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Research Article

Impacts of Smart Configuration in Pedelec-Sharing: Evidence from a Panel Survey in Madrid

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Despite the recently increasing research interest, this is one of the first studies employing a panel sample of users and nonusers to understand the bike-sharing phenomenon ($N = 205$). On the basis of a novel surveying technique, a case study on the clients of the state-of-the-art bike-sharing scheme of Madrid (Spain) is presented. BiciMAD is a system of the latest generation, namely, multimodal demand responsive bike-sharing: a fleet of electric pedal-assisted bicycles (pedelecs) with an advanced technology and unique smart service configuration to tackle challenges that may hinder the promotion of cycling and bike-sharing in the city. A statistical test has verified that there is a moderate association between previous intention and actual use of bike-sharing (Cramer's $V = 0.25$) and both barriers and motivators of further use have been identified. Indicators on mobility patterns show that although drawing primarily from other sustainable modes of transport, bike-sharing has increased mobility (total number and distance of trips) and especially active travel but decreased the perceived travel time.

1. Introduction

Bike-sharing has been expanding rapidly worldwide from the mid-2000s. It is estimated that there are more than 800 systems worldwide, mostly in cities of Europe, North America, and Asia. In parallel to the rapid rise of bike-sharing, there has been growing research interest in its study. Some frequent issues related to service design, configuration, and operation are station location, bicycle rebalancing, pricing, and, most recently, dockless systems and e-bike-sharing. By reaching a certain level of maturity in many cities, demand side research topics include not only user characteristics and preferences but also impacts on individual mobility patterns and on the urban transport system. A recent synthesis of the literature [1] has resulted in three main conclusions about bike-sharing users, namely, that (1) they have different demographic characteristics than the general population (male, higher average income and education, more likely to live and work in the bike-sharing operational zone, etc.), (2) convenience (perceived usefulness) is the key factor that motivates frequent use, (3) modal shift from individual motorized modes is lower than expected.

Although a lot has already been said about bike-sharing users, seemingly there is a lack in longitudinal research activities to study impacts in a specific social group or a panel of potential and actual users. In this context, Ricci [2] suggests the use of innovative research methods combining users' travel behavior history as a result of bike-sharing, socioeconomic data, and cycling patterns. This kind of research would allow a better understanding of user and nonuser profiles and changes of travel behavior.

In the present paper, after a brief but comprehensive literature review, a case study is presented about BiciMAD users in Madrid (Spain). On the basis of a panel survey, the present paper aims to highlight the effects of the introduction of a smart pedelec-sharing scheme on using the service (by measuring the relationship of intention-to-use and actual use), factors that may motivate nonusers to become clients, and impacts on mobility patterns.

2. Literature Review

Study of readiness to use a new product or service and to pay for it is a classical issue of academic and marketing research. In the field of urban transport research, willingness-to-pay and acceptance play a significant role in the study of feasibility of new charges, especially congestion charge and road tolls [e.g., [3–5]], as well as new pricing schemes in public transport [6–8]. Analysis of intention-to-use is applied to identify persuasion strategies and promotion tools before the introduction of a new or improved product or service, such as information services [9], improved quality and integration of public transport [10–12], and automated driving [13]. Intention-to-use bike-sharing has also been investigated recently, including the identification of factors that may affect adoption [14–16], especially among young drivers [17] and tourists [18], as well as the study of acceptability of ICTs and new pricing policy [19]. Relationship of willingness/intention and actual use in urban mobility has not yet been researched extensively, despite the fact that it may bridge the gap between the above mentioned studies and what has been learnt about actual users after introduction (modification, improvement, etc.) of a product or service.

Impact assessment is a relatively frequent topic of transport research and considerable effort has also been devoted to the analysis of the effects of bike-sharing on urban mobility. Besides basic literature and review papers on the role of bike-sharing [1, 20–24], there has also been specific interest on impacts on travel patterns. In the following paragraphs, the most influencing contributions are presented, which may be linked to three principal researchers (not in order of importance).

Shaheen et al. [25, 26] and Martin and Shaheen [27] focus on the varying degree of modal shift from/to public transport in different contexts of North American cities. They employ a set of survey techniques and data sources (online questionnaire among members, onsite survey among potential users, expert interviews, and population statistics) to understand mobility implications. They come to the conclusion that bike-sharing draws from all modes and it is increasing cycling and reducing car and taxi usage. Impact of bike-sharing on public transport use depends on the urban environment, that is, the degree to which public transport serves long trips (in which cycling/bike-sharing is not competitive) or short trips (in which cycling/bike-sharing may be a substitute). Bike-sharing tends to be more substitutive in larger and denser cities and more complementary as a first or last mile connection in small to medium size and less denser cities.

Fishman et al. [28–30] provide the definition of a theoretical framework of impact assessment and a quantification of impacts on active travel and car use in different contexts (USA, Australia, and UK). On the basis of previous research on walking and cycling, they have created a framework to measure the monetized benefits of bike-sharing in terms of congestion, climate change, and physical activity. Online survey and data obtained from operators have been used to determine the effects on other modes of transport: an average of 60% of bike-sharing trips replaces sedentary travel modes. Although there is a reduction in active travel time when bike-sharing replaces walking, overall there is a positive impact on active travel. They have concluded that only a certain car mode substitution level can ensure a reduction in the use of motorized vehicles. Consequently, they suggest that user-based or nonpolluting redistribution of bicycles and a mode shift from car and taxi (and even public transport) to bike-sharing shall be encouraged in all systems.

Ricci [2] has carried out an extensive review of policy documents, academic and grey literatures (including publications of the above mentioned authors) on user profiles; determinants, barriers, and characteristics of use; new travel patterns; impacts on urban mobility; and health, environmental, and economic impacts. Among far-reaching conclusions, the study reveals an interrelationship of the promotion of cycling and bike-sharing and that there is mixed evidence about the changes of travel patterns as a result of bike-sharing. Cycling seems to increase, whilst driving and other forms of physical activity (especially walking) tend to decrease. Bike-sharing can connect to or replace public transport depending on scheme attributes, user preferences, and characteristics of the area of implementation.

As Spain is one of the countries with the highest number of bike-sharing systems, there is growing interest in their research [e.g., [31–36]] and there is an initiative to publish data and information about bike-sharing systems [37], but there is still room for further investigation in the topics of the present paper.

3. Case Study

BiciMAD was introduced in the dense inner city of Madrid, in districts of approximately 15 to 30 thousand inhabitants per km^2. This is the commercial and residential city center with nearly 850,000 inhabitants (out of 3.16 million in the municipality in 2016) and one of the top European destinations with 8.9 million national and international tourists in 2016. Mobility in this central area is characterized by a traditionally high share of walking (54.4% in 2014, according to the last travel survey) and public transport (30.1%). The latter is due to, among others, an extensive and high-capacity metro system and bus network. Bike-sharing was launched with 1560 bicycles in 123 docking stations in mid-2014 and expanded towards other parts of the inner city in the next years. In total, there are 2028 bicycles and 165 stations in early 2017.

It is an example of the latest generation of bike-sharing, that is, multimodal demand responsive systems [38]. Its unique design, advanced technology, and smart service configuration intend to give response to some barriers and challenges that may undermine the promotion of cycling and bike-sharing in Madrid (see Figure 1). First, it employs state-of-the-art pedelecs to tackle issues of an ageing population, low modal share of cycling (0.8% in 2014), lack of proper cycling infrastructure, and hilly streets in the city center. For one of the very first fully pedelec-based bike-sharing schemes in Europe, a unique fleet was developed and tailor-made to be introduced in Madrid. Second, it applies a fee policy that unlike the vast majority of systems makes all users pay for each ride, including subscribers who can use the service free of charge for the first 30 minutes in other schemes (up to

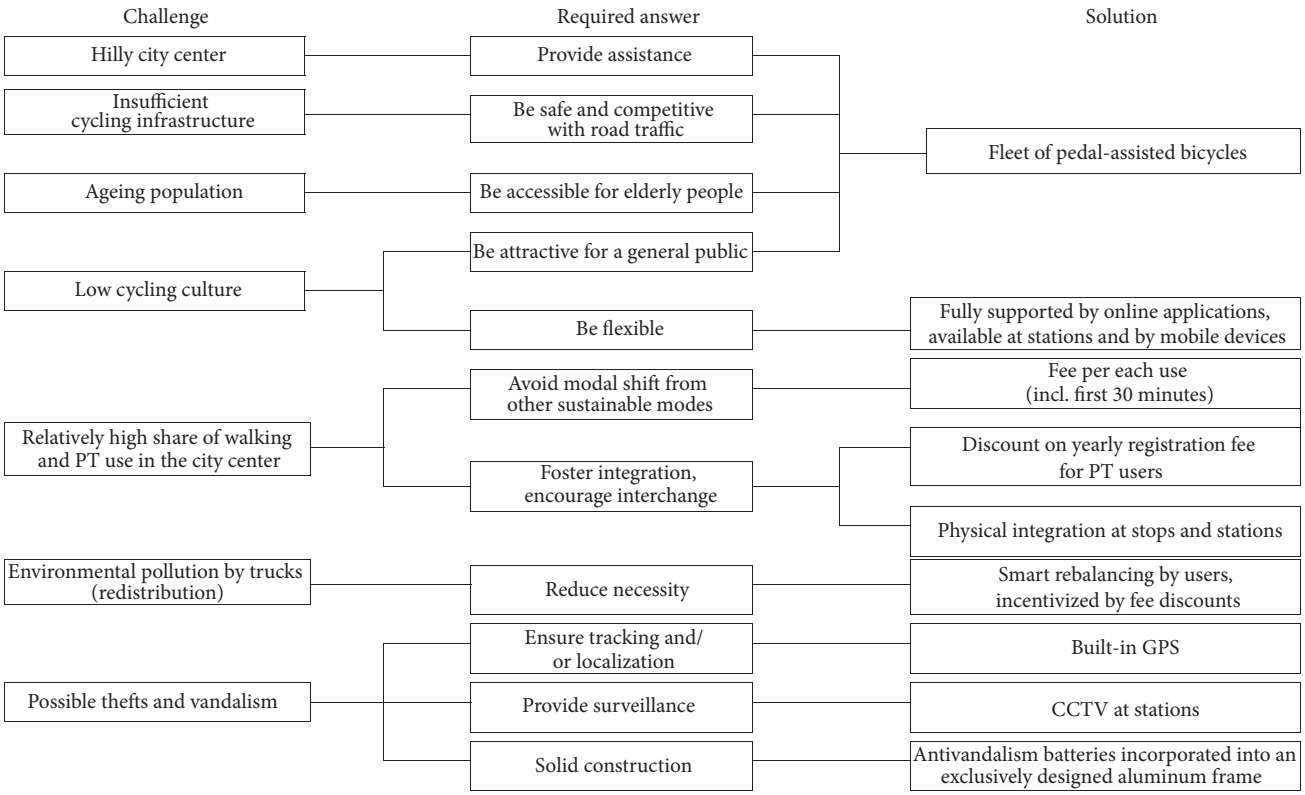

Figure 1: Demand responsive characteristics of BiciMAD.

45 or 60 minutes in some cases). This is to offer a relatively cheap and eco-friendly alternative to individual motorized modes but to prevent people to stop walking and using public transport due to a "free of charge" mobility option. Third, it incentivizes user-based rebalancing of docking stations by a discount on the fee per ride for clients who pick up a bicycle from an overloaded station, return it to a low occupancy one, or make online dock reservation at departure. Smart redistribution may decrease the negative effects of the use of trucks and counterbalance the few negative externalities of bike-sharing (e.g., in terms of land use).

BiciMAD was introduced in a social system with low cycling culture [39], without the application of classical marketing tools, such as wide-scale market research or advertising. The only seemingly effective promotion tool was the installation of docking stations on the streets of the city center. Only a limited road infrastructure development has been carried out: although extensive in length (about 70 km), the new network of *ciclocarril* means assigning dedicated mixed traffic lanes with a speed limit of 30 km/h, mainly on busy streets and avenues.

Taking into account the significance of the introduction of a new travel mode in an urban transport system, a research project was launched (1) to better understand urban mobility (especially travel patterns) in Madrid and (2) to study the bike-sharing phenomenon in a certain context. A series of surveys among potential and actual users was realized from 2014 to 2016, and complementing publicly available data (number of users, daily use, etc.) has been gathered. Previous outcomes of the project include a classification of potential users and nonusers [40] and an assessment of the impacts of bike-sharing on urban mobility and the use of bicycle [41] employing advanced statistic techniques of factorial and cluster analysis, as well as a study on the peculiarities of the adoption of bike-sharing as an innovation, applying the Theory of Diffusion of Innovations (under publication).

4. Methodology and Sample

A survey method developed by TRANSyT (Transport Research Centre, Universidad Politécnica de Madrid) [40, 42], the combination of an intercept interview and an online questionnaire was used to ensure the desired number of complete responses by competent and encouraged respondents in an economic and easy-to-analyze manner. After a brief, 30- to 120-second long introduction of the topic and the incentives at a bike-sharing station to users or potential users (and some records, such as sex, age, place, time, and weather kept by surveyors), an access code to an online survey was provided. Respondents could fill in the questionnaire by a mobile device or computer with internet access within a few days. In this case, the contact data provided by interested participants in the questionnaire allowed the realization of a panel survey in the upcoming phases. The number of complete responses may be seen in Table 1.

In the present contribution, for the analysis of intention and actual use as well as the changes of travel behavior and attitudes towards urban mobility and especially cycling,

Table 1: Survey phases.

Phase	Date	Potential user	Actual user	Potential user (panel)	Actual user (panel)	Total
1	May/June 2014	1811 (1859*)	—	—	—	1859*
2	June 2015	25	403	63	93	584
3	June/July 2016	30	302	62	140	534

*In the first survey phase, a specific questionnaire was administered to Spanish-speaking tourists, but due to the low number of respondents (48), no detailed analysis was done.

responses of the panel survey are considered. A total number of 205 individuals who responded in both the 1st and 2nd or 3rd phase are included in the study. (In case of filling in both the 2nd and 3rd questionnaires, responses in the 3rd are taken into account.)

The questionnaires included questions about general travel patterns, use of bicycle, attitudes towards cycling, and bike-sharing, as well as the willingness and actual use of bike-sharing. Some topics were addressed by Likert-type scale statements. Socioeconomic characteristics have been analyzed by a specific group of questions. Due to constraints (especially in terms of completion time), some modification of the questionnaire had to be done from phase to phase, leading to a nonperfect comparability in a few aspects.

After the standardization of data and matching answers by panel respondents, a statistical analysis has been carried out, including a test to estimate the relationship between intention-to-use and actual use of bike-sharing. Pearson's chi-square test is computed from the contingency table:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}}. \quad (1)$$

On this basis, Cramer's V is calculated to measure association:

$$V = \sqrt{\frac{\chi^2}{n \times \min\left(r-1; c-1\right)}}. \quad (2)$$

O_i is observed frequency, E_i is expected (theoretical) frequency, r is number of rows, c is number of columns (in the contingency table), and n is total number of observations.

Modal shift indicators (e.g., change in number of trips, distribution of replaced modes, and modal share) are employed to explore the changes of individual travel behavior and urban mobility after the introduction of bike-sharing.

In line with previous research on the role of user demographics in the evaluation of impacts [26], some general data of the survey sample ($N = 205$) may be seen in Table 2. Three users categories of BiciMAD have been defined: frequent users *(subscribers)*, who after registration pay a yearly subscription fee and may use the service for a price per ride (0.5 EUR for the first 30 minutes and 0.6 EUR for further 30 minutes of use, up to a maximum of 2 hours in total; prices as of early 2017 (prices have not been altered since the inauguration of BiciMAD in 2014)); *occasional users*, who pay a deposit of 150 EUR and may use the service for the price of 2 EUR for the first 60 minutes (4 EUR for the second hour); and *nonusers*, who have never tried out or used the system.

Changes from 2014 (before implementation) to 2015/2016 (after) that may affect urban mobility patterns (itineraries, mode choice, number of trips, etc.) include the following:

(i) some people who have finished school and entered the job market;

(ii) a positive trend on the job market: lower unemployment rate and more people employed or self-employed;

(iii) less single-person households (converted into households of two members, presumably young couples without children);

(iv) lower average household income levels;

(v) less people with motorbike but more with car and driving license;

(vi) varied alteration in the use of public transport (as reflected by the number of PT pass holders) and private bicycle (through the rate of owned bicycles).

5. Results

5.1. Intention and Actual Use. To better understand potential user profiles and identify characteristics (beyond intention-to-use) that make people similar to each other in a limited number of groups, a cluster analysis was carried out after the ex-ante survey. It resulted in three clusters [40]:

(i) A group of people in their 20s and 30s, mainly women, many of them still studying or inactive, mostly PT users, have not ridden a bike in four weeks. They were relatively positive about the efficiency of BiciMAD in urban mobility and rather positive about its pricing, with a relatively strong intention to become frequent users (called "Fans" in the study).

(ii) Individuals mostly in their 20s, mainly men, mostly students, both car and PT users, have not ridden a bike in one year. They were a bit negative about the system and indifferent (but rather negative) about BiciMAD fees and they would rather become occasional users ("Vacillating and indifferent").

(iii) A cluster of men and women equally, between 30 and 50 years of age, mostly employees and self-employed, have ridden a bicycle in the last month. They were very negative about bike-sharing fees and quite negative about BiciMAD and they would not (or some might eventually) use the service ("Opponents and/or frequent cyclists").

Table 2: Panel sample: some general, socioeconomic, and transport related characteristics in the before and after survey phases.

	Total		Subscribers		Occasional users		Nonusers	
% in survey	100		21.4		20.4		58.2	
Age in 2016 (standard deviation)	37.6 (11.6)		37.5 (9.2)		34.8 (12.3)		38.6 (12.1)	
Female : male (%)	41 : 59		38 : 62		39 : 61		43 : 57	
	Before	After	Before	After	Before	After	Before	After
	% of respondents							
Occupation								
Student	22.9	17.1	10.6	4.3	23.9	26.8	34.2	18.8
Employee	60.7	66.3	74.5	85.1	51.2	58.5	59.0	61.5
Entrepreneur	2.0	4.9	4.2	4.3	0.0	4.9	1.7	5.1
Unemployed	10.5	9.8	6.4	6.4	14.6	9.8	10.3	11.1
Pensioner	1.5	1.5	0.0	0.0	2.6	2.6	0.0	0.0
Education								
Higher	74.6	77.6	77.9	78.7	75.6	78.0	72.6	76.9
Secondary	24.9	20.0	19.1	19.1	24.4	22.0	26.5	19.7
Household size								
1	14.4	11.7	12.8	14.9	17.1	7.3	13.7	12.0
2	25.9	29.8	36.2	31.9	24.4	34.1	23.9	27.4
3	25.4	23.4	17.0	17.0	26.8	24.4	27.4	25.6
4	25.4	25.4	25.5	23.4	19.5	22.0	27.4	27.4
More	9.0	9.8	8.5	12.8	12.2	12.2	7.7	7.7
Household income (€)								
–1300	18.9	23.9	17.0	14.9	22.0	29.3	19.7	25.6
1300–2500	40.3	39.0	38.3	38.3	39.0	39.0	41.0	39.3
2500–	40.8	37.1	44.7	46.8	39.0	31.7	39.3	35.0
Bicycle ownership	78.1	76.1	70.2	70.2	80.5	85.4	79.5	75.2
PT pass	53.7	52.2	38.3	51.1	56.1	52.1	59.0	52.1
Driving license	83.6	85.4	89.4	91.5	73.2	75.6	84.6	86.3
Access to car	58.7	60.5	59.6	63.8	46.3	48.8	61.5	63.2
Access to motorbike	18.4	12.7	12.8	6.4	26.8	12.2	17.1	15.4

These results are in line with the three above defined user groups of BiciMAD (subscribers, occasional users, and nonusers). On this basis, three categories are applied in the research of intention-to-use (will not use; will use occasionally; will become a frequent user) and actual use (nonuser; occasional user; frequent user). An outcome of this approach in the analysis of the panel sample is represented in Figure 2.

On the one hand, results show that a majority of respondents have not started to use bike-sharing, even those who reported an intention to ride on BiciMAD frequently. Consequently, although the predicted use is reflected in the highest proportion in the same actual use category (no/not tried: 64%; occasional/occasional: 26%; frequent/frequent: 45%), only no/not tried has the highest proportion in absolute terms within the same category, not tried being the top outcome in the two others. On the other hand, data indicates a similarly varied distribution from another point of view, namely, that despite having the highest proportion of intention in the same category (not tried/no: 44%; occasional/occasional: 41%; frequent/frequent: 57%), not all of them are the top items in each case (see occasional/no: 44%). Peculiarly, two out of five actual subscribers did not intend to use the service (or only eventually) and nearly the same percentage of actual occasional users reported on not willing to become clients. These results indicate that intention-to-use expressed before implementation is not strongly connected to the final decision about becoming clients.

A statistical test has been applied to confirm the assumption that there is a relation between intention-to-use and actual use (which seems obvious) and to quantify the association (that is not expected to be strong). The test is based on 3×3 contingency table, rows, and columns representing the above-mentioned categories. Results may be seen in Table 3.

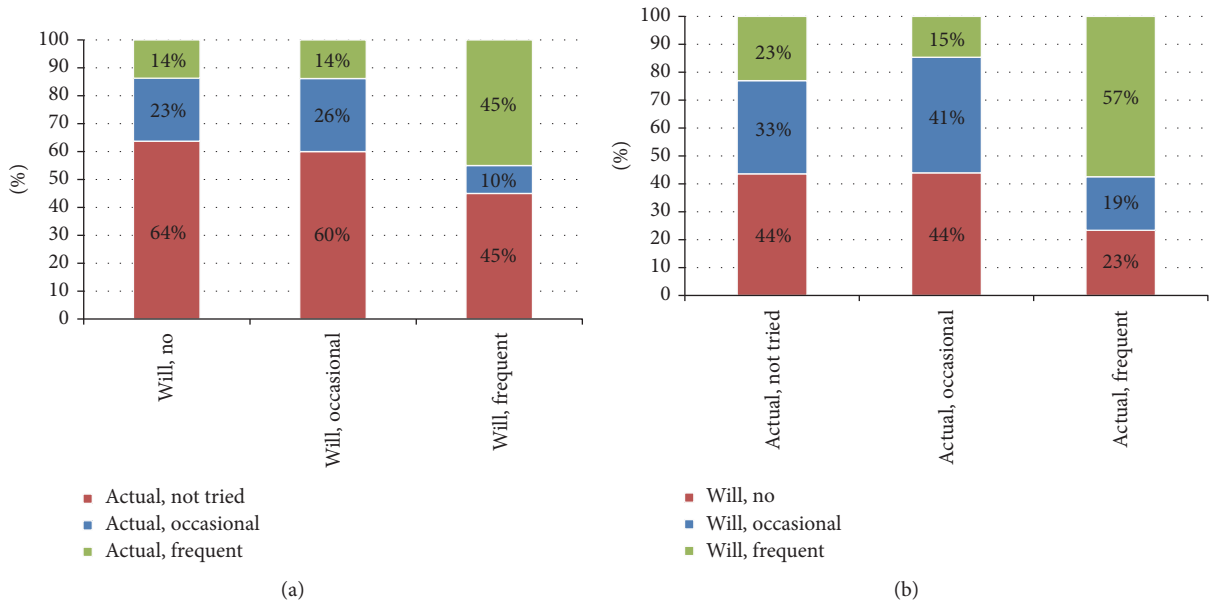

Figure 2: (a) Actual use in light of intention-to-use. (b) Intention-to-use in light of actual use.

Table 3: Results of the statistical test.

Pearson's χ^2	df	p	Cramer's V
24.76268	4	.00006	0.245758

As expected, results indicate an association with a medium magnitude; that is, intention-to-use (before system implementation) has a moderate connection to the final decision about becoming a BiciMAD user. In other words, some individuals have changed their minds: a not insignificant percentage of refusers (37%) seem to have become fascinated by the new travel mode and started to use it as an occasional or even frequent user and others are subscribers instead of casual users (and vice versa). The last one, namely, becoming a subscriber and not an occasional user, may be the result of an obvious financial consideration: on the basis of prices from 2014 to 2017, a yearly registration fee plus a fee per each ride is more economical than paying an occasional fee after the 16th ride (10th for PT pass holders).

Most people who reported on casual or frequent use finally decided not to become clients after inauguration. This may be due to unpredictable changes in one's life, such as socioeconomic (e.g., new workplace) and other personal reasons (e.g., health problems), but there must be some factors originating from the (perceived) attributes of the bike-sharing service and/or the transport system, as well.

Thus, in the second and third survey phases, respondents had to evaluate the relevance of some of these possible factors in their decision: for what reason they do not (or not frequently) use the service (Table 4) and if they would start to use it under certain conditions. An obvious answer is a greater convenience of another mode of transport: (1) owning bicycle has a high percentage as a reason for nonuse or non-frequent use (nearly one out of two individuals) in both categories; (2) as bike-sharing is not intended to replace all the trips in the city, some people may find other transport modes, especially public transport, faster or more convenient in other terms in their itineraries.

Bike-sharing related factors are geographical coverage (an extension was realized toward other zones of the city center during the 2nd and 3rd survey phases) and pricing policy. Problems related to the design, comfort, and ease-of-use of bike-sharing pedelecs, as well as their availability, seem to prevent fewer people from using the service. Most relevant transport system related reasons are lack of a proper network of bicycle infrastructure and feeling unsafe in road traffic. Apparently, perceived danger on the road is reported as a barrier to start using bike-sharing by a much higher proportion of nonusers than to become subscribers by casual users. This may indicate that an exploratory or occasional use may result in a different attitude toward the safety of cycling.

This is in line with the intention-to-use in case of some changes; that is, one out of two nonusers report on willingness to surely become a client if there was a more extensive and especially safer bicycle infrastructure. The same proportion of respondents report on a firm willingness to become users if the first half an hour would be free of charge. Seemingly, a system extension toward other parts of the city would also help an efficient promotion of bike-sharing among potential users. On the contrary, improvements of the technology, for example, an enhanced ease-of-use of pedelecs, would not affect a decision about starting to use bike-sharing.

Peculiarly, yearly subscription fee and fee per each use are barriers to the same extent for occasional users. When they are asked to express their level of agreement with fees, they seem to be more critical about a fee per each ride both before and after implementation (Figure 3). They have become extremely negative about the price that they pay for their casual rides. On the contrary, nonusers are more

Table 4: Why don't you use the service (or use it more frequently)? (% of respondents).

	Nonusers	Occasional users
	% of respondents	
I use my own bicycle	43.7	48.5
The network does not fit into my itineraries	42.0	27.3
Too expensive fee per each use	39.5	30.3
Too fast or too dangerous motorized traffic	30.3	18.2
No bike path on my itineraries	27.7	27.3
Too expensive yearly subscription fee	24.4	30.3
It is faster by other modes of transport	23.5	18.2
Inappropriate bike paths/lanes on my itineraries	6.7	3.0
Bike-sharing bicycles are uncomfortable	3.4	0.0
Bike-sharing bicycles are hard to use	1.7	0.0
Low availability of bicycles and/or docks	—	9.1
Other: personal (e.g., health) issues, negative comments by peers, system failures (exploratory use), and so on.	10.1	6.1

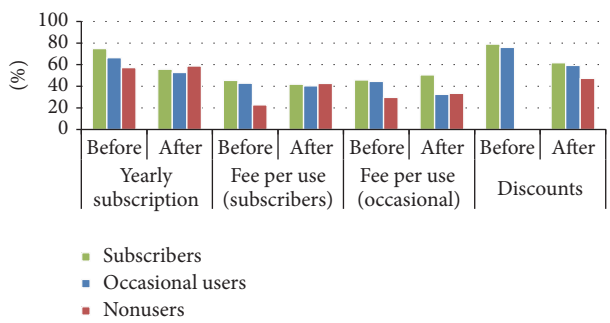

Figure 3: Evaluation of prices and discounts (evaluation on a Likert-type scale from 0 to 5; average score compared to the maximum).

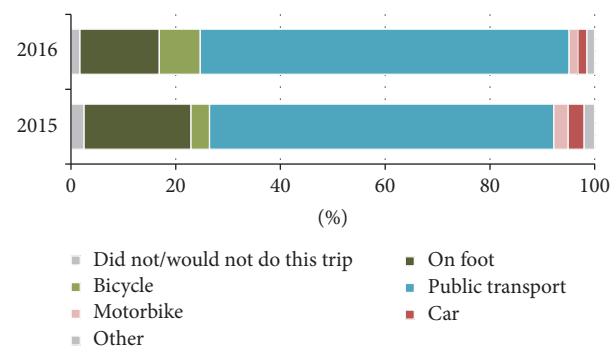

Figure 4: By what other mode did or would you take your most frequent bike-sharing trip? (% of respondents, full sample, $n = 397$ in 2015 and $n = 409$ in 2016).

positive than before, being the most positive among all categories after implementation about the yearly subscription fee and the fee per ride that subscribers pay. It seems obvious that pricing policy was and remains the most controversial issue about service configuration.

From another point of view, attributes that clients consider relevant in their decision about frequent and occasional use of bike-sharing are being faster (38%), more environmentally sound (38%), and more economical (26%) than other modes, as well as being a form of doing exercise whilst travelling (26%). Frequent users are influenced by the relative advantage in comparison to other modes especially in terms of speed and eco-friendliness. Occasional users seem to depend less on attributes like costs and speed and take the first ride out of curiosity or by observation or opinion of others.

5.2. Impact on Travel Patterns. As a mobility management measure, bike-sharing is introduced in urban areas nowadays to promote sustainable mobility, that is, to attract people who use motorized modes on relatively short distances and to provide citizens with an eco-friendly service as a first/last mile connection to public transport. In Madrid, BiciMAD was intended to offer an additional option to public transport and walking on certain distances (an estimated 2 to 6 kilometers) and a complementary service (e.g., during night hours), avoiding a mass modal shift from these modes with a relatively high share in the city. Consequently, a modal shift from motorized individual modes would have been a desirable outcome after implementation, but in light of all (and, in this case, not only panel) responses, a vast majority of bike-sharing rides is replacing trips on foot or by public transport (Figure 4).

Obviously, clients frequently or eventually make use of bike-sharing on trips that would be less convenient by public transport (it would involve transfer, costs more, congestion, etc.) or active modes (hilly streets, return trip as passenger in a car, no parking facilities for private bicycle, being late, etc.) and therefore only a lower proportion of trips (4 to 6%) was before or would have been done by car or motorcycle. However, public transport and walking are still predominant modes in the city center and bike-sharing has been adopted rapidly (40,000 subscribers in 12 months, 65,000 in 24). Furthermore, bike-sharing availability could have been an influencing factor on route decisions for some people (2-3%)

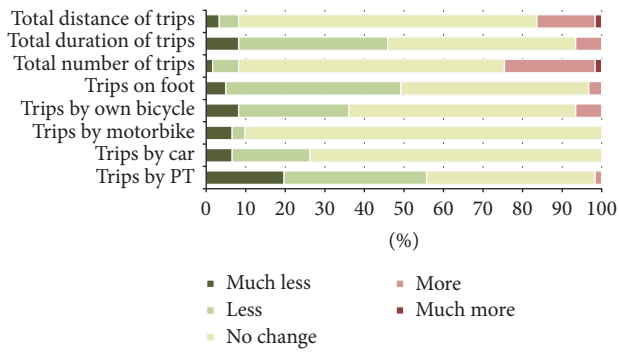

Figure 5: Impacts of bike-sharing on trips (% of respondents).

who did or would not take some of their frequent trips without the service.

Most of the panel respondents (two out of three) reported no changes in the number of daily trips; however, one out of four people travels more frequently than before starting to use bike-sharing (Figure 5). In terms of total distance of trips, there are no changes for a vast majority (three out of four respondents), but the average total trip length is higher than it was without bike-sharing. A positive effect of bike-sharing on urban mobility is that in this context the average duration of all daily trips is less after implementation; that is, people take more trips and may travel higher distances but these trips take less (perceived) time. In the comparison of travel modes there is a clear trend towards fewer trips by sustainable modes (that are mostly replaced by bike-sharing) and also by motorized individual modes to a lower extent (a high rate of "no change" may refer to using these modes neither before, nor after). On the contrary, more trips are taken only by sustainable modes (on foot, by own bicycle or by PT) and no one reports on new rides by motorbike or car.

By trip purpose, a daily (going to work or school) and a less frequent trip (going out with friends) are studied (Figure 6). Other purposes (e.g., visiting friends or relatives, shopping) may have a destination relatively far from home and probably outside the city center; therefore, some modes may not be considered as an option. For instance, the only modal shift of shopping/doing errands type trips seems to be less walking and more cycling/bike-sharing; that is in 2015/2016, people still went on foot (32%), by PT (32%) or car to do shopping (28%, for example, to shopping malls in the outskirts) and replaced walking by cycling/bike-sharing only on some trips to small shops in the city center that are not around the corner. Modal distribution of trips to work or school indicates that (1) a growing number of trips is due to increasing activity, especially in case of occasional users (decreasing unemployment rate reflected by an increasing mobility to work), (2) proportion of the use of a car has slightly increased, maybe in parallel to an increased access to an automobile and a slightly higher rate of driving license holders (Table 2), (3) share of rides on motorbike has increased in all user categories in spite of a decreasing access to these vehicles, that is, less people ride more, (4) use of bicycle/bike-sharing has increased in all user categories, and (5) the share of PT and walking has decreased.

Changes before and after the implementation of bike-sharing seem to be specific to the user category: subscribers ride bicycle/bike-sharing and motorbike instead of trips on foot; occasional users do new trips (partly due to a new job) and use PT less than before but go more by both bicycle/bike-sharing and individual motorized modes; and nonusers have nearly the same travel patterns than before: slightly more rides on two-wheelers and less by PT. The proportion of PT pass holders before and after implementation also reflects these new travel patterns.

Going out is a trip that one may take on a regular or occasional basis (only 4% in 2014 and 6% in 2015/2016 is the rate of people who report that never meet up friends) and it may be supposed that most of these trips have an origin and/or destination in the city center, that is, the bike-sharing catchment area. Furthermore, being a 24/7 service, bike-sharing is an alternative to the infrequent late night public transport schedule and its limited network as well as taxi. Whilst people who never use bike-sharing have not changed their travel patterns on these trips, the introduction of bike-sharing have influenced mode choice of both subscribers (who go more on foot and especially bicycle/bike-sharing instead of car, motorbike, and PT) and occasional users (more people take PT and bicycle/bike-sharing and less go on foot).

6. Conclusion

Characteristics, attitudes, and travel behavior before and after implementation of a smart pedelec-sharing system have been analyzed to extend the knowledge about the bike-sharing phenomenon and profile of its (non)users. This approach and this kind of panel survey is applied for the first time to understand similarities and particularly discrepancies of intention-to-use and actual use. Results may be of interest in not only the field of transport but also marketing research.

A statistical test has verified that there is a relationship between an a priori and the final decision, but only to a moderate extent. It seems that despite the availability of information about service configuration and conditions of use (by social media as well as by surveyors and contents in the online questionnaire), a certain degree of observability (as docking stations and bicycles were being installed during the ex-ante surveying period), and information or experience in other bike-sharing systems (85% had information about other schemes before implementation), not all potential users are competent to predict their decision about becoming clients. Other factors, such as opinion of peers who already use the service, exploratory tests, and a thorough consideration of its advantages in contrast to competitive modes may be of utmost importance after implementation. Consequently, about half of respondents who reported their intention-to-use have not become clients, but two out of five previous "refusers" finally started to ride on bike-sharing pedelecs. The latter indicates that, in spite of shortcomings of the introduction (lack of proper cycling infrastructure in the operational zone, a controversial pricing policy, etc.), Madrid's pedelec-sharing is finally considered an attractive public

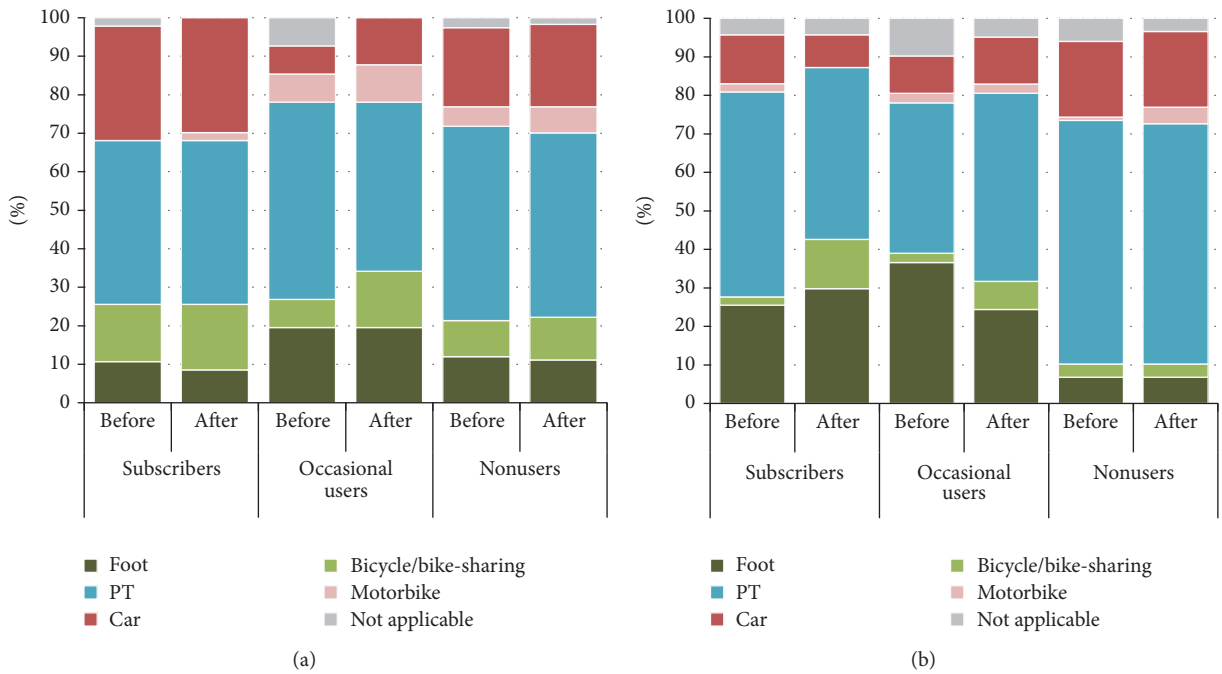

Figure 6: (a) Modal distribution of trips to work or school and (b) to go out (% of respondents).

transport service by a relevant number of tentative potential users.

The study has identified some factors that may contribute to an even more efficient promotion of bike-sharing: an extension towards other parts of the city (foreseen in Madrid), road infrastructure development to enhance the perceived and actual safety and security of cycling (foreseen), awareness-raising campaigns and promotion of exploratory use, and review of the pricing policy. The last one apparently prevents potential clients from becoming occasional or frequent users. Obviously, in case of BiciMAD, the operation of a fleet of pedelecs is much more expensive than a system of traditional heavy bikes. Therefore, price levels and a fee per each ride is said to be, in addition to being a mobility management measure intended to prevent undesirable modal shifts, not another way to increase profit, but a requisite to avoid extreme losses. Both seem to be crucial, as price levels have not been altered after the public takeover of the system operation from a private transport company two years after implementation.

Taking into account these aspects, competent authorities and service providers of any bike-sharing schemes may attract more potential users by efficient awareness-raising campaigns about the economical character of bike-sharing and by the provision of a dense and extensive network of stations from the very beginning. An intense marketing would likely have positively influenced early adoption in Madrid; thus there is still room for further advertisement of bike-sharing benefits for potential clients in the current and future catchment area. More information to target groups could have contributed to a more reliable estimation of future demand and a more realistic identification of potential user profiles, as well.

In addition to the relevance of awareness-raising, another shortcoming of the implementation of bike-sharing in Madrid was the lack of test rides during the first months of operation (occasional use was not possible from June to October 2014). In other words, first adopters had no chance to try out bike-sharing and later adopters seem to be much more dependent on their experiences by exploratory uses. Furthermore, there is a moderate association between intention and actual use; that is, decision about bike-sharing use is taken after the first personal contact with the system. In consequence, not only occasional use must be allowed from the earliest moment, but also some pilot tests have to be carried out before implementation, to adjust system configuration to actual needs and familiarize potential users with the new service.

Findings about motivators and barriers of using bike-sharing are consistent with previous results, especially about the importance of a network that fits into one's itineraries [1, 15], a key issue of recent bike-sharing research [31, 32, 43, 44]. Nevertheless, adaptation of outcomes in other planned or existing systems needs precaution in light of the review of previous literature and results of the present paper. Findings shall be interpreted in their context, that is, Madrid having a dense city center, with an extensive public transport service and walking of high modal share, with a low level of cycling infrastructure, and so on. For instance, although nonusers and occasional users of BiciMAD report on the relative advantage of using other travel modes, this is not the most influencing barrier like in other urban environments, for example, Australian cities [14], where car convenience is traditionally predominant. Demographic and socioeconomic characteristics of a social system have to also be taken into account; for example, higher income levels and age (people

in their late 20s and early 30s) seem to be more associated with the frequent use of bike-sharing in Madrid than in other cities where people of these characteristics tend to be more reluctant, for example, in Greece [17].

According to a synthesis on bike-sharing literature, its main social and environmental benefits are (1) reduced car use, (2) increased bicycle use for daily mobility, and (3) growing perception of the bicycle as a convenient mode of transport [45]. Results on the changes of individual travel behavior and urban mobility patterns in Madrid after the implementation of bike-sharing seem to verify all three: there are fewer trips by car as well as greater modal share of cycling/bike-sharing in travel to work or school and in some other trips in the city center. Peculiarly, there is varied effect on the use of motorbikes. On the one hand, the special bike-sharing bicycles, namely, pedelecs seem to be competitive on some routes; thus there is a decrease in the access to and number of trips by motorized two-wheelers. In this case, substitutive character of pedelecs may help cities to tackle air and noise pollution as well as land use (parking) anomalies by motorbikes. On the other hand, there are more rides on motorbike to work or school than before in the panel sample; that is, further investigation may be conducted to study the interrelationship of the use of pedelecs (or e-bikes) and motorcycles [46].

User categories (subscribers, occasional users, and non-users) are linked with different new travel patterns, obviously with more changes in the travel behavior of actual users, influenced also by personal, social, and economic factors (e.g., finding a job). On daily utility trips, mode choice of clients with no registration has been altered the most after the implementation of bike-sharing (e.g., share of trips by bike or bike-sharing has doubled). On less frequent trips, such as going out, both casual and frequent users are characterized by a new travel behavior; that is, bike-sharing seems to have strong effect on these kinds of trips.

There is lack of evidence whether existing bike-sharing schemes have achieved their objectives [2] and this is also a question of context as an urban mobility problem and an issue of available data as a research topic. Other studies indicate that the relationship of bike-sharing and alternative travel modes is complicated [27, 47] and this is true in Madrid as well. Despite being introduced to compete with individual motorized modes and complement public transport and walking of distances of 2 to 6 kilometers, most of the trips by bike-sharing replace the last two. This is in line with conclusions in many other cities [1] and may not be considered as a failure of pedelec-sharing as a smart mobility management measure in Madrid. On the contrary, based on the outcomes of the panel survey, it has contributed to promoting active travel, improving cycling culture, and increasing mobility (total number and distance of trips) and decreasing (perceived) travel time, which may be considered a key impact of bike-sharing.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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