Carsharing use by college students: The case of Milan and Rome

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ABSTRACT

The paper analyses carsharing (CS) use by college students in the Italian cities of Rome and Milan. We use an adapted stated preference approach to study CS preferences by collecting information on the individual mobility patterns and by distinguishing between commuting and non-commuting trips. We develop six hypothetical scenarios to explore how mobility decision would change when varying the characteristics of the current CS supply. We estimate a random parameter discrete choice model to evaluate CS preferences and simulated CS demand. The main finding is that college students use CS on an occasional basis and vary rarely their habitual transport choice. The students prefer the free-floating CS type over the station-based or roundtrip one. Lower fares and a higher CS supply of preferably electric cars would increase the number of CS student users from the current 2% to up to 10–15%. CS substitutes mainly the private car and, to a lesser extent, public transport.

1. Introduction

In the last four years, Italian cities have experienced a large increase in carsharing (CS) service supply. In Italy, CS is offered by two types of organization: state-sponsored companies and private companies. The former offer either a roundtrip or a station-based service,[1] and some of them are supported by the Car Sharing Initiative (ICS, Iniziativa Car Sharing), promoted and financed by the Ministry of the Environment (Ministero dell'Ambiente e del Territorio, 2018). According to Istat (2016), in 2014 roundtrip or station-based CS was offered in 23 medium-large Italian cities. In the years 2011–2014, the number of available vehicles increased from 656

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[1] In the paper we distinguish three main CS types: roundtrip, station-based and free-floating. Peer-to-peer CS is not discussed. In roundtrip CS, users begin and end their trip at the same location. Station-based and free-floating CS allow users one-way trips: they might begin and end their trips at different locations. In station-based CS, member must leave the car at designated parking locations, whereas with free floating CS users can pick up and drop off the car anywhere within a pre-specified area of the city, saving time and avoiding unnecessary trips. From the point of view of the user, free-floating grants the highest flexibility. From the point of view of the CS company, roundtrip and station-based CS are stationary in nature and easier to manage: since the cars are left in fixed stations, the CS company can easily track the cars. Moreover, if the fleet consists of electric cars, they can also easily be recharged at the parking stations. Because of the similarities between roundtrip and station-based CS, they tend to be associated and confused. Free-floating CS, instead, requires the use of tracking systems and recharging the cars, if electric vehicles are used, is more complex. Although stationary CS is reliable and simple, it can also be more expensive to operate. Parking lots, building infrastructure and location management staff might generate high overhead costs. Roundtrip CS is the oldest type of CS organization and is offered, e.g., in medium-size Italian cities and was offered in Rome up to the year 2017 by Carsharing Rome (https://romamobilita.it/it/carsharing/oneway). Station-based CS is offered in Rome by Carsharing Rome and in Milan by E-Vai and Ubeeqo. Free-floating is offered in many cities, including Rome and Milan, by Car2go, Enjoy and Share'ngo.

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to 915 and the number of stations increased from 435 to 521. The real game changer was the market entry of the private companies supplying free-floating systems.[2] It is estimated that, in total, by the end of 2017 7,679 CS cars were in service, managed by 29 CS companies (Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2018).

Notwithstanding the recent growth, many areas of uncertainty exist and deserve more research. An important one regards the CS demand. The CS market is still in its initial phase. The suppliers are adjusting their business models in an effort to control costs and make a profit. The users have yet to adapt their transport mode choices. It is unclear whether CS is used merely on occasional basis or if it is to some extent a habitual transport mode choice. The preference structure of CS demand is unknown. The CS providers need to know the preferences of the current and potential demand in order to better meet the customers' needs and to increase their market share. Furthermore, in the Italian context, the substitution between CS and other transport modes remains, by and large, unexplored. This information is crucial not only for evaluating the impact of CS on social and environmental efficiency, but also for understanding the distributional impacts on other transport suppliers, and consequently, the acceptability of CS.

In this paper these topics are analyzed with respect to college students attending the Universities of Milan and Rome. The research is specifically focused on college students because they represent an important current and potential segment of the CS market. A research conducted in 2016 involving 37 Italian universities and 70.000 individuals estimates that 11% of the university students interviewed use a free-floating CS service, while 4% use a station-based CS service.[3] Lodigiani (2017) reports that in Milan 27% of CS members are college students and they use the service more frequently than the other market segments. A recent study carried out in Rome by the local administration reports that 90% of college students have a driver license but only 35% have a private vehicle and represent a promising and large potential segment for the CS providers[4]. Moreover, it is well known that young generations are more sensitive to environmental issues and green products, and find it easier to accept technological changes, as found by Yu et al. (2016). Younger people have limited disposable income and find advantageous to use CS, since it allows them to avoid the fixed costs of owing a private car and the fees to be paid when travelling downtown (parking and congestion charges). Finally, as suggested by Martin and Shaheen (2011b), college students have a highly dynamic life, characterized by frequent moving, changes in roommates, employment, course schedules, and vehicles. Often, they live in different cities and houses during different times of the year. Their travel pattern can be very different from one year to the next. Consequently, it is advisable to study their mobility needs in a separate and segment-specific study.

CS providers are aware of the importance of serving this particular market segment. In fact, they have launched pilot projects with many Italian Universities who, in an effort to attract more students, strongly support and partly finance the CS services inside their campuses. Universities frequently join CS schemes[5] with the aim of offering additional services to students, faculty, and staff, promoting an environmentally-conscious image of their institution and decreasing on-campus parking demand (Zheng et al., 2009). These initiatives prove that, as reported by Millard-Ball et al. (2005) and, more recently, by Shaheen et al. (2009), CS providers deem important to enter university markets since these allow them to gain a foothold into new local urban markets.

The choice of focusing on Milan and Rome is based on their importance within the Italian context[6] and on the size of their student population, equal to 175 and 188 thousand students, respectively (Istat, 2016). Currently, in Rome CS is offered by 4 CS companies (Car2go, Enjoy, Share'ngo, Carsharing Roma), all providing a free-floating service except for Carsharing Roma, who offers a roundtrip and station-based service, for a total of 2,188 cars, 534 of which are electric-powered. In Milan, there are 6 companies: Car2go, DriveNow,[7] Enjoy, and Share'ngo, offering a free-floating CS, and E-Vai and Ubeeqo offering station-based CS; in total, 3,290 cars are available, 788 of which are electric-powered. The two cities substantially differ in terms of transport accessibility. Commuting time takes longer in Rome (33 min) than in Milan (28 min). Milan offers a much larger supply of public transport services than Rome, 14.3 vs. 8.1 seat-km per 10^3 inhabitants, respectively, and it has a larger public transport modal share (37% vs. 27%). The implications for the CS use are unclear. On the one hand, higher public transport availability allows one to give up the private car and rely on CS for trip destinations that cannot be reached conveniently by public transport; on the other hand, it reduces the potential need for CS.

The paper aims at contributing to the existing literature assessing: a) how many students take advantage of the existing CS service,

[2] Car2Go started in Milan in August 2013. The innovation was surprisingly successful. Within a few months, 60,000 members enrolled. In 2014, Car2Go introduced the same service in Rome and in Florence. Other companies followed suit. Enjoy, a joint company by Fiat, Trenitalia and Eni, started a free-floating CS service in Milan, Rome, Florence, and Rimini. Twist by Volkswagen offered a competing service in Milan. In Turin CS services are offered by Car2Go, Enjoy and by Bollorè's Blue Turin with electric cars. In the last year, Share'ngo, an Italian newcomer, started a similar electric CS service in Milan, Rome, and Florence.

[3] https://www.unimib.it/node/9498.

[4] https://romamobilita.it/sites/default/files/studi%20ed%20indagini/status/01_introduzione.pdf.

[5] The University of Milan subsidises the students with 50% of the subscription fees of all the CS services provided in the city. Recent examples of partnership between Italian Universities and CS providers are: the "Aygo fun service" programme at the Politecnico of Milan, consisting of 8 Toyota Aygo cars to be shared by the university community and to be managed by 4 students; the "Andale" programme at the University Cattolica of Milan, granting students 150 min of free CS service; the "FIAT likes you" programme with the University LUISS Guido Carli in Rome (and other 9 Italian Universities), providing a fleet of 5 vehicles to be shared among students; the "e-go Car Sharing" programme by Enel, supplying the University Roma Tre (Rome) with a fleet of 33 electric vehicles and 30 electric charge stations.

[6] According to ANIASA, comprising 95% of the companies offering CS services in Italy, in 2015 CS members in Milan were 320,000, increasing up to 550,000 in 2016. Also in Rome the CS members' growth was substantial increasing from 220,000 in 2015 to 350,000 in 2016. CS providers are well aware of the current and prospective relevance of both cities as testified by the significant increase of the vehicles used to serve Milan, growing from 1,900 in 2015 to 2,900 in 2016, and Rome, increasing from 1,200 to 1,600 within the same time horizon.

[7] Car2go and DriveNow announced their merging in March 2018.

how their preferences are structured and which role CS plays in satisfying their mobility needs; b) what are the students' preferences for CS services; c) which transport modes are substituted by CS.

The paper is structured as follows. Section 2 presents the existing evidence on CS use and reviews the existing literature on the characteristic of the CS users, paying special attention to college students. The literature analysing whether CS is a substitute or a complement of other transport modes is also reviewed. Section 3 presents the research methodology, the questionnaire and the case study. Section 4 presents and discusses the results. Section 5 summarises and concludes, illustrating further research needs.

2. Literature review

CS is rapidly growing worldwide. According to Shaheen et al. (2018) in 2016 the compound annual member growth rate was 76%, the fleet growth rate was 23%, while the member-vehicle ratio was 95.6. Relative to the year 2014, in 2016 the world free-floating market share increased by 76% in membership and by 11.5% in the number of available vehicles. On the contrary, the roundtrip car sharing market share decreased by 16.2% in membership and by 3.6% decrease in the number of available vehicles.

In Italy, official data on CS use and supply are provided by the National Institute of Statistics (ISTAT, https://www.istat.it/it/archivio/188348). In 2014, station-based CS was offered in 23 large and medium-sized cities with a total of 915 vehicles, 222 of which were electric. The registered users amounted to 28,713 people (ISTAT, 2016, Mobilità urbana, Tables 26.1 and 26.2[8]).

Free-floating CS data are reported in Table 1. Although in 2014 the service was offered in three cities only, the available vehicles and the registered members were 3,354 and 382,284, respectively. Milan is the leading city, with 19% of the population registered as CS members and 1.32 vehicles per 1,000 inhabitants (ISTAT, 2016, Mobilità urbana, Tables 27.1 and 27.2).

However, there is a lack of information at the micro level with regards to the socio-economic characteristics of the CS users. Initial evidence, based on small ad hoc surveys, is reported and discussed by Danielis et al. (2014, 2016). On the contrary, the international literature is abundant. Table 2 lists some of the contributions. It is found that CS users are generally young, have a higher education level and high income, and belong to small households. They use public transport or non-motorized transport modes, live in larger cities, have stronger environmental awareness and a good CS knowledge. Consequently, college students appear to be a very promising target group for CS use.

Some papers focus specifically on college students. Zheng et al. (2009) analyze the preferences for CS of the students, faculty and staff of the University of Wisconsin-Madison. They find that students are more likely to use CS than faculty and staff, and that the probability of joining a CS scheme positively depends on gender (if the students are female), environmental awareness and familiarity with a CS service, while it is negatively affected by private vehicle availability. Zhou (2013) studies the CS preferences of the employees of the University of California, Los Angeles (UCLA) arguing that universities represent a niche market for CS. According to his research CS users are mostly female, in their late thirties, having an income level which is lower than the average, and using public transport services more frequently than the average. Most of them do not own a car and use CS especially for personal reasons. Danielis et al. (2014, 2016) analyze the potential demand of a hypothetical CS service to be offered at the University of Trieste (Italy). They find that college students would largely benefit from the provision of a CS service, with an estimated potential CS demand equal to 31% of the students' community.

A number of papers discuss mobility management issues at the University level, with no specific focus on CS. For instance, Rotaris et al. (2014, 2015) evaluate the effectiveness and the efficiency of different parking and regulation policies aimed at reducing the environmental impact of college students' transport demand in Trieste (Italy). Dell'Olio et al. (2014) analyze the impact that parking regulation, bike-sharing and shuttle bus services could produce on transport demand at the University of Cantabria (Spain). Eboli et al. (2013) investigate the factors influencing the choice between walking and moving by a transit system at the University of Calabria (Rende, Italy).

The substitution between CS and other transport modes has been dealt with in several papers, although not exclusively focused on students' choices. This is a very relevant topic for the acceptability of CS, as Firnkorn (2012) argues. Most literature reports that CS substitutes private cars (Martin et al., 2010; Martin and Shaheen, 2011a) and reduces parking demand, though Stasko et al. (2013) find that car ownership of students living on campus is less affected than that of students living off campus. Finally, Burkhardt and Millard-Ball (2006) claim that many members of CS services might refrain from purchasing a car, or might even sell it after joining the scheme. The substitution between CS and public transport is discussed by Zoepf and Keith (2016) who find that the regular users of bus or train are more willing to travel farther to pick up a CS vehicle. This is interpreted as an evidence of a complementary relationship between CS and public transit, as already suggested by Douma et al. (2008) and Cervero (2009). Martin and Shaheen (2011a) argue that joining CS schemes increases overall public transit and non-motorized modal use. Efthymiou and Antoniou (2016) suggest, however, that CS compete with taxi services for social activity destinations as they share many features.

3. Methodology and sample description

The research methodology used in this paper is based on stated preferences data to analyse discrete choices. The pros and cons of such a methodology and data source are discussed at length in many papers (e.g., Louviere, 1988; Hensher and Cherchi, 2015; McFadden, 2017). The hypothetical bias is probability the most important limit of this approach which can be, at least partially, controlled combining revealed and stated preference data and carefully selecting the design of the choice experiments.

[8] https://www.istat.it/it/archivio/188348.

Table 1
Free-floating CS in Italy.

	Vehicles 2014	Members 2014	km travelled	Inhabitants 2014	% members per inhab.	Veh./1000 inhab.	km/members	km/inhab.
Milan	1,754	248,955	19,739,680	1,332,514	19%	1.32	79	15
Rome	1,200	115,130	11,866,108	2,651,040	4%	0.45	103	4
Florence	400	18,199	1,179,000	381,037	5%	1.05	65	3
Total	3,354	382,284	32,784,788	4,239,679	9%	0.79	247	8

Source: ISTAT (2016), Mobilità urbana, Tables 27.1 and 27.2.

Table 2
Socio-economic characteristics of CS users based on the literature review.

Characteristics	Literature references
Age range: 25–44 years old	Millard-Ball et al. (2005), Burkhardt and Millard-Ball (2006), Douma and Andrew (2006), Zheng et al. (2009), Loose (2010), Sioui et al. (2013), Firnkorn and Müller (2011), Habib et al. (2012), Coll et al. (2014), Le Vine et al. (2014a, 2014b), Kawgan-Kagan (2015), Kim et al. (2015), Lang (2015), Becker et al. (2017), Kim et al. (2017), Martínez et al. (2017)
Income: higher than average	Firnkorn and Müller (2011), Firnkorn (2012), Le Vine et al. (2014a, 2014b), Kawgan-Kagan (2015), Kopp et al. (2015), Lang (2015), Kim et al. (2017)
Household size: smaller than average	Millard-Ball et al. (2005), Douma and Andrew (2006), Zheng et al. (2009), Loose (2010), Habib et al. (2012), Sioui et al. (2013), Kim et al. (2015), Efthymiou and Antoniou (2016), Kim et al. (2017)
Education attainment: higher than average	Millard-Ball et al. (2005), Burkhardt and Millard-Ball (2006), Zheng et al. (2009), Loose (2010), Shaheen and Martin (2010), Firnkorn (2012), De Lorimier and El-Geneidy (2013), Coll et al. (2014), Le Vine et al. (2014a, 2014b), Kopp et al. (2015), Kawgan-Kagan (2015), Becker et al. (2017), Kim et al. (2017)
Professional status: students or self-employed	Burkhardt and Millard-Ball (2006), Douma and Andrew (2006), Zheng et al. (2009), Loose (2010), Kim et al. (2015), Lang (2015), Becker et al. (2017)
Car availability: lower that average	Burkhardt and Millard-Ball (2006), Douma and Andrew (2006), Stillwater et al. (2009), Loose (2010), Sioui et al. (2013), Zhou and Kockelman (2011), Costain et al. (2012), Habib et al. (2012), Ciari et al. (2013), Coll et al. (2014), Le Vine et al. (2014a, 2014b), Kopp et al. (2015), Martínez et al. (2017), Becker et al. (2017)
Use of public transport and non-motorized modes: more frequent than average	Douma and Andrew (2006), Loose (2010), Costain et al. (2012), Efthymiou et al. (2013), Ohta et al. (2013), Coll et al. (2014), Le Vine et al. (2014a, 2014b), Becker et al. (2017)
Use of taxi: more frequent than average	Efthymiou and Antoniou (2016)
Environmental awareness: higher than average	Burkhardt and Millard-Ball (2006), Zheng et al. (2009), Loose (2010), Costain et al. (2012), Efthymiou et al. (2013), Lang (2015), Efthymiou and Antoniou (2016)
CS knowledge: higher than average	Shaheen et al. (2006), Shaheen and Martin (2007), Clavel et al. (2009), Zheng et al. (2009), Ohta et al. (2013)

With specific reference to investigating the choice of CS as an alternative\complement to other transport modes the setup of the experiment needs to take into account that:

- the demand for CS is highly dependent on the mobility patterns which could be partly recurrent (such as work or study commuting) and partly non-recurrent;
- a person\group of people might use many modes of transport or vehicles depending on the trip distance, trip purpose, weather, physical status, and so on;
- CS systems are quite new and evolve over time: the growth rate of both network density and fleets are positive, and the market share and membership of free-floating services are increasing, while the station-based ones are decreasing.

The research methodology draws from previous research carried out by the authors (Danielis et al., 2014, 2016; Rotaris and Danielis, 2017).[9] It consists in collecting detailed data, via face-to-face interviews, on the individuals' current habitual mobility pattern and on how it would vary under alternative hypothetical scenarios.

3.1. The questionnaire

The interview consists of three parts. The first part collects data on the socio-economic characteristics of the respondent such as gender, age, income, possession of a driving license, number of family members with a driving license, number of cars owned within

[9] Previous research carried out by the authors was aimed at estimating if there is a potential role for CS also in medium to small-sized towns and in less-densely populated rural areas. The respondents were asked if and how their mobility patterns would have changed if a CS was provided. Differently from this research, however, the details about the hypothetical CS fare, access distance, vehicle's propulsion system and service type were not provided.

Table 3
Current habitual mobility pattern (Status Quo Scenario).

Current habitual weekly mobility pattern for COMMUTING (home-university) trips		
Transport mode	***N. of round trip journeys***	***Average distance per journey (km)***
Car		
Scooter		
Public transport (bus, tram and subway)		
InterCity Train		
Taxi		
Walking		
Bicycle		
Carsharing		
Current habitual weekly mobility patterns for NON-COMMUTING (recreational, shopping, etc.) trips		
Transport mode	***N. of round trip journeys***	***Average distance per journey (km)***
Car		
Scooter		
Public transport (bus, tram and subway)		
InterCity Train		
Taxi		
Walking		
Bicycle		
Carsharing		

the family, knowledge of what CS is and previous CS use.

In the second part, the respondent is asked to provide information regarding the habitual mobility pattern for weekly commuting and non-commuting trips, as illustrated in Table 3. It was explained that a habitual pattern meant systematic as opposed to occasional. The respondent is asked to report the number of round trip journeys made per week and the average distance travelled per journey. Information is requested by transport mode: private car, scooter, local public transport (bus, tram and subway), inter-city train, taxi, walking, bicycle, CS. The number of trips made with other people and the number of accompanying people is also asked, but only with respect to journeys made by private car and by CS.

In the third part of the interview the respondent is asked to describe how her/his habitual mobility pattern, both for commuting and for non-commuting trips, would change if a CS service, differing from the one currently provided, were offered. Table 3 illustrates this last part of the interview. The characteristics of the hypothetical CS service appear in the upper part of Table 4.

The respondent is asked to repeat the Stated Preference exercise six times, since each of the six scenarios proposed during this part of the interview is characterized by different hypothetical CS services.[10] The same six choice tasks have been administered to each respondent. As illustrated in Table 5, the hypothetical CS service described in each scenario is defined in terms of:

- fare, ranging from 0.20 €\min to 0.40 €\min, equivalent to a minimum of 12 €\hour and a maximum of 24 €\hour. The fare levels are based on the current Italian market values;
- access distance to be walked to get the nearest vehicle, ranging from 0.5 km to 1.5 km. The access distance is linked to the density of the CS network\vehicles[11];
- propulsion system of the vehicle, which can be electric or with internal combustion. According to Wielinski et al. (2017), the distance to be travelled has a major influence on the choice between electric and internal combustion vehicles;
- CS type, which can be roundtrip (the car has to be returned to the same CS station where it was accessed by the user), station-based (the car has to be returned to any station belonging to the CS organization), or free-floating (the car can be returned to any parking place within a given area).[12]

An efficient design was created using the Ngene software to be used in the hypothetical scenarios. Efficient designs, unlike the orthogonal ones, minimize the asymptotic variance and allow the analyst to obtain robust estimates even with small samples (Hess and Rose, 2009).

[10] The length of the interview might have generated potential fatigue effects.

[11] We opted for using distance in km instead of estimated walking time since the former is more objective. In reality, carsharing apps often provide information in terms of both distance and walking time (e.g. Sharengo).

[12] As a reviewer pointed out, free-floating and station-based are quite different services, they might require different organizational skills and most probably satisfy different needs. However, we opted for using the attribute carsharing type with three labels (round-trip, station-based, free-floating) in order to test if increasing carsharing flexibility affects its use. Recently (May 2017), Milan launched a tender for a station-based service designed for large firms, condos, and daily car rent. To our knowledge, the new service is not yet operational. In the future, it will provide an interesting case study to compare the two technologies, using different questionnaire and different samples, overcoming the limitation of our approach.

Table 4
Hypothetical mobility pattern (first out of six hypothetical scenarios).

Assume that a new CS service is available.
The per minute fare is €0.2, the average distance to be walked to get the nearest available car is 0.5 km, the engine type is electric and the vehicle has to be returned to the same location where it has been accessed.
Please state how your habitual mobility pattern would change under this hypothetical scenario.

Stated new weekly mobility pattern for COMMUTING (home-university) trips		
Transport mode	*N. of round trip journeys*	*Average distance per journey (km)*
Car		
Scooter		
Public transport (bus, tram and subway)		
InterCity Train		
Taxi		
Walking		
Bicycle		
Carsharing		
Stated new weekly mobility patterns for NON-COMMUTING (recreational, shopping, etc.) trips		
Transport mode	***N. of round trip journeys***	***Average distance per journey (km)***
Car		
Scooter		
Public transport (bus, tram and subway)		
InterCity Train		
Taxi		
Walking		
Bicycle		
Carsharing		

3.2. The sample

The survey has been carried out in Rome and Milan. In both cities considerable efforts have been made in order to promote CS use among college students. The questionnaires were administered at the Politecnico University of Milan in April 2016 and at the Roma Tre University of Rome in June 2016. The sample includes students attending the courses offered by the Departments of Engineering and by the Departments of Architecture in Milan, and the Departments of Political Science, in Rome. The number of students currently enrolled both at the Politecnico University and at the Roma Tre University is about 40 thousands. Both universities are located in central areas.[13] They are very well served by public transport (buses and underground trains) and offer limited parking space. Consequently CS, which provides users with free parking in public spaces, represents an attractive alternative to private cars, but competes with the cheaper public transport. The sample consists of 400 students (192 men and 208 women), living in Milan (257) or in Rome (143).

The majority of the students (69% of the sample) are between 18 and 23 years of age, 16% are 24 or 25 years old, the remaining 15% are older. The average monthly family income of the sample is distributed as follows: 28% less than €2,000, 42% between €2,000 and €4,000, 18% more than €4,000 and 13% missing values, with a national average family income of €2,500. A large percentage of students (58%) have a car or a scooter available for their daily use, quite a large number compared to other European cities. Yet, the sample comprises more than 40% of respondents who have a driving license, but do not have a private vehicle and, therefore, are potential users of the CS service. Both in Milan and Rome, CS users can travel and park inside the Limited Traffic Zone for free, which could induce also some of the students owing a private vehicle to, occasionally, use the CS service.

Although the large majority of the sample (85%) is familiar with the CS service, only 20% of the students interviewed in Milan and 22% of those interviewed in Rome have, at least occasionally, used it. CS users are more frequent among students not having the availability of a car, in line with the results reported in the literature described in Section 2. No significant differences in terms of CS use could be detected distinguishing by gender (contrary to the evidence reported by TCRR, 2005, and Zhou, 2013).

4. Results

4.1. Habitual mobility pattern of the sample

Based on the information collected, the current habitual weekly mobility pattern is calculated. Table 6 reports the average number of trips performed by the students within a week by transport mode, trip purpose (commuting and non-commuting) and city.

[13] More information on the campuses location and layout for Milano Città Studi at https://maps.polimi.it/maps/ and for Roma Tre University at http://scienzepolitiche.uniroma3.it/.

Table 5
Description of the hypothetical CS service proposed in each hypothetical scenario.

	Hypothetical scenarios					
	1	2	3	4	5	6
Fare: €\min	0.2	0.3	0.4	0.3	0.4	0.2
Fare: €\hour	*12*	*18*	*24*	*18*	*24*	*12*
Access distance km	0.5	0.5	1	1.5	1	1.5
Vehicle's propulsion system	Electric	Gasoline	Electric	Electric	Gasoline	Gasoline
CS type	Roundtrip	Free-floating	Station-based	Free-floating	Roundtrip	Station-based

Table 6
Weekly habitual mobility pattern: average n. of trips per week by transport mode (standard deviation in brackets).

	Car	Scooter	LPT	Train	Taxi	Walking	Bike	CS
Commuting	1.70 (3.59)	0.27 (1.48)	3.06 (5.70)	1.60 (2.26)	0.01 (0.11)	2.72 (6.10)	0.33 (1.25)	0.01 (0.13)
• Milan	1.44 (3.78)	0.17 (1.36)	3.57 (6.76)	1.89 (2.39)	0.00 (0.06)	2.98 (7.22)	0.43 (1.43)	0.02 (0.16)
• Rome	2.16 (3.17)	0.45 (1.66)	2.13 (2.75)	1.08 (1.90)	0.01 (0.17)	2.24 (3.21)	0.15 (0.78)	0.00 -
Non-commuting	2.43 (3.33)	0.25 (1.05)	1.07 (2.05)	0.25 (1.84)	0.03 (0.33)	1.85 (4.70)	0.48 (2.06)	0.05 (0.31)
• Milan	2.41 (3.77)	0.21 (0.90)	1.17 (2.24)	0.25 (2.22)	0.05 (0.41)	2.07 (5.40)	0.63 (2.43)	0.04 (0.22)
• Rome	2.45 (2.35)	0.31 (1.28)	0.88 (1.64)	0.26 (0.80)	0.01 (0.08)	1.43 (3.04)	0.22 (1.09)	0.08 (0.42)

Table 7
Students willing to use CS by scenario and trip purpose.

	Commuting (n. individuals)	Non-commuting (n. individuals)
Status quo	4	13
Scenario 1: fare 12 €\h, distance 0.5 km, electric, round-trip	28	36
Scenario 2: fare 18 €\h, distance 0.5 km, gasoline, free-floating	22	29
Scenario 3: fare 24 €\h, distance 1 km, electric, station-based	12	20
Scenario 4: fare 18 €\h, distance 1.5 km, electric, free-floating	14	29
Scenario 5: fare 24 €\h, distance 1 km, gasoline, round-trip	4	13
Scenario 6: fare 12 €\h, distance 1.5 km, gasoline, station-based	6	18

With regard to commuting trips, the prevailing transport modes are local public transport (bus, subway or tram) and walking.[14] The situation is quite different, however, in the two cities. In Milan, having a denser public transport network, the average number of trips by public transport is twice as high as that by private car. In Rome, instead, the private car use is slightly higher than that of public transport. A striking difference concerns also the use of intercity trains, being much higher in the Milan than in Rome. CS, as a habitual transport mode, is used, although marginally, only in Milan.

With regard to non-commuting trips, the private car is the most frequent transport mode both in Milan and in Rome, followed by walking and public transport. CS usage is low, although more frequent than for commuting trips (similarly to the evidence reported by Stasko et al., 2013; Ciari et al., 2013) especially in Rome.

In terms of individuals (Table 7), 4 students (all located in Milan) reported that they currently use CS at least once a week in their commuting mobility pattern, while the number increases to 13 (7 located in Milan and 6 in Rome) when the weekly non-commuting mobility pattern is considered. Under the conditions of the hypothetical scenarios proposed, they would increase up to 28 for commuting trips and 36 for non-commuting trips.

4.2. Preferences for CS service

The changes of the weekly mobility patterns stated by the respondents with respect to the hypothetical scenarios proposed in the last part of the interview allowed us to perform an econometric analysis. In order to better take into account the heterogeneity of the sample's preferences and the correlation of the repeated observations collected from each respondent, we estimated a random parameters (or mixed) logit model.[15]

[14] The average distance walked for commuting trips is km 1.4 in Milan and km 1.1 in Rome, while the average distance walked for non-commuting trips is km 1.7 in Milan and km 1.3 in Rome.

[15] The probabilities estimated via these models are the integrals of the standard logit probabilities over the density function of the parameters that have been specified in the model as being random. Indeed, the mixed logit probability is a weighted average of the logit formula evaluated at different values of the random parameter, with weights equal to the density function of the parameter. These kinds of models are also called mixed logit models since, in the statistics literature, the weighted average of several functions is called mixed function (Train, 2003).

The dependent variable of our models is a dummy variable which is equal to 1 if in the hypothetical scenario proposed the respondent states that s\he would perform at least one trip by the hypothetical CS service and 0 otherwise.

Since 6 different hypothetical scenarios, both for commuting and for non-commuting trips, had been proposed to each respondent, we have collected 12 repeated observations for each individual: 6 regarding to the stated preferences for the commuting trips, and 6 regarding to the stated preferences for the non-commuting trips. A total of 4,800 observations have been collected over the whole sample.

The independent variables are the characteristics of the hypothetical CS services described in each scenario: the fare (€/h), the access distance (km), the vehicle's propulsion system (binary variable equal to 1 if the vehicle is electric and 0 otherwise), the CS type. The latter characteristic is described by two binary variables termed "station-based vs. roundtrip" and "free-floating vs. roundtrip". The first one is equal to 1 if the service is provided via a station-based system and is equal to 0 otherwise; the second one is equal to 1 if the service is provided via a free-floating system and is equal to 0 otherwise. Hence, the model estimates the probability of using CS at least once a week depending on fare, access distance, vehicle and CS type.

Several specifications have been tested. We found that the best one is a mixed logit model with two random parameters, fare and access distance, since the standard deviation of the density function of the vehicle and the CS type parameters were not statistically significant. We assumed a constrained triangular distribution for each random parameter in order to control for the range and the sign.[16] The following specification of the utility function of using CS (U_{USING_CS}) rather than any alternative transport mode is used:

$$U_{USING\_CS} = \beta_{ALC} * ASC + \beta_{FARE} * FARE + \beta_{ACCESS} * ACCESS + \beta_{ELECTRIC} * ELECTRIC + \beta_{STATION\_BASED} * STATION\_BASED + \beta_{FREE\_FLOATING} * FREE\_FLOATING$$

The estimated model (Table 8) has a high goodness of fit (adjusted Rho^2 equal to 0.79[17]), capturing a lot of the preference variability of the sample. All parameters have the expected sign: negative for fare and access distance (in line with the results reported by De Lorimier and El-Geneidy, 2013; Martínez et al., 2017; Kim et al., 2017) and positive for electric vs. gasoline vehicle and for more flexible CS types (free-floating or station-based vs. return trip).

An analysis of the determinants of the preference heterogeneity was also performed. Several mixed logit models were estimated using different covariates. For the sake of brevity, the detailed results are not reported, but they are available on request by the authors. They allow us to state that:

- the difference between the preferences of the students living in Milan and Rome is not statistically significant. It has been tested using a dummy variable interacted with each random parameter. Hence, we can state that urban density and public transport supply appear not to play a role for our sample;
- the disutility perceived for the access distance is higher for commuting trips, in line with our expectations, since commuting trips are performed more frequently and have more stringent time constraints;
- the disutility of fare and access distance is lower for the students that have already used CS, in line with the evidence reported by Shaheen et al. (2006), Shaheen and Martin (2007), Clavel et al. (2009), and Zheng et al. (2009) according to which the deeper the CS knowledge the more frequent and probable is its use;
- the students' preferences do not depend on scooter availability, whereas car availability increases the disutility for access distance, consistent with the evidence reported by Burkhardt and Millard-Ball (2006), Douma and Andrew (2006), Stillwater et al. (2009), Loose (2010), Sioui et al. (2013), Zhou and Kockelman (2011), Costain et al. (2012), Habib et al. (2012), Coll et al. (2014), Le Vine et al. (2014a, 2014b), and Kopp et al. (2015) according to which the lower the car ownership, the higher the probability of using CS;
- the fare disutility is lower for student having a better knowledge of CS and for older students;
- the fare disutility is slightly lower for male than for female.

Based on these result the following restricted model has been specified and estimated (Table 9).

$$U_{USING\_CS} = \beta_{ALC} * ASC + \beta_{FARE} * FARE + \beta_{FARE\_COMMUTING} * FARE * COMMUTING + \beta_{FARE\_CS\_USER} * FARE * CS\_USER + \beta_{ACCESS} * ACCESS + \beta_{ACCESS\_COMMUTING} * ACCESS * COMMUTING + \beta_{ACCESS\_CS\_USER} * ACCESS * CS\_USER + \beta_{ELECTRIC} * ELECTRIC + \beta_{STATION\_BASED} * STATION\_BASED + \beta_{FREE\_FLOATING} * FREE\_FLOATING$$

The variable termed "commuting" and specified in the model as an interaction term with the variable fare and access, is a dummy variable which is equal to 1 when the data collected refers to a commuting trip and 0 otherwise. The variable termed "cs_user", specified in the model as an interaction term with the variable fare and access, is a dummy variable which is equal to 1 if the respondent reported that s\he had used CS before and 0 otherwise.

[16] More specifically, we allowed the mean of the distribution to be a free parameter, β, but we fixed the two endpoints of the parameter distribution (defining the range of the triangular density function of the two random parameters included in our model) to be equal to 0 and 2β, respectively. It implies that the mean of the distribution of the random parameter is a free parameter, while the variance is not. The constraint is necessary in order to fix the sign of the parameter that in our case study, both for fare and access distance, is constrained to be negative.

[17] Significantly improving from the 0.23 Rho^2 of a multinomial logit with fixed parameters.

Table 8
Random parameter logit model.

Parameters β	Estimates	t-ratio
ASC (alternative specific constant)	−1.02	−3.6
Fare €/h (random triangular)	−0.41	−12.9
Constrained abs. range of Fare	*0.82*	*12.9*
Access distance km (random triangular)	−1.27	−3.9
Constrained abs. range of Access distance	*2.54*	*3.9*
Vehicle's propulsion system: Electric	0.75	3.9
Station-based vs. return	0.66	2.2
Free-floating vs. return	1.30	5.4
McFadden Pseudo R-squared	0.79	
N. obs.	4,800	

Table 9
Random parameter logit model with interaction terms.

Parameters β	Estimates	t-ratio
ASC (alternative specific constant)	−0.49	−1.54
Fare €/h (random triangular)	−0.42	−10.99
Constrained abs. range of Fare	*0.84*	*10.99*
Fare _Commuting	0.01	0.65
Fare _CS_user	0.10	3.54
Access distance km (random triangular)	−0.81	−2.40
Constrained abs. range of Access distance	*1.62*	*2.40*
Access distance_Commuting	−1.17	−3.14
Access distance_Cs_user	0.63	1.82
Vehicle's propulsion system: Electric	0.75	3.90
Station-based vs. return	0.39	1.36
Free-floating vs. return	1.12	4.70
McFadden Pseudo R-squared	0.81	
N. obs.	4,800	

Table 10
Scenarios' description and probability of CS use.

Attributes	Standard\station-based	Standard\free floating	Favorable\gasoline	Favorable\electric
Fare €/h	18 €/h	18 €/h	12 €/h	12 €/h
Access distance km	2 km	2 km	0.5 km	0.5 km
Vehicle's propulsion system	Gasoline	Gasoline	Gasoline	Electric
CS type:	Station-based	Free-floating	Free-floating	Free-floating
Prob. of using CS	1.5%	2.4%	9.6%	15%

The results reported in Table 9 show that the disutility of fare and access distance is perceived as less important by the students who have used the CS service before ($\beta_{FARE\_CS\_USER} = 0.01$ and $\beta_{ACCESS\_CS\_USER} = 0.63$), and that the access distance disutility is critical and much more important when the service is used for commuting trips ($\beta_{ACCESS\_COMMUTING} = -1.17$), most probably due to the more stringent time constraints of the commuters.

In order to get a better perception of the empirical significance of the values obtained, four scenarios have been developed (Table 10). The first two scenarios are called "standard", since they are characterized by: a fare of 18 €/h, i.e. € 0.30 per minute, similar to the fares currently prevailing in Rome and Milan; an average access distance of 2 km, in line with the existing network density; a fleet consisting of gasoline cars, the prevailing case both in Rome and Milan.

The other two scenarios are termed "favorable", since they are cheaper, denser and are provided via a free-floating system. The difference between them relates exclusively to the vehicle's propulsion system used. One is assumed to be offered with vehicles with internal combustion engine and the other one with electric vehicles.

On the basis of the estimates reported in Table 9, we have estimated, consistently with the mixed logit model, the probability that the respondents would use the CS services described in each column of Table 10 at least once within a week. Technically, the Nlogit software, that we used for the econometric analysis, performs a scenario analysis computing the predicted probabilities using the sample data and the estimated parameters. Then, it re-computes the probabilities after changing the variables in the way specified in the scenarios. The result is a point estimate.

It turns out that the probability of using CS at least in the weekly mobility pattern would increase from about 2% in the standard scenarios (average value of the first two "standard" scenarios, equal to 1.5% and 2.4%, respectively), to 9.6% in the "favorable \gasoline" scenario and to 15% in the "favorable\electric" one.

Table 11
Current n. of commuting trips by transport mode and changes of the mobility patterns by scenario.

	Car	Scooter	LPT	Train	Taxi	Walking	Bike	CS	CS average distance travelled km
Status quo	680	108	1,223	639	3	1,087	133	5	3
Scen. 1	−58	−5	−20	−2	0	−3	−5	+93	19
Scen. 2	−34	−3	−13	0	0	−8	0	+58	16
Scen. 3	−18	−2	−1	0	0	−6	0	+27	17
Scen. 4	−25	−2	−5	0	0	−3	−1	+36	18
Scen. 5	0	0	0	0	0	0	0	+0	3
Scen. 6	−12	0	0	0	0	0	0	+12	11

Table 12
Current n. of non-commuting trips by transport mode and changes of the mobility patterns by scenario.

	Car	Scooter	LPT	Train	Taxi	Walking	Bike	CS	CS average distance travelled km
Status quo	971	98	427	399	13	738	193	21	16
Scen. 1	−45	−2	−20	−2	−1	0	−5	+75	15
Scen. 2	−29	−3	−17	0	−1	−5	−2	+57	14
Scen. 3	−9	0	−3	0	−1	−1	0	+14	14
Scen. 4	−6	0	−20	−1	0	−4	0	+31	11
Scen. 5	0	0	0	0	0	0	0	+0	16
Scen. 6	−10	0	−2	−1	0	0	0	+13	20

According to our estimates, the CS providers willing to expand the demand for their services should reduce the access distance to an average of 0.5 km. The roundtrip and station-based system should be substituted by the free-floating one and the gasoline vehicles should be replaced by electric ones. Some of this developments are in reality taken place both in Rome and in Milan[18]. The local administrators and the universities' mobility managers could further boost the demand arising from college students subsidizing the service via discounts equal to 30% of the current fares.

4.3. Substitutability between CS and other transport modes

The stated changes of the mobility patterns collected in the third part of the interview (Table 4) compared to the current habitual mobility patterns (Table 3) allowed us to observe how CS would replace the currently used transport modes.

Table 11 describes in the first row the number of trips by transport mode that are currently performed by the sample, while in following rows the transport mode variations that would take place for the commuting trips in each hypothetical scenario are depicted. For instance, in the first scenario, 93 additional trips would be performed by CS substituting the private car (−58), the scooter (−5), the local public transport (−20), the train (−2), walking (−3) and the bicycle (−5). The first two scenarios have the largest impact on the current mobility patterns, since they are cheaper and are characterized by shorter access distance. In the last column the average distance actually travelled by CS, that is 3 km, and the distance that would be on average travelled by CS in each hypothetical scenario, ranging from 3 km to 19 km, are described. The distances reported for most of the hypothetical scenarios, except for Scenario 5, are longer than the current one and by the average distances reported by ANIASA.[19]

Similarly, Table 12 describes the current number of non-commuting trips performed by each transport mode (first row) and the transport mode variations that would take place in each hypothetical scenario. Again, the first two hypothetical scenarios have the largest impact. In the last column, we report the average distanced actually travelled by CS, that is 16 km, and the distances that would be travelled on average by CS in each hypothetical scenario.

It results that CS is a very good substitute for private car, in line with the evidence reported by Martin et al. (2010), Martin and Shaheen (2011a), and De Lorimier and El-Geneidy (2013). On the contrary, the use of the scooter, a popular means of transport in Italian cities, appears not to be significantly affected. The second most impacted transport mode is local public transport, particularly in scenarios 1, 2 and 4, and especially for non-commuting trips. This result is not in line with the evidence reported in the literature (Douma et al., 2008; Cervero, 2009; Martin and Shaheen, 2011a; Zoepf and Keith, 2016) according to which there is a complementary relationship between CS and public transit. However, a more recent study by Becker et al. (2017) supports at least partially our results, demonstrating that according to the CS type provided, the demand and use for public transport service could increase (in the case of station-based schemes), or decrease (in the case of free-floating systems). Moreover, ANIASA, surveying 2,000

[18] In fact, in Rome the operator Carsharing Rome has recently introduced the one-way option (https://romamobilita.it/it/carsharing/oneway). New CS service (e.g., in Turin) makes use of electric vehicles (cars and mopeds).

[19] According to ANIASA, not distinguishing by trip purpose, the average distance travelled by CS is equal to 7km in Milan and 8km in Rome (www.aniasa.it).

people, finds that 55% of the sample substitute CS for public transport services.[20] The other transport modes would be much less affected, contrary to the results obtained by Martin and Shaheen (2011a), who found that joining a CS scheme increases non-motorized transport use, but in line with the results found by Efthymiou and Antoniou (2016) and by Becker et al. (2017) according to which CS is a substitute also for taxi.

5. Conclusions

The paper discusses the use of CS by college students in the cities of Milan and Rome. Three main issues are investigated: 1) how many students use CS and what are the main determinants of their choice; 2) how the probability of using CS varies under hypothetical supply scenarios; and 3) what would be the impact on the use of other transport modes.

College students are a relevant market segment for CS providers, since they possess many characteristics that makes them favorably inclined to become CS users (low car ownership, heavy smartphone users, sharing propensity, commuting to the city center, multi-mode oriented, etc.). However, due to the fact that students have specific mobility needs and lower car ownership, the results obtained in this research cannot be extended to other market segments nor to other cities. Milan and Rome, in fact, are the two largest Italian cities having the highest CS supply. Nonetheless, the results we obtained are valuable both to service providers and to city administrators, since, to the best of our knowledge, much of the evidence we collected and of the conclusions we draw are novel, at least for the Italian context.

From a methodological point of view, we apply the stated preference methodology which is frequently used for transport demand analysis, adapting it to the very specific and difficult case of CS demand. We deemed it essential to collect information on the full mobility pattern at the individual level (number of trips and average distance by all available transport modes) distinguishing between commuting and non-commuting purposes. We designed six scenarios to explore how the mobility patterns would change as a result of hypothetical variations of the current CS supply. Each scenario is characterized by fare, access distance, vehicle's propulsion system, electric vs. gasoline, and CS service type, distinguishing among roundtrip, station-based and free-floating. We carry out discrete choice analysis to estimate the factors that influence the probability of CS use and the resulting parameters have been used for policy analysis.

With reference to the first research question (demand level and type), we find that about 20% of the sampled students have used CS at least once. However, when asked about their habitual weekly mobility pattern, only 4 students out of 400 report that they use CS for commuting trips. The number increases to 13 when non-commuting trips are considered. This evidence reflects an important feature of the current CS demand: CS service is used more on an occasional basis than as a substitute for the conventional transport modes in the habitual mobility pattern. Similar findings are reported by Zheng et al. (2009) and by Zhou (2013). The occasional CS use might be due to the frequent changes of course schedules and residential locations characterizing the university students' life (Martin and Shaheen, 2011b). Potential occasional motives to CS use, as informally reported by the sampled students, include travelling late at night, when the destination is not served by public transport, or travelling with a group of friends.

As to the preferences for CS service, we find that private car availability plays a crucial role, very much in line with the results already reported in the literature. Contrary to some early literature, we find that gender plays almost no role. Furthermore, contrary to our expectations, no significant differences could be detected between students living in Rome and Milan, notwithstanding the differences between the two cities. We are able to confirm that fare, access distance, propulsion system of the vehicle and CS type are important determinants of CS use and significantly affect the choices of the students. More specifically, fare and access distance negatively impact the probability of using CS (as in Zheng et al., 2009), while the provision of the service by electric vehicles and via a free-floating system positively impact the probability of using CS. However, the preference structure depends on the trip purpose. The sensitivity to CS fare is slightly lower and the sensitivity to access distance is much higher for commuting trips than for non-commuting trips, most probably because of the more stringent time constraints characterizing commuting trips. Moreover, previous, although occasional CS use appears to significantly impact the preference structure, as already reported by Zheng et al. (2009). This result bodes well for the increase in transport demand and, consequently, in transport supply, as it seems to be true for both Rome and Milan. The more students use the service, the more they are prone to include it in their transport mode choice. In turn, this triggers supply and public support. In recent months, both in Milan and in Rome, the number of CS providers has increased as well as the number of electric cars offered in their fleets.

The estimated econometric model allowed us to perform scenario analysis to evaluate the probability of using CS, which is our second research question. The outcome is particularly relevant for the CS providers in order to choose the characteristics of the service that better meet the preferences and needs of the users. This analysis is also important for the policymakers since it provides an estimate of how the potential demand would increase if subsidies are granted either to the users or to the providers of the service, enabling them to improve the quality of the service or to reduce the fare. It turns out that a cheaper service (12€/h) and a denser CS network (0.5 km access distance), together with a free-floating technology, could increase the use of CS for at least one trip within a week from the estimated current 2% to either 9% or 15%, depending on the type of CS car provided, gasoline or electric car, respectively. This information is particularly relevant also for the universities' mobility managers, frequently subsidizing college students in favor of more sustainable transport modes.

With reference to the third research question, regarding what transport modes are substituted by CS, we find that CS mainly substitutes the private car, both for commuting and non-commuting trips, in line with the previous literature (Martin et al., 2010;

[20] www.aniasa.it.

Martin and Shaheen, 2011a). To a lesser extent, CS substitutes also local public transport service. This result differs from the majority of the evidence so far reported in the literature (Douma et al., 2008; Cervero, 2009; Martin and Shaheen, 2011a; Zoepf and Keith, 2016), but is in line with the evidence reported by Becker et al. (2017) and with a recent survey by ANIASA. The difference might be due to the specific segment that we have studied, that is college students. According to our evidence, CS only marginally substitutes taxi service (as reported by Zoepf and Keith, 2016, and by Becker et al., 2017), the scooter and the non-motorized modes, which are meant for shorter distances.

Future research effort will be devoted to overcome some of the shortcomings of this research. First, we plan to increase the number of interviews by applying the same methodology to other cities, especially the medium-size ones, and to other market segments. In fact, the occasional use of CS might be a specific feature of the students' segment. Individuals with a permanent occupation might be better able to plan their mobility choices in a medium time horizon. Second, the questionnaire can be enriched by tracing the origin-destination pair of each respondent and the day of the week and time of the day when CS is used. Collecting such information will certainly imply a longer interview, but we deem it essential to understand the nature of CS use. On the contrary, we do not believe it would be feasible to collect additional detailed information on all the alternative transport modes available to the respondent with the aim of estimating a full modal choice model, since it would too burdensome to the respondent and might cause fatigue effects.

Third, preferences for free-floating vs. station-based CS service might also be segment- and city-specific. Indeed, in the medium-size Italian cities, characterized by shorter distances and more predictable origins and destinations, a station-based type might be sufficient to satisfy the users' needs and to meet the providers' cost concerns. In order to fully analyze this issue, as suggested by a reviewer, it might be useful to clearly distinguish between free-floating and station-based CS since they appeal to different segments of the population and satisfy quite different needs. Instead of simply modelling CS type as an attribute, we plan to design specific questionnaires for each CS type.

Finally, the substitutability or complementarity between CS and public transport might also be segment- and city-specific. In order to test this hypothesis, information on origin-destination pairs, on the time of CS use and on public transport supply should be collected.

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