

Among the staff population, no socio-economic characteristic seems to reduce or increase exclusive cycling. On the other hand, men and employees who telework regularly are more likely to use the bicycle in combination with other modes of transport to get to work, while single people and couples without children are less likely to do so than people with children (in couples or single). This suggests that the presence of children in the household may encourage combined cycling. However, the international literature suggests that in countries with low levels of cycling (such as France), the presence of (young) children reduces the likelihood of cycling, often in favor of car commuting (Harms et al., 2014; Ryley, 2006). This discrepancy is probably due to the fact that our sample is made up of staff from the university community, who may be more environmentally aware than the general population (Balsas, 2003; Van den Berg & Russo, 2017), and the effect of having children on cycling may be reversed beyond a certain level of environmental awareness, with a strong consideration of the impact on future generations.

In our study, as in the literature, there is no consensus on the influence of a number of socio-demographic characteristics (e.g., gender, age, household income, presence of children) on bicycle use. For example, our results are partially consistent with the study by Barberan et al. (2017), which suggests that younger people who study and work simultaneously are more likely to use a bicycle for their daily commute, while gender was not significant. Studies prior to ours had already shown that cycling was not related to income, while others found a significant effect (positive or negative) (Heinen et al., 2010). However, our study may suggest that the impacts of the socio-economic factors on cycling as a whole is all the more complex to capture, as some characteristics play a different role in the exclusive versus combined cycling.

3.2.2 Place of residence, a stronger determinant of staff cycling behavior than for students

For our two sub-populations of the university community, the residential location is not a significant factor in the choice of combined cycling. In other words, all other things being equal, people who live outside the Lyon agglomeration, in the inner suburbs or in the city center are just as likely to combine cycling with another mode of transport to get to the UdL campuses. Conversely, the place of residence has a strong influence on the use of the bicycle as an exclusive mode of transport. On the basis of the marginal effects calculated using logistic regressions, we estimate that university employees living outside the Lyon agglomeration are 12.7 percentage points less likely to use the bicycle as their exclusive mode of transport than their counterparts living in the city center. Similarly, living in the outer and inner suburbs reduces this probability by 8.9 and 5.4 percentage points respectively.

Table 3. Estimation results from the logistic regressions on the bicycle use for the student population

	Cycling as an exclusive mode		Cycling as a combined mode	
	Coef.	P>z	Coef.	P>z
Socio-economic factors				
Gender				
Male	0.179	0.162	0.137	0.509
Age				
18 to19 years old	Ref.	Ref.	Ref.	Ref.
20 to 21 years old	-0.289	0.167	-0.409	0.194
22 to 24 years old	-0.135	0.530	-0.342	0.294
25 years and over	-0.130	0.621	-0.348	0.387
Scholarship student	-0.162	0.283	0.238	0.318
Dwelling type				
Living at the parents' home	-0.844	0.001	-0.297	0.385
Living in a public student residence (Crous)	-0.793	0.022	0.538	0.232
Living in a private student residence	-1.784	<0.001	0.116	0.761
Other	Ref.	Ref.	Ref.	Ref.
Student job during the academic year				
None	Ref.	Ref.	Ref.	Ref.
Weekends only	0.023	0.929	0.533	0.125
Weekdays or weekdays + weekends	-0.220	0.179	0.577	0.015
Type of institutions				
University	-0.093	0.524	-0.026	0.911
"Grandes Ecoles"	Ref.	Ref.	Ref.	Ref.
Alternating periods between courses and work placements	0.107	0.594	0.496	0.081
Usual number of days on campus	-0.031	0.634	-0.081	0.420
Home location				
City Center (Lyon, Villeurbanne)	Ref.	Ref.	Ref.	Ref.
Inner suburbs	0.081	0.784	-0.433	0.369
Outer suburbs	-0.291	0.504	-0.754	0.251
Outside the agglomeration	-1.608	0.020	-0.914	0.283
Home-campus distance (log)	0.326	<0.001	0.337	0.009
Memberships and available means of transport				
Driving license and car ownership				
No driving license	Ref.	Ref.	Ref.	Ref.
Driving license but no car available	0.227	0.373	-0.267	0.428
Driving license and car available	-0.460	0.091	-0.201	0.568
Own a bike	3.489	<0.001	1.452	<0.001
Bike sharing membership	1.459	<0.001	1.505	<0.001
Public transport membership	-2.555	<0.001	0.413	0.086
Practicing car-sharing	-0.895	0.021	0.177	0.707
Practicing car-pooling	0.173	0.180	-0.254	0.228
Indicators of accessibility				
Accessibility to self-service bicycle station (residence)	0.494	0.030	-0.263	0.394
Accessibility to public transport station (residence)	-0.013	0.980	-0.503	0.466
Accessibility to self-service bicycle station (campus)	1.678	<0.001	0.024	0.930
Accessibility to public transport station (campus)	-0.411	0.318	-0.581	0.198

Table 3 (continued)	Cycling as an exclusive mode		Cycling as a combined mode	
	Coef.	P>z	Coef.	P>z
Usual arrival time (campus)				
Before 7.30 am	Ref.	Ref.	Ref.	Ref.
Between 7.30 and 8.00 am	0.534	0.329	-0.534	0.312
Between 8.00 and 8.30 am	0.585	0.293	-0.505	0.368
Between 8.30 and 9.00 am	0.589	0.298	0.009	0.868
Between 9.00 and 9.30 am	0.391	0.504	0.032	0.957
Between 9.30 and 10.0 am	0.470	0.426	-0.196	0.751
After 10.0 am	1.018	0.091	-0.959	0.198
Usual departure time (campus)				
Before 5.00 pm	Ref.	Ref.	Ref.	Ref.
Between 5.00 and 5.30 pm	-0.239	0.388	0.548	0.323
Between 5.30 and 6.00 pm	-0.055	0.833	1.086	0.036
Between 6.00 and 6.30 pm	-0.043	0.867	1.207	0.020
After 6.30 pm	0.243	0.357	0.936	0.076
Intercept	-4.842	<0.001	-4.231	0.001
Number of observations	6,124		6,124	
Log-likelihood	-921.9		-409.12	
Mc Fadden R^2	0.5352		0.3960	

Among the student population, only young people living outside the agglomeration are less likely to use the bicycle as their exclusive means of transport (-5.7 percentage points). Living in the suburbs rather than in the city center does not seem to penalize cycling by students, contrary to the results obtained for employees.

All other things being equal, and particularly for a given type of place of residence (city center, inner and outer suburbs, outside the agglomeration), the distance between home and work/study turns out to be an important factor for cycling: the greater the distance, the greater the likelihood of using a bicycle, whether exclusively or combined for students and only combined for UdL staff.

3.2.3 Cycling combined with other modes is not significantly increased by proximity to a bike share station

Another spatial factor, the accessibility of a self-service bicycle station has a strong influence on the use of bicycles for commuting. What’s even more surprising, however, is that this is only the case for exclusive use of the bicycle. More specifically, holding other characteristics constant, having a bike-share station in less than 300 meters away from one’s usual campus increases the individual probability of using the bicycle exclusively by 7.4 percentage points for students and 5.4 percentage points for staff. This result is consistent with the literature, which has shown that accessibility to destinations is highly relevant for the use of alternatives to the car, whether public transport or active modes (Bouzouina et al., 2020). The proximity of bike-share station to the place of residence (origin accessibility) has a weaker effect: it increases the probability of exclusive use of the bicycle by only 2.2 percentage points for students and is not significant for staff. In contrast, the likelihood of cycling in combination with other modes is not increased by the proximity of a bike-share station to the place of residence or work/study. However, between 35% (among students) and 59% (among staff) of cyclists who combine cycling with another mode do so using a Vélo’v. Similarly, accessibility to a public transport station does not influence cycling, although public transport is often combined with cycling (Figure 3), especially among students.

Table 4. Estimation results from the logistic regressions on the bicycle use for the staff population

	Cycling as an exclusive mode		Cycling as a combined mode	
	Coef.	P>z	Coef.	P>z
Socio-economic factors				
Gender				
Male	0.211	0.266	0.770	0.006
Age				
under 35 years old	Ref.	Ref.	Ref.	Ref.
35 to 44 years old	-0.262	0.357	0.230	0.533
45 to 54 years old	-0.281	0.352	-0.554	0.198
55 years old and over	-0.448	0.221	0.575	0.223
Marital status				
Couple with children	Ref.	Ref.	Ref.	Ref.
Couple without children	-0.184	0.483	-1.155	0.003
Single	-0.412	0.231	-1.024	0.025
Single with children	-1.027	0.057	-0.405	0.543
Household income per month				
Less than 2,000 euros	0.247	0.650	1.030	0.146
[2,000 , 3,000[euros	0.380	0.416	0.408	0.513
[3,000 , 4,000[euros	0.164	0.710	0.259	0.666
[4,000 , 6,000[euros	0.687	0.095	-0.330	0.575
6,000 euros and above	0.064	0.888	0.219	0.731
Profession				
Lecturer- Researcher	0.020	0.935	0.421	0.218
Administrative staff	Ref.	Ref.	Ref.	Ref.
Type of institutions				
University	-0.210	0.280	0.093	0.721
"Grandes Ecoles"	Ref.	Ref.	Ref.	Ref.
Usual number of days on campus	-0.076	0.542	0.288	0.082
Teleworking				
Yes, sometimes	-0.049	0.842	0.359	0.285
Yes, regularly	0.229	0.461	1.180	0.002
No	Ref.	Ref.	Ref.	Ref.
Home location				
City Center (Lyon, Villeurbanne)	Ref.	Ref.	Ref.	Ref.
Inner suburbs	-0.921	0.009	0.545	0.302
Outer suburbs	-1.640	0.001	0.950	0.117
Outside the agglomeration	-2.624	<0.001	1.130	0.162
Home-campus distance (log)	-0.107	0.401	0.640	0.001
Memberships and means of transport				
Driving licence and car ownership				
Yes	-0.289	0.239	-0.413	0.194
No	Ref.	Ref.	Ref.	Ref.
Own a bike	4.107	<0.001	1.946	<0.001
Bike sharing membership	0.792	0.002	2.356	<0.001
Public transport membership	-3.047	<0.001	0.818	0.003
Practicing car-sharing	0.541	0.290	-0.322	0.616
Practicing car-pooling	0.284	0.216	0.643	0.022
Indicators of accessibility				
Accessibility to self-service bicycle station (residence)	-0.028	0.929	0.374	0.370
Accessibility to public transport station (residence)	0.042	0.923	0.074	0.899
Accessibility to train station (residence)	0.272	0.192	-0.489	0.127
Accessibility to self-service bicycle station (campus)	1.064	<0.001	0.020	0.956
Accessibility to public transport station (campus)	0.230	0.696	-0.359	0.584
Accessibility to train station (campus)	0.179	0.637	0.193	0.697

Table 4 (continued)	Cycling as an exclusive mode		Cycling as a combined mode	
	Coef.	P>z	Coef.	P>z
Usual arrival time (campus)				
Before 7.30 am	Ref.	Ref.	Ref.	Ref.
Between 7.30 and 8.00 am	0.530	0.199	0.157	0.738
Between 8.00 and 8.30 am	0.195	0.645	0.141	0.768
Between 8.30 and 9.00 am	0.675	0.102	0.052	0.911
Between 9.00 and 9.30 am	0.782	0.079	-0.118	0.821
Between 9.30 and 10.0 am	0.042	0.955	0.312	0.679
After 10.0 am	0.464	0.563	0.565	0.592
Usual departure time (campus)				
Before 5.00 pm	Ref.	Ref.	Ref.	Ref.
Between 5.00 and 5.30 pm	-0.643	0.086	0.370	0.430
Between 5.30 and 6.00 pm	-0.356	0.343	0.856	0.064
Between 6.00 and 6.30 pm	0.115	0.762	0.169	0.733
After 6.30 pm	-0.347	0.359	0.571	0.254
Intercept	-4.087	0.001	-9.567	<0.001
Number of observations	2,501		2,501	
Log-likelihood	-410.8		-203.4	
Mc Fadden R^2	0.5797		0.158	

Residential location (in the city center, in the suburbs, or outside the agglomeration) therefore seems to be a more important factor in the decision in choosing to cycle exclusively than accessibility to different modes of transport, although the two are correlated. These spatial factors are not relevant for the choice of combined cycling. They may play a greater role in the modes used once the decision to combine has been taken.

3.2.4 Important contribution of bike ownership and bike sharing membership in explaining bike commuting

Our results show that all types of access to a bicycle are logically positively related to bicycle use, which is consistent with previous studies (Dill & Voros, 2007; Munoz Lopez, 2016). Indeed, bike ownership and bike-sharing membership are the most important contributors to explaining bicycle commuting in the university community. Figure 4 shows the average marginal effects associated with these determinants of exclusive and combined cycling to work/study. Regardless of the sub-population studied, owning a bicycle is associated with a stronger effect on the likelihood of exclusive cycling than being a member of the Vélo'v shared bike network (+15.3 pp vs +6.4 pp for students; +20.7 pp vs + 4.0 pp for staff). On the other hand, these two factors have a statistically similar effect on the likelihood of using the bicycle in combined mode (+2.8 pp for students; +6.5 pp for staff). Consequently, policies that encourage personal purchase of a bicycle would be more likely to increase exclusive use of the bicycle for commuting, while policies that encourage membership of a bike-sharing service would increase combined cycling as much as exclusive cycling.

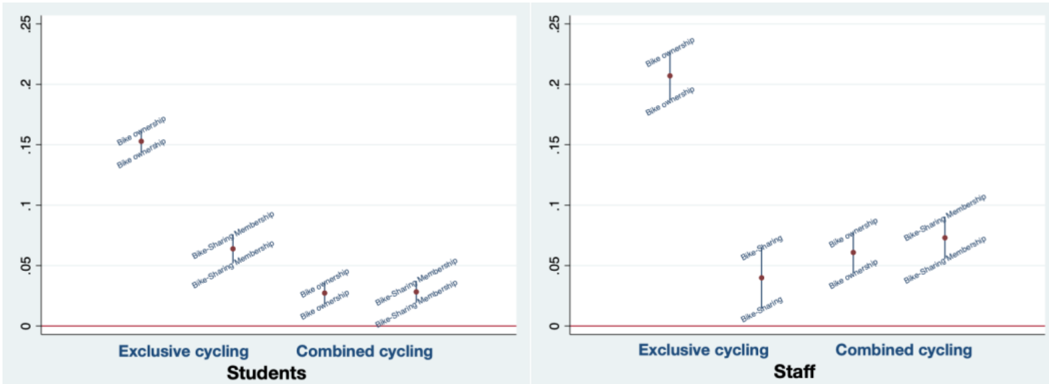

Figure 4. Average marginal effects with 95% CI's (with respect to bike ownership and bike sharing membership)

A more surprising result is that car ownership appears to neither encourage nor discourage students and university staff from cycling to work/study. In fact, previous studies have shown that higher levels of motorization, and in particular access to a car, are negatively related to bicycle choice (Barberan et al., 2017; Parkin et al., 2007). However, they referred to study populations that are likely to be less environmentally aware than our university community and to older study periods (UK in 2001 for Parkin et al. (2007) and Spain in 2012-2014 for Barberan et al. (2017)) where fuel prices were much lower, and therefore the opportunity costs of transport mode choice were different. Our findings suggest that within the UdL community, considering using a bicycle for daily journeys is becoming independent of car ownership. In other words, there would be an obvious opportunity for bicycles to replace cars for some trips among car owners, especially for commuting. Moreover, in the case of individual modal shifts, switching from car to bike most often starts with the purposes of travelling to and from work and school, before extending to other purposes. Thus, the decision to commute by car or bicycle would be determined more by spatial variables (e.g., place of residence, distance) than by the fact of owning a car per se.

Conversely, owning a public transport season ticket is associated with a lower probability of exclusively using a bicycle to get to work or study among the UdL community (-11pp for students; -15 pp for staff). This result confirms the intuition that the exclusive use of the bicycle and the exclusive use of public transport are two substitutable modes of transport. However, the possession of a public transport season ticket is also associated with a higher probability of combined cycling among university staff. Therefore, cycling and public transport may also be two complementary modes for individuals who choose to combine modes. This phenomenon of complementarity between cycling and public transport is not observed among the student population. This is undoubtedly due to the fact that the preferential public transport fares they benefit from, combined with their limited financial resources and their low level of personal bicycle ownership (Table 1), encourage them to use public transport exclusively, which is cheaper than combining it with a subscription to the Vélo'v bike sharing network.

Among university staff, another factor that is positively correlated with combined cycling is a subscription to a car-pooling platform. Its impact, measured by the average marginal effect, is almost as large as that of a subscription to public transport (+2 pp for car-pooling and +2.5 pp for public transport membership on the probability of combined cycling).

Overall, our results suggest that the development of cycling in the university community obviously requires policies that encourage access to private bicycle and to the network of shared bicycles. However, other levers can also be used to promote cycling by encouraging its use in combination with other modes of transport rather than only encouraging its exclusive use. In order to increase the combined use of cycling, all measures that improve the articulation between cycling and public transport, as well as between cycling and car-pooling, could be relevant. As car ownership no longer appears to be a barrier to cycling to work or study, the potential for modal shift from car to bike seems increasingly feasible with such measures.

4 Conclusions

As a clean and active mode of transport, cycling is increasingly included in national strategies which target the reduction of CO2 emissions, local air pollution, oil dependency, congestion on roads and public transport at peak times, and to improve public health. Understanding the factors that influence bicycle use is necessary to implement efficient pro-bike transport policies, i.e., to promote cycling with the most effective and least costly measures. This is why our study aims to identify the main factors affecting the bicycle choice for commuting by the members of the university community in the Lyon metropolitan area.

Beyond the MobiCampus-UdL survey as such, the first original feature of our study is to propose a quantitative analysis of the determinants of commuter cycling based on French data. Until now, the most common approach to this question in the French context has been qualitative, probably because of the low level of cycling in France (around 5% for daily trips). The second original feature is that our study focuses on all commuter cycling practices, regardless of whether they take place on all or part of the home-work or home-study trip. In this way, we can take better account of the heterogeneity of realities and profiles of cycling, in particular between the use of the bicycle as the sole mode of transport for commuting and the use of bicycle in combination with other modes. We therefore estimate separate econometric models to explain not only exclusive cycling, but also combined cycling. They include socio-economic variables, spatial characteristics (area of residence, distance from home to campus), individual modal availability (access to a private car, bicycle ownership, public transport season ticket membership) and accessibility indicators of the different modes of transport. The third original feature of our study is that we measure this accessibility both at the origin and destination of commuting trips, i.e., for the place of residence and for the campus where our respondents work or study. Many studies on cycling have only focused on accessibility at the destination.

The present study shows, firstly, that students and university staff use of bicycles to get to their campus at a relatively high rate (11% and 15.5% respectively) compared to the average level of cycling for daily trips in the French population, confirming that cycling is most popular among the youngest age group and in managerial and intellectual occupations (Hu & Schneider, 2015; Rybarczyk & Gallagher, 2014). This use is all the more important given that the rate of personal bicycle ownership is low in both populations (17% and 29% respectively), as is the bike-sharing membership rate (24% and 11%, respectively). In this sense, the policies of the Cycling and Walking Plan 2023-2027 aimed at making bicycles available or subsidizing their purchase are highly relevant to encouraging bicycle use.

Although exclusive use of the bicycle is the dominant mode, due to the possibility of making door-to-door journeys, the combination of cycling with other modes is significant (2% of journeys among students and 3% among staff), putting into perspective the hypothesis of strict substitutability between this mode and other alternative modes, particularly public transport. Our study shows significant differences between the determinants of the two types of cycling. Thus, the exclusive and combined cycling behaviors should be treated separately in policy making as otherwise desired policy objectives may not be achieved. Analyses of the differences in bicycle use should therefore go beyond the simple dichotomy between commuter and leisure cyclists. For example, among commuter-cyclists, those who use the bicycle exclusively for work or study trips and those who combine this mode with another do not require exactly the same bicycle facilities: the former mainly use a personal bicycle, while the latter mainly use the shared bicycle network.

Differences and similarities in the impact of spatial factors and accessibility can be highlighted. Access to a shared bike station on campus encourages exclusive use of the bicycle by students and staff, but has no effect on combination with others modes. On the other hand, good accessibility to public transport, whether at home or on campus, does not prevent either sub-population from using the bicycle, either exclusively or in combination. This again puts into perspective the hypothesis of concurrence between the two modes. Furthermore, while the place of residence is an obstacle to the exclusive use of bicycle, especially for staff, it does not at any way prevent its use in combination with other modes such as the train. In the context of discussions on the implementation of metropolitan regional express services in France, with the development of a metropolitan RER network in ten major cities over the next ten years, these results open up avenues for anticipating the development of intermodality between public transport and cycling.

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Data availability

The data that support the findings of this study are not publicly available as they are part of an ongoing project. They are, however, available from the authors upon reasonable request.

Appendix

Appendix available as a supplemental file at https://doi.org/10.5198/jtlu.2024.2450.

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