Potential User Profiles of Innovative Bike-Sharing Systems: The Case of BiciMAD (Madrid, Spain)

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Abstract: The latest generation of bike-sharing, i.e. demand responsive multimodal systems are relatively new and highly innovative elements of urban mobility. Bike-sharing is also an emerging topic of urban transport and sustainable mobility related research. Due to its novelty, most scholars focus on the supply (repositioning problem, optimising the location of stations, pricing, etc.) and not the demand side problems (user behaviour and profiles, trip characteristics, etc.). The aim of this paper is (1) the analysis of the evolution of bike-sharing and the exploration of how innovative technologies have changed bike-sharing systems for users, (2) the review of cycling and bike-sharing related literature on user characteristics, and (3) the identification of user (and non-user) profiles of the latest generation of bike-sharing on the basis of an ex-ante case study on the BiciMAD system in Madrid, Spain.

Keywords: Bike-sharing, Cycling, User profiles, Innovation, Urban Mobility

1. INTRODUCTION

Bike-sharing, public bicycle share system (PBSS), public-use bicycles (PUBs), rental bike, bike hire, smart bikes, are different names of “a self-service, short-term, one-way-capable bike rental offer in public spaces, for several target groups, with network characteristics” (Büttner et al., 2011: 10). It is “the shared use of a bicycle fleet” (Pucher and Buehler, 2012: 184) - “a bank of bicycles that can be picked up and dropped off at numerous points across an urban area” (Transport Canada, 2009: 2).

Some benefits of these systems are: flexible and increased mobility options; emission reductions; increased physical activity and health benefits; reduced traffic congestion and fuel use; greater environmental awareness; increased use of public transport and alternative modes; individual financial savings; lower implementation and operation costs (in contrast of, e.g., shuttle services) and support for multimodal transport connections (Fishman et al., 2012; Shaheen et al., 2010).

The recent worldwide spread of bike-sharing schemes is due to many obvious reasons (eco-friendly, relatively cheap, efficient both individually and on first/last mile of intermodal trips, etc.) and also to the intelligent technologies that makes them easy-to-operate and easy-to-use. ITS solutions make the integration of bike-sharing systems possible in the urban transport system from both the user’s (route planning, tariffs, etc.) and the operator’s point of
view (smart redistribution, real time tracking, etc.). The latest systems feature a wide scale of innovations, such as flexible docking stations, smart redistribution, advanced pedalling technology, bicycle localization and tracking, smart access, online apps, etc. Towns and cities that introduce a bike-sharing scheme nowadays, opt for one or more of these features.

Recent growth of bike-sharing is obviously linked to the renaissance of cycling (Pucher et al., 2011; Pucher and Buehler, 2012) from the late 1990s in European, North American and Australian cities as well as to its popularity in countries of Latin America or China. This is due to many interconnected factors, such as individual (eco-friendly attitudes, cycling-friendly lifestyle, etc.), social (urban mobility problems, urbanization, etc.) and policy factors (EU transport policy, awareness campaigns and events, etc.). Reasons have been previously analyzed from many points of view in past years, including some papers on previously not studied topics, e.g. attitudes, perceptions or other characteristics of cyclists.

Bike-sharing has recently become a key topic of urban mobility and related research activity. Due to its relative novelty, most scholars focus on the supply side characteristics (repositioning problem, optimising the location of stations, network planning, pricing, etc.) and not those of demand (user behaviour and profiles, trip features, etc.). Data about users has not yet been collected, processed or analyzed on a comparable level, since most of the systems have been introduced recently, or heterogeneity of both exogenous (e.g. city size, population density, existing infrastructure) and endogenous factors (network size, service provider, etc.) make the comparison of systems difficult. Thus, studies related to the demand side characteristics are mainly for market rather than scientific research, with some exceptions included in the literature reviews by Fishman et al. (2013) and Fishman (2016). Some examples from Europe and North America are the studies of Rudloff and Lackner (2013) and Frade and Ribeiro (2014) about demand modelling (Vienna, Austria; Coimbra, Portugal) as well as Ji et al. (2014) on the simulation of critical demand and supply parameters of e-bike-sharing in a university campus (Knoxville, Tennessee, USA).

In parallel with the spread of bike-sharing programs in Asia, especially in China, there has been also a growing interest in the related scientific research. Papers focus on design (Lin and Yang, 2011; Lin et al., 2013), case studies and evaluation of systems in operation (Liu et al., 2012; Nakamura and Abe, 2014a, 2014b; Zhao et al., 2014; Zhang et al., 2015) as well as some specific demand related topics, such as Shaheen et al. (2011) on the adoption and behavioural response to the introduction of bike-sharing in Hangzhou (China) and Kim et al. (2012) on the factors that influence bike-sharing travel behaviour in South Korea.

The present paper aims to analyse the evolution of bike-sharing and explore how innovative technologies have changed bike-sharing systems for users by reviewing cycling and bike-sharing related literature on bike-sharing generations, user characteristics, and to identify potential user (and non-user) profiles of the latest generation of bike-sharing on the basis of an ex-ante case study about BiciMAD, the bike-sharing program of Madrid.

2. BIKE-SHARING GENERATIONS AND USER PROFILES

Recently, from the late 2000s, many cities have introduced a bike-sharing system as a mobility management tool - a form of promoting non-motorised trips in the city centre. The reference city in this respect is Paris, where the state-of-the-art system Vélib’ was set up in 2007. In 2015, according to Fishman (2016) and the Earth Policy Institute, there are more than 800 programs in 56 countries worldwide, more than the half of them introduced in the 2010s. Besides the pioneer Europe, bike-sharing is gaining popularity worldwide, especially in Asia, where the biggest programs are in operation (as of 2016, the biggest one is the
Hangzhou Public Bicycle program in China, with approximately 70,000 bicycles.

The evolution of bike-sharing is divided by scholars into four generations: (1) free-bike systems, (2) coin-deposit systems, (3) information technology based systems, and (4) demand responsive multimodal systems. Steps from one generation to another speeded up during the past half century. The idea of the first generation dates back to 1965, and the first urban-scale realization was in 1974. The second started in 1991 whilst a precursor of the third emerged in the mid-1990s (DeMaio, 2009) and on a city-wide level it was launched in 1998 (Midgley, 2011). A first example of the fourth generation dates back to 2005 (Pucher and Buehler, 2012).

In spite of its half-century long history, bike-sharing is relatively new as a common element of urban mobility. Due to its adaptable character and the diversity of places where it may be introduced, bike-sharing leads to continuous technological innovation. An example is BiciMAD in Madrid, Spain, which is the very first bike-sharing fleet in a big city that consists exclusively of pedal-assisted bicycles (pedelecs).

The characteristics of BiciMAD pedelecs are different to conventional “heavy bikes” of other bike-sharing systems. Firstly, due to its different speed it allows: longer itineraries (different trip habits); access to high points of the city centre (extended area of use); minor differences in speed to motorized road traffic (more varied itineraries) and less effort needed (accessible to more users). It offers improved accessibility and higher self-confidence of users in a city centre with unfavourable topography (in terms of cycling). It was expected that all these characteristics make the profile and habits of BiciMAD users different to other bike-sharing systems.

In the following discussion basic information of bike-sharing generations is given, including some information on user profiles of the first three generations. An ex-ante case study about state-of-the-art BiciMAD will be presented in order to study potential user profiles of the fourth generation.

2.1 First Generation: Free Bike Systems

First generation bike-sharing schemes are characterised by well-identifiable bikes, which may be used free of charge, without any registration or other administrative procedure. The bikes are randomly distributed in a designated zone and the safety and security of the bicycles and users is not ensured at all.

The first free-bike system was launched without considerations for transport policy. An anarchist movement in Amsterdam (Provo), created the so called “white plans” in 1965, in order to make the city face its ecological and social problems (Home, 1988). The most memorable was the “White Bicycle Plan”. Fifty well-identifiable white-painted bicycles (Witte Fietsen) were distributed in the city centre, which could be used by anybody for any trip. Since the users were not identified, they did not have to pay a fee and there were no safety or security measures (there was no system or organisation at all) and the bikes were stolen or vandalised within a very short time (DeMaio, 2009; Frade and Ribeiro, 2014; Midgley 2011; Pucher and Buehler, 2012). As per Home (1988: 65–66): “The plan proved an enormous success as a ‘provocation against capitalist private property’ and ‘the car monster’, but failed as a social experiment”. A few days later, local police collected all available white bikes from the streets of Amsterdam.

In spite of the failure of the first experiment, the “white bike” (or free-bike) concept was not forgotten. Some small cities adapted the original anarchist plan and included some transport policy considerations as well. Yellow Bikes (Vélos Jaunes) of La Rochelle, France, was launched in 1976. The Cambridge, “Green Bike Scheme” system started in 1993 but
failed like the one in Amsterdam - most of the 300 bicycles were stolen soon after their introduction (Pucher and Buehler, 2012).

In terms of mobility, users of the first generation are random (or “lucky”) pedestrians that find a bicycle on their way and are able to use it for any purpose, for example (but not necessarily) to reach a destination. In an optimal case, they use it for a one-way trip inside the system area and leave it appropriately parked on the street.

2.2 Second Generation: Coin-deposit Systems

The idea behind the new generation is a response to the problem of theft and vandalism. Bicycles are constructed from non-standard components, such as “heavy bikes” with solid rubber tires and wheels, specially designed for intense utilitarian use (Midgley, 2011; Pucher and Buehler, 2012). These bikes are available in designated docking stations after paying a small amount of deposit. The service area and location of stations are defined on the basis of transport policy considerations.

The second generation was led by small towns in Denmark. Farsø and Grenå launched its small-scale system in 1991, Nakskov in 1993 (DeMaio, 2009). Following that, the first participating large city was also in Denmark - City Bike (Bycyklen) in Copenhagen was launched in 1995 (Pucher and Buehler, 2012). After that, other cities like Sandnes (Norway, 1996), Helsinki (Finland, 2000) and Aarhus (Denmark, 2005) also opted for the new type of bike-sharing.

Due to their complexity, these systems are more expensive for cities than the first generation but they are still relatively cheap tools to develop cycling and promote not-motorised transport in urban areas. Administration of the system is carried out by non-profit organisations, which have public subsidy ensured by each local government (Pucher and Buehler, 2012). These bike-sharing schemes are not unsuccessful, however, due to the small amount of the deposit, theft has remained a challenge to be addressed (Frade and Ribeiro, 2014). In some cities ordinary bicycles were used and in this case, many bikes and their parts or units were stolen, vandalised or damaged (Zanussi, 2003).

Second generation systems are planned as a network of docking stations in an urban area (most commonly, in a city centre) but are hardly integrated into the public transport system. Thus, users might ride a bike for individual trips (beginning and ending inside the system area) or for first/last mile connections in the case of docking close to other transport modes. According to DeMaio and Gifford (2004) the research by the Danish Environmental Protection Agency about Copenhagen in 1999 is representative of all the European bike-sharing schemes of that time: most of the users of the coin-deposit systems were young adults in their 20s or 30s. Customers of Bycyklen were not only residents: as a first example of bike-sharing in a large city, Bycyklen became a tourist attraction to be “visited” (used) during a stay in Copenhagen (Haines and Skinner, 2005).

2.3 Third Generation: Smart Card Systems

Bike-sharing systems of the third generation have an improved design. Docking stations are operated by computer kiosks (user technology interface) and the service is supported by advanced technology, such as mobile apps (information, registration, payment, localisation of available bikes, etc.), magnetic stripe cards or smart cards. Identification of the user (registration) is common in all schemes of this generation, which makes the security of bikes and the responsibility of the users higher. Fees are differentiated, proportional to usage (Midgley 2011; Pucher and Buehler, 2012). In general, however, the first 30 minutes of use is
free of charge for registered users.

Smart card systems are a result of IT development in the 1990s. Portsmouth University introduced a magnetic card based system to students in 1996 on its campus (DeMaio, 2009) and the first city to launch an IT-based system was Rennes, France (Vélo à la Carte) in 1998. Third generation programs have been introduced outside Europe, as well, gaining popularity rapidly in North America (especially in the USA) and Asia (China).

During the evolution of the third generation, many steps have been taken towards functional integration. Besides installing bike-sharing docking stations in interchanges or close to public transport stops and train stations, some cities have introduced common public transport and bike-sharing access cards (administrative integration) and/or applied discounts to users of both systems (fare-related integration). These features incentivized the use of bike-sharing among public transport travellers. Furthermore, improved heavy bikes, IT-assisted administrative procedures, improved safety and security features made smart card systems an attractive alternative to some other modes (long walking, short rides on public transport, etc.).

A survey was conducted among the 2,000 users (average age: 31 years) of Vélo à la Carte in the medium-size city of Rennes in 2004 (in total, 63,000 trips recorded, 69% combined with other transport modes). The most frequent trip purposes were utility cycling (trips to work: 24%, trips to school or university: 15%) and shopping (27%). One of every two cardholders (46%) rode a shared bicycle regularly and a huge majority (92%) was “quite” or “very” satisfied with the service (Bührmann 2007). Although the smart card system in the town of Sandnes, Norway, was intended for regular use by residents, tourists became the main users in the first years of operation. Most of the users were young adults (45% between 21 and 45 years old) (Zanussi, 2003; Haines and Skinner, 2005).

2.4 Fourth Generation: Demand Responsive Multimodal Systems

Recently introduced bike-sharing systems offer a flexible, accessible and reliable mobility option. Latest systems feature innovations (Midgley, 2011; Pucher and Buehler, 2012; Shaheen et al., 2010) like: (1) flexible docking stations (e.g. in case of events) or no docking stations at all (e.g. mobile technology led smart lock); (2) bicycle redistribution innovations (automated technologies, incentivising user-based redistribution, etc.); (3) smart access- smart card integration with other transportation modes (public transport, car-sharing, etc.) or no smart card (identification by mobile apps); (4) advanced pedalling technology, power-assisted bicycles (e-bikes or pedelecs); (5) bicycle tracking (GPS, RFID); (6) state-of-the-art docking stations (solar power, touchscreen kiosks) and/or; (7) online apps (e.g. real time availability).

Each demand responsive multimodal system has a different configuration of these characteristics, we can hardly find two identical combinations. Furthermore, most cities aim to fully integrate bike-sharing into urban transport, offering a seamless link (in both physical and administrative terms) to public transport.

During the early 2000s, cycling gained huge popularity and its promotion was supported by urban transport policy in many countries worldwide, popularly known as the “bicycle boom”. That was the time when the first demand responsive multimodal system, Vélo’v in Lyon was launched in 2005, and a few years later metropolises like Paris (Vélib’, 2007) and London (Barclays Cycle Hire, 2010) also introduced their specific large scale system (DeMaio, 2009; Kumar et al., 2012; Midgley, 2011; Parkes et al., 2013; Pucher and Buehler, 2012). The introduction of Vélib’ in 2007 was the starting point of the worldwide “bike-sharing boom”.
3. CASE STUDY

BiciMAD has been implemented in Madrid at a time (mid 2014) when many experiences had been gathered from other cities, as well as when bike-sharing technology development was one of the most ambitious challenges of urban transport engineers and planners. BiciMAD is different to its predecessors and bike-sharing systems in other cities due to it having the following set of configuration:

- It is the very first city-wide bike-sharing system with exclusively electric pedal-assisted bicycles (pedelecs). A hilly city centre, like the one of Madrid, is an appropriate place to test or apply such a solution.
- All the bicycles are tracked by GPS, in order to avoid thefts.
- There is a fee per use for any trip, including the first 30 minutes for registered users (0.5€ / 30min.) in order to favour walking and public transport.
- The redistribution of bicycles is partly user-based. Users who take a bike from a highly occupied station (more than 70% occupied) or return it to a relatively empty station (less than 30%), get a discount of €0.10.
- The system is fully supported by online applications, available from mobile devices and BiciMAD stations’ kiosks.

As one of the most recent bike-sharing systems, BiciMAD represents the most up-to-date characteristics of a bike-sharing scheme. That means that a successful implementation would pave the way for other cities. Thus, understanding attitudes, opinion, willingness-to-use of the target groups is a burning issue in order to calibrate correctly systems in other cities and modify the one in Madrid (if necessary). That is why the present study aims to analyse, in the light of the evolution of bike-sharing and based on an ex-ante survey, profiles of potential users (and non-users) of BiciMAD.

3.1 Context

3.1.1 Madrid and BiciMAD

Madrid, capital city of Spain with 3.16 million inhabitants (2014), is not a ”cycling city” and its cycling culture is relatively low (Munoz et al., 2013). Some factors (existing infrastructure, mobility behaviour, topography, etc.) make cycling less attractive than in reference cities like the European “cycling capitals” or municipalities where bicycle use has gained huge popularity recently, including some towns and cities in Spain (e.g. Barcelona, San Sebastián, Seville). However, there is already a positive trend going on. The local government of Madrid has carried out some cycling policy measures, such as the development of bicycle infrastructure and awareness-raising by promotion campaigns and events. Consequently, both the length of bicycle routes (2006–2012) and the demand (2008–2012) tripled in a few years (Anonymous 2013). Based on a traffic count in May 2012 by the Municipality (Ayuntamiento de Madrid), 0.6% of the people moving in the city centre (inside the M30 ring road) were cyclists.

Right before this case study was made (i.e. in April 2014), Madrid had 316 km of bicycle routes and 1,167 public bicycle parking places. Nevertheless bicycle infrastructure is insufficient in the city centre: there is only an East-West bike lane axle, a short South–North section as well as some tracks in the University Campus. A project for installing or designating 70 km new bicycle route is in progress, with some parts having been terminated in 2014. However, most of the new network consists of shared lanes with motorised traffic on busy roads without proper adaptation.
One of the most ambitious measures of the government was to implement a bike-sharing system (BiciMAD) in three phases. The first phase, in the monumental area and central residential and commercial zone, was finished and opened in June 2014 (for registered users) and became fully operational (for occasional users as well) in December 2014. A total number of 1,580 pedelecs (with a pedal-assistance up to 18 km/h) in 123 docking stations and 3,120 racks, were installed and put in service on a 24/7/365 basis. It is operated by a transport company and financed by the Municipality through the local public parking scheme. In spite of its public service character, the bike-sharing is not managed by the regional public transport coordinator CRTM, the operator has been contracted directly by the local government.

Before implementing a bike-sharing system, as information on future users is not available, only presumptions may be made about their socio-demographic (e.g. mostly young people), current mode choice (e.g. more public transport users and pedestrians than motorists) and other characteristics. Systems are set up by local governments according to expected target group members’ supposed profile. Definition of this profile and meeting expectations are both difficult to properly achieve. Although target groups had not been explicitly defined beforehand (just a minimum age of 14 years was set), the following innovative system configuration has made BiciMAD a tailor-made system, to be an attractive alternative of motorised transport modes in Madrid (especially taking into account the insufficient cycling infrastructure in the city centre):

- flexible administration, available online by mobile devices or onsite by high-tech kiosks (easy access, no need to appear in person for registration or other matters),
- a fee per use for all trips, in order to avoid people stopping using public transport and especially walking (not to be an alternative on walkable trips or on parallel short itineraries with public transport services),
- discount for flexible users that support the system operation, especially rebalancing procedures (by pre-reservation of a docking rack; picking up a bike in a station with high or dropping it off in one with low availability),
- improving accessibility by the electric pedal-assistance of all bikes in the fleet (lower travel time compared to traditional heavy bikes; extension of the bikeable area in a certain timeframe, incl. in difficult topography; accessible for elderly and sedentary people).

3.1.2 Data and methodology

An ex-ante survey was carried out from April to June 2014, before the implementation of BiciMAD in Madrid. The aim of the research was to identify general characteristics of possible users (and groups of users), their attitudes towards cycling, their expectations and opinion about and their willingness-to-use of the service.

A survey method was applied that synthesises the benefits of personal intercept interviews (directness of the personal contact, interviewer can keep records or observations about the respondents, more representative sample) and online surveys (more confidential and honest due to anonymity and privacy, almost any type of question may be asked, relatively cheap) (Babbie, 2010). The method consists of two main steps:

- ‘interviewers’ stop members of a target group (in this case: potential future users of BiciMAD, i.e. anyone passing by the service area) onsite (nearby or next to already installed bike-sharing stations), briefly explain the purpose of the project (e.g. a new service to be implemented), invite them to participate in the survey (following a URL and entering by a personal access code), respond to their questions about the service
and/or the survey and keep records of them (gender, estimated age, other comments) as well as the place and time of surveying;

- respondents fill in a web questionnaire afterwards (at home, on-board a vehicle during their trip, etc.) by a mobile device or a personal computer and get a direct incentive or take part in a prize draw (in this case, the latter). In some cases, especially of elderly people, interviewers fill in the questionnaire on-site, by a mobile device.

Based on the outcomes of former surveys carried out in the city centre of Madrid (inside the M30 inner ring road), 12 survey zones were defined, from which 11 are in the service area of BiciMAD and 1 outside (in the future extension zone of the bike-sharing service). After a pilot survey in April 2014, the intercept part of the survey was carried out in May 2014, with half of the job done on weekdays and half on weekends or holidays.

3.1.3 Survey topics

The survey had three main topics: (1) cycling habits (bicycle use and the opinion about the factors that influence cycling), (2) the opinion about BiciMAD and the willingness to use it, (3) personal (demographic and socioeconomic) information.

Special attention was paid to the attitudes of respondents towards factors that influence their cycling habits as well as to their opinion about unique set of characteristics of a state-of-the-art new bike-sharing service, which would be implemented soon in their hometown (or workplace, destination, etc.). Although the primary target group of the survey was Madrid (and Madrid area) residents, a slightly modified questionnaire was administered among Spanish-speaking tourists as well.

Respondents had to express their opinion in the survey topics on a Likert-type scale of 0 (totally disagree or similar) to 5 (totally agree or similar).

4. RESULTS

4.1 Respondents

A total number of 12,000 people were invited to participate and 1,200 answers (100/survey zones) were expected. The final number of analysed responses is 1,859 (although, including partial responses, 2,040 answers have been gathered) - the goals of each survey zone being achieved.

Concerning motivation of stay in the survey zone, most of the respondents are residents, followed by leisure, work and study purposes. Respondents are 53% men and 47% women. The age of the youngest is 8, the oldest 87. Since the survey was filled in online, young people were more willing to answer and the median is 32 years of age. Most of the respondents have university degrees or completed secondary education. They are typically employed (55%) or students (28%). The proportion of unemployed people (9%) and pensioners (2%) is lower than their rate in society. Most of the respondents live in a family of 2 to 4 persons.

A huge majority of the respondents (97%) can ride a bike but almost 30% of them do not own one (i.e. a potential target group of a bike-sharing scheme). Those who have bicycles, typically own one (however, more than 10% own three or more). Almost two-thirds of the bicycle owners have a mountain bike, one-third of them an urban bicycle, 10% a folding bike and 10% a road bicycle.

Half of the respondents have ridden a bicycle in the past month and only one in four
have not cycled in the past twelve months. The main cycling trip purposes are leisure and sports, as well as tourism. A majority, 73% of respondents, never bike to work or school and approximately 60% never do shopping or visit friends or relatives by bike. Public transport is the typical transport mode for going to work, going out in the evening and visiting friends. Most of the respondents (80%) have a driving license. 50% is the rate of car ownership as well as monthly transport pass holding.

4.2 Factors Influencing the Use of Bicycle

The survey addressed some questions about the personal attitudes towards factors that influence cycling. Respondents had to evaluate the importance of these factors in two groups of questions (one about general factors and one about those related to the infrastructure).

![Graph showing willingness to use BiciMAD and rating of influencing factors](image)

Figure 1. Willingness to use BiciMAD and rating of influencing factors

Some questions are adapted to the specific conditions of cycling in Madrid. Topography is a crucial issue, streets being hilly in the city centre and a barrier to cycling for many people. Climate is a similar challenge, due to the hot summers (and cool or sometimes cold winters). Furthermore, the local government has introduced speed limits (30 km/h) in many shared lanes in the city centre before the implementation of BiciMAD. Most of these shared lanes are one of the three or four lanes of overcrowded avenues, where many people could find cycling to be dangerous or inefficient in peak hours. Respondents had to express their opinion about all these issues.

The questions addressed not only the opinion of the respondents but also the challenges that the government of Madrid has to tackle in order to promote cycling. Inhabitants of Madrid consider bicycle infrastructure as most important: bicycle routes, parking places as well as the efficient integration with public transport. In contrast, individual factors, such as it being economical character or cycling related lifestyle are less relevant. However, environmentally friendly characteristics are quite appreciated. Marginally, it may be concluded that people prefer using the bicycle for shopping or going out over going to work or school (they rate much higher the adaptation of public centres, like shopping or cultural centres, than workplaces or schools).
Infrastructure is crucial for any target group (Figure 1), e.g. men and women, young and elderly people, cyclists and motorists. Obviously, there are some differences in the evaluation, e.g. elderly people (60+) consider less important the price of cycling or the access of workplaces or schools. For women, the use of bicycles depends more on weather conditions, danger of accidents or the integration with public transport than for men.

Frequent utility cyclists (i.e. people who bike to work at least once a week) have the same main priorities like others (especially infrastructure development) but they do not consider important external factors like the weather or hilly streets. For them, flexibility and modernity of cycling (i.e. it fits into their lifestyle) are some of the most rated factors. This is something that the government and the operator will need to consider. Utility cyclists who do not wish to be frequent users may be not among the top target groups of a bike-sharing system.

Ratings of people who wish to use BiciMAD on a frequent basis are very similar to those of frequent cyclists, excepting the individual factors that make frequent cyclists a relatively homogeneous group. For those who plan to register in BiciMAD, weather conditions and topography are much more important than for utility cyclists and they do not feel that the use of a bicycle forms part of their modern lifestyle.

Some questions addressed general features of cycling and some important issues about infrastructure and intermodality. However, a lower number of variables and a better understanding of (unobserved or not identified, secondary, aggregate) factors seemed to be useful for further analysis and advanced statistics in the following stage of the study. Consequently a factor analysis was carried out (see Table 1; rotation: varimax raw, extraction: principal components) and three factors have been identified:

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<th>Variables</th>
<th>Factor loadings</th>
<th>“Parking and intermodality”</th>
<th>“External factors”</th>
<th>“Advantages of cycling”</th>
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<td>0.242851</td>
<td>-0.343531</td>
<td>0.533967</td>
<td></td>
</tr>
</tbody>
</table>

- **Parking and intermodality**: variables linked to parking the bike (in public spaces, at commercial, cultural and other public institutions as well as at workplaces and schools); services related to parking facilities or institutions with parking racks (e.g. locker, shower) and integration of cycling and its infrastructure with other transport modes.
- **External factors**: variables that affect cycling conditions and habits, such as climate
(e.g. that makes cycling seasonal, from Spring to Autumn). In Madrid the weather is quite favourable to cycling, although Summers are sometimes extremely hot and Winters may be cold. Geographical conditions (e.g. that makes cycling difficult or even impossible for some people in case of height altitudes) is a key topic in Madrid, due to the hilly city centre, where one can rarely take a bike ride without slopes. Cycling safety also fits into this category, i.e. the danger of accidents of cyclists as unprotected road users.

- **Advantages of cycling:** characteristics of using a bicycle that puts it in a favourable position compared with other transport modes, such as that cycling is an economical, environmentally-friendly and flexible means of transport, offering a door-to-door mobility option, easily parkable anywhere.

### 4.3 Evaluation of the State-of-the-art Characteristics

A few questions addressed the opinion of people about the latest technology of BiciMAD. In this area, two main topics are briefly described: (1) the evaluation of the fleet consisting of electric pedelecs as well as (2) the tariff system combined with a user-based redistribution scheme and supported by online applications. Both topics have been evaluated as part of the ex-ante survey (i.e. before the implementation); however, by the time of the investigation most of the BiciMAD stations and pedelecs had been already installed.

#### 4.3.1 Electric pedal-assistance

All bicycles of BiciMAD are pedelecs (electric power-assisted bicycles) - the user can choose from electric pedal-assistance and mechanical mode. In electric mode, pedalling is assisted by a small electric motor (weighting 3.5 kg), stopping if the rider is not pedalling or a speed of 18 km/h has been reached. In mechanical mode or once the maximum speed of the electric assistance has been reached, riders pedal as usual.

PEDelecs have at least four obvious benefits for BiciMAD: (1) Madrid is a hilly city, where topography is a barrier to cycling, (2) climate, especially during Summer, may be also a barrier for cycling in Madrid, (3) most of the bicycle routes are shared lanes, i.e. the cyclist has to reach a proper speed at traffic lights or junctions in order to move safely among motorised vehicles, (3) elderly people (quite usual in an aging society like the one in Madrid) would not easily opt for traditional bicycles.

According to the survey, less than 1% of bike owners have an “electric bike” (e-bike or pedelec)\(^1\). Most of them have other bicycle(s) as well (urban bike, folding bike, etc.). All of them bike more often than the average: all “electric bike” owners have ridden a bicycle at least in the past month (one third of them even on the same day) and most of them go to work/school by bike. They rate the importance of barriers below the average: climate 3.67 (average 3.92), topography 2.92 (3.42), danger 3.17 (3.83) but they give more relevance to infrastructure: bike tracks and lanes 4.67 (4.57), parking facilities 4.67 (4.29), access and parking in public centres 4.42 (4.01) as well as speed limits 4.00 (3.45).

Nevertheless, people are not familiar with pedelecs and e-bikes, a huge majority (87%) have never ridden one. Maybe that is the reason why they do not really appreciate that all BiciMAD bikes will be pedelecs - the average rating is only 3.5. (E-bike and pedelec owners rate it much higher: 4.2). People who wish to register or occasionally use shared bikes attach

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\(^1\) In contrast, as of 2012, the proportion of EPACs (electric power-assisted cycles) in new bicycle sales in Spain was 3.8% (COLIBI-COLIPED, 2013). Taking into account that EPAC sales are growing rapidly in the EU, a higher proportion of e-bikes or pedelecs is foreseen for upcoming years.
more importance to the electric pedal assistance (3.7 points) than those who will never ride one (3.2). The same is true for those who rate higher (4 or 5 points) than the average that bicycles will be “electric”, as they are more keen on using BiciMAD.

One can conclude that people have limited knowledge of electric pedal-assistance and consequently, they do not consider it a relatively important characteristic of a bicycle. As this is the very first city-scale bike-sharing system with a fleet of pedelecs, after the first months of use, a more realistic (probably more positive) evaluation may be expected. The experience of Madrid will be crucial for other municipalities to decide about the type of bicycle of a new or renewed bike-sharing scheme, especially in hilly cities.

4.3.2 Tariffs, discounts and online apps

The government of Madrid decided to apply a tariff per each use, a quite unusual measure for bike-sharing. On the one hand, the government tries to maintain the modal share of walking in the city centre, considered to be one of the highest in Europe. On the other, it is aware that a fee per each use may keep many people away from the using BiciMAD. Finally, decision-makers opted for a relatively low yearly fee of €25 (London €112, Copenhagen €112, Budapest €61, Barcelona €47.16, Brussels €32.6, Paris €29) and a relatively low fee per each use of €0.50 / 30 minutes for registered users (free of charge in other cities).

Before its implementation, the success of such a measure was more than questionable (Figure 2). Although the yearly subscription fee is considered acceptable by respondents, tariffs per use are apparently refused. They rated it unacceptable or nearly unacceptable (as well as leaving many commentaries about this topic: as three out of four people know at least one bike-sharing system in another city, many respondents are aware of the concept of free of charge use during the first 30 minutes). The idea of attracting motorists but not short-trip pedestrians seems to fail: both commuter car and motorbike drivers (1.85 points for the fee of €0.50) and people who walk to work (1.95) would hardly accept the prices per use. Tariffs for occasional users are also rejected by the respondents. Tourists rate it better than local residents.
who would use the shared bike occasionally (2.5 vs. 2.3). Maybe it is due to the fact that BiciMAD bikes are cheaper than traditional bike rental services in some cases (the latter ranging from €4 to 5 per hour and €15 to 30 per day). Nevertheless, this benefit of BiciMAD “bike rental” is limited to the service area and not for an all-day long city-wide use.

BiciMAD fosters the user-based redistribution by reducing the fees if a bike is picked up from a full station (>70% of occupancy) or returned to an empty one (<30%). Surveyed people evaluated this discount much more positively than the tariffs. Nevertheless, 13% of the people who wish to use BiciMAD would not walk more than 3 minutes and 52% of them do not plan to walk more than 3 to 5 minutes to find an available bicycle, even having a discount. That means that they would like to find an available bike at the nearest or the second nearest docking station. It is also highly appreciated that mobile apps help to locate a bicycle or reserve an end-trip docking rack. These applications may reduce the tariff by letting people know the availability of bikes and stations.

4.4 Global Assessment of BiciMAD

In spite of the officially announced inauguration foreseen for the 1st May 2014, most of the respondents (53%) had no idea about the BiciMAD project during the survey period, taking place in May 2014. (BiciMAD was finally inaugurated in late June 2014.) One of the possible reasons is that the project was first drafted by the cycling mobility plan of Madrid in 2008 and the financial constraints during the crisis made the project to be postponed. Another reason is that there was no relevant public participation in the planning of the project and no direct advertisement before the introduction, only a few press releases were published. Although BiciMAD is considered as a mobility management tool, i.e. it is designed to be attractive for urban travellers, the issue of public acceptance of the bike-sharing system and the service configuration was not directly addressed by the local government or the service provider. Those who had information about the project, heard about it from their friends or relatives (44%) or they were informed online (30%) or by traditional press (15%).

Taking into account the conditions and characteristics of the system, 57.5% of the respondents would use BiciMAD. Despite planning to subscribe (21% of all respondents), even frequent users will ride a shared bike rarely - most frequently for leisure trips, sometimes going to work or doing shopping. Leisure and sport is the top reason for occasional users (36.5% of all respondents) as well, followed by shopping. The less important motives are visiting friends and going out by night. Concerning the general opinion about the use of BiciMAD bikes, respondents think that those who will ride them the most are: (1) tourists, (2) residents for leisure trips and (3) residents for going to work or school.

Respondents consider BiciMAD a moderately effective measure to promote cycling in Madrid (an average of 3.46 points on a scale of 0 to 5). Those who have left a commentary, welcome the implementation of such a scheme but complain about tariffs (lack of a free period), limited service area in the first project phase, lack of proper infrastructure and inefficiency of shared lanes (instead of visually or physically separated bike tracks or lanes) in the city centre as well as the behaviour of motorists.

4.5 User (and Non-user) Groups

In order to identify potential user groups or target groups, this part of the study aims to identify attitudes towards the bike-sharing service to be soon implemented in Madrid, as well as properties of future users (and non-users). Socioeconomic characteristics and factors that influence cycling have been analysed. Responses of some participants of the ex-ante survey
have not been involved in this part: those who cannot ride a bicycle (approx. 3%) and tourists, who are not relevant in terms of frequent or seasonal/occasional use of bike-sharing (and are low-represented in the survey). Consequently, the total number of analysed responses is 1,694.

Based on the basic statistics, it became obvious that respondents (also due to the nature and contents of the questionnaire) have different views about BiciMAD, and have diverse opinions about testing or using bike-sharing after its implementation. As the local government did not undertake a comprehensive study about target groups (neither awareness-raising, nor marketing campaign), the present research aimed to typify local people in relation to the future bike-sharing service. The conclusion may lead to relevant information about BiciMAD: who will use shared bikes, who will reject their use and who may be targeted by campaigns after implementation.

Analysed variables are related to socioeconomic status (gender, age, education, occupation), transport (means of most frequent trips, cycling habits, attitudes towards cycling) and bike-sharing (knowledge about it, evaluation of BiciMAD’s features, willingness-to-use). Based on these variables, user and non-user profiles of the future system have been identified. This analysis may allow a refinement of the set of configuration of BiciMAD and a proper adjustment of awareness-raising and marketing activities to specific target group characteristics.

In order to divide respondents into relatively homogeneous group, a cluster analysis has been carried out. Three clusters have been identified (see Table 2), as follows:

- **Opponents and/or frequent cyclists:** On the one hand, this is a homogeneous group: these are the people who would not use BiciMAD and it would be hard to convince them. On the other, it is also quite heterogeneous, since it comprises people who use a bicycle frequently and those who almost never ride one. Middle-aged (or older) people are overrepresented in this group; most of the group members have a degree in higher education and they are working (with the highest percentage of employees and self-employees among clusters). There is a high number of frequent cyclists and walkers (who “do not need” bike-sharing). Non-cyclists are average car or public transport users. They give more relevance to cycling related factors than others, parking and intermodality being the most relevant for them when deciding about riding a bike. They know of bike-sharing systems but their knowledge about BiciMAD is average (one of every two have never heard about it). They are the more negative about BiciMAD pricing structure - they strongly criticize both the annual registration fee and the fee per use. Only a few of them would register as a frequent BiciMAD user and this is the group where occasional use has the lowest chance.

- **Vacillating and indifferent:** This is the cluster with the lowest number of elements. On average, they are the less frequent cyclists. For them, being flexible, environmentally-friendly and economical are the most important characteristics of cycling. Many members of this cluster became informed about BiciMAD for the first time through the survey, so they could not have an established opinion about it. (However, most of them have knowledge about bike-sharing systems.) Although their general opinion about BiciMAD is negative, worse than the average, they would like to use it sometimes. Registration for frequent use would be rare among them. A balanced rate of genders may be observed, with a slight majority of men. They are mostly young people, still studying. They usually travel by public transport. Also the use of motorised modes (both car and motorcycle) is over the average.

- **Fans:** Members of this cluster wish to use BiciMAD frequently. They have a relatively
positive evaluation of BiciMAD (most of them had information about the bike-sharing system before the survey), and in comparison with the other two groups it is significantly positive. Most of them are public transport users. Occupation is varied: students are in majority but inactive people (unemployed, pensioners, housewives) also belong to this cluster. Most of them are young adults, and there are slightly more women than men. They care more about cycling related factors than others, and parking and intermodality is crucial for them, closely followed by external factors. The majority have not ridden a bicycle in the past month or even more time.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling last time</td>
<td>Not in the last 4 weeks</td>
</tr>
<tr>
<td>Most important cycling</td>
<td>Infrastructure and connections</td>
</tr>
<tr>
<td>related factor</td>
<td>Advantages of cycling</td>
</tr>
<tr>
<td>Sex</td>
<td>More women</td>
</tr>
<tr>
<td>Age</td>
<td>20–40</td>
</tr>
<tr>
<td>Education</td>
<td>Mostly secondary education or still studying</td>
</tr>
<tr>
<td>Occupation</td>
<td>More students and inactive</td>
</tr>
<tr>
<td>Transport mode</td>
<td>Mostly PT users</td>
</tr>
<tr>
<td>Information about BiciMAD</td>
<td>Heard more about BiciMAD</td>
</tr>
<tr>
<td>Attitude towards BiciMAD</td>
<td>Relatively positive</td>
</tr>
<tr>
<td>BiciMAD pricing policy</td>
<td>More positive</td>
</tr>
<tr>
<td>Global evaluation of</td>
<td>Rather negative</td>
</tr>
<tr>
<td>BiciMAD</td>
<td>Will use (frequently and/or occasionally)</td>
</tr>
<tr>
<td>Willingness to use BiciMAD</td>
<td></td>
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<tr>
<td>Group size</td>
<td>735</td>
</tr>
</tbody>
</table>

5. CONCLUSION

Bike-sharing is one of the recent success stories of urban cycling policy. During a half-century-long history, bike-sharing systems have been developed from generation to generation, from a social experiment to a flexible, integrated, high-tech mode of urban transport. In terms of services to users, those of the first generation and especially the second and the third, were relatively uniform - provided by only a few companies worldwide (advertising companies, street furniture providers, etc.). The demand responsive character of recently introduced systems has led to a higher level of diversification in terms of set of configuration. Although the same service providers are still present in the market, new systems are highly adapted to city or target group specifications. In addition, engineers, urban planners, bike-sharing companies and local authorities have successfully faced the challenges of the first three generations - like thefts and vandalism (GPS tracking or localization of
bicycles), shortage of bicycles or racks (real time availability by online applications, smart redistribution) and limited integration with other transport modes (smart access cards or online access).

In Madrid, exogenous factors make the promotion of cycling and bike-sharing difficult: firstly, a city centre full of slopes and secondly, a seasonally hot climate. Both barriers are tackled by the introduction of a fleet that consists exclusively of electric pedal-assisted bicycles, easy-to-use both in hilly areas and in unfavourable weather conditions. Like in the other bike-sharing generations and other cities, young people (up to 40) in Madrid are more open to the use of shared bikes than middle age or elderly people. Also this challenge is faced by introducing a fleet of pedelecs, a type of bicycle suitable for at almost any age and any level of fitness.

Furthermore, the local government decided to introduce a unique fee structure to achieve goals related to mobility management and environmental protection: each user has to pay per each use (including registered users with annual pass). In order to prevent people not walking or using public transport, there is a wide range of discounts to incentivize user-based redistribution, i.e. to improve efficiency and eco-friendliness.

Nevertheless, the identification of three groups of users and non-users through the present study may help the service provider to adapt the system configuration to the needs and expectations of other potential users more efficiently. One aspect to be considered is the lack of information that makes people indecisive about their intention to use shared bikes and makes their expectations rather negative.

In the case study it may be seen that the implementation of a bike-sharing system is appreciated and respondents rate some of the state-of-the-art characteristics high (like mobile apps, smart redistribution). On the other hand, evaluation of the pricing structure is negative among potential users, but there is a group of respondents (“Fans”) who rate the fees much better than others. However, the real effect of such a tariff system may be observed after a few years of operation, i.e. if it will really prevent the modal shift from walking or public transport to bike-sharing and if riders will actually make use of redistribution related discounts and really help rebalancing the system as well and if the fee per each use will not discourage some potential target groups of motorists, pedestrians and public transport users from using the shared bikes. In this context, it must be remembered that “[s]mart bikes can provide additional mobility choices for transit users and pedestrians, and thereby help retain transit riders and attract new customers” and also that “[s]mart bikes can assist pedestrians reach destinations that are too far or will take too long to reach by foot” (DeMaio and Gifford, 2004: 5).

Another lesson for the local government is that not just factors like climate and topography are crucial when one decides about riding a bicycle in Madrid but also: infrastructure, parking facilities, access to public spaces and connection to other transport modes. In light of the case study, one can also conclude that “parking and intermodality” is the most relevant factor for both “Fans” (i.e. people who wish to use BiciMAD) and “Opponents and/or frequent cyclists” (who do not). It is clear that the designation of shared lanes on busy roads in the city centre of Madrid (a project of the Municipality) is strongly criticized by the survey respondents. To make the service more attractive for future users and to attract as many people as possible who at this time do not consider it an alternative to other modes, infrastructure development must be fostered by the local government. However, “Vacillating and indifferent people”, i.e. a potential target group of BiciMAD, care more about the flexible, economical and eco-friendly character of cycling, which may also be taken into account in future marketing campaigns or system improvements. Integration is another relevant issue to be addressed by the local government to attract more users (e.g. one smart card for bike-sharing and public transport) and to ensure a more efficient institutional
coordination of public services (e.g. bike-sharing service to be contracted and managed by the regional public transport coordinator instead of the local government).

The survey was designed not only for an ex-ante study but also for the analysis of BiciMAD during its implementation, by repeating it after 12 and 24 months of operation. Several aspects of BiciMAD may be studied during the next survey phases, e.g. experiences of its unique characteristics (first city-wide system of electric pedal-assisted bikes, a novel tariff system that tries to foster not only cycling but also walking), the success or failure of a new public service expected to be attractive without the actual involvement of potential users in the planning phase and no direct advertisement in the implementation phase as well as a comparison of BiciMAD with other recently introduced systems. Also the potential development of a cycling culture in Madrid or changes of the attitudes and factors that influence the use of the bicycle are some of the topics to be examined in a future research, based on the outcomes of the next survey phases.

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