UNIVERSIDAD POLITÉCNICA DE MADRID
ESCUELA TÉCNICA SUPERIOR
DE INGENIEROS DE CAMINOS, CANALES Y PUERTOS

USER PROFILES AND ADOPTION ATTRIBUTES OF INNOVATIVE BIKE-SHARING SYSTEMS: THE CASE OF BICIMAD (MADRID)

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ANDRÁS CSABA MUNKÁCSY

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ESCUELA TÉCNICA SUPERIOR
DE INGENIEROS DE CAMINOS, CANALES Y PUERTOS**

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EL PRESIDENTE

LOS VOCALES

EL SECRETARIO

Szüleimnek
To my parents

Πάντων χρημάτων μέτρον ἐστὶν ἄνθρωπος
Man is the measure of all things
(Protagoras)

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Munkácsy András

25 June 2017

Abstract

Bike-sharing nowadays is a must-have element of the urban transport system that is changing mobility patterns in cities worldwide. BiciMAD, introduced in Madrid in June 2014, is an example of the latest generation (demand responsive multimodal systems), a unique technology at the moment of implementation and a new element in the urban mobility of Madrid.

It is also a relatively new topic of academic research, thus many issues have not yet been analysed in detail. Accordingly, the introduction of BiciMAD may be considered relevant in at least two aspects: locally, as a new (active and eco-friendly) mode of transport in the specific context of Madrid, and universally, as one of the first large fleets of bicycles with electric pedal assistance (pedelecs) and as a unique smart service configuration, including advanced mobility management measures.

The present dissertation aims to respond to these research gaps. It comprises three main parts that follow the conceptual line of (1) reviewing the circumstances that influence the transition towards the massive use of bicycles and exploring the evolution of bike-sharing schemes in cities, (2) analysing a recently introduced pedelec-sharing system through user and non-user surveys and statistical methods, as well as (3) making conclusions to extend knowledge about potential user profiles, the bike-sharing adoption process and impacts on mobility in order to better understand the bike-sharing phenomenon and related travel behaviour.

A combination of personal intercepts and online questionnaires has been employed to study user (and some non-user) characteristics in three survey phases (2014: 1859 responses; 2015: 584; 2016: 534), including a before-and-after panel survey (205 responses). Statistical methods (factor analysis, cluster analysis, measures of correlation) have been applied to identify and typify groups of (non-)users, as well as reveal the determinants and evolution of their willingness to use the service.

For the analysis of bike-sharing as a new element in the urban transport system, the Innovation Diffusion Theory has been applied and amended by the employment of cycling familiarity as a potential adoption attribute. Outcomes indicate that the diffusion of bike-sharing is different from typical innovation adoption processes. One of the main conclusions is that those who report an experience of riding a bicycle in the city centre mostly are among the first and last adopters.

Impacts of BiciMAD on individual travel behaviour (mode choice, bicycle use, etc.) and urban mobility patterns (modal shift, number of trips, etc.) have also been examined. Findings indicate that it has contributed to promote active travel and improve cycling culture. It has also increased mobility (total number and distance of trips) and decreased perceived travel time, which may be considered a key impact of bike-sharing.

Resumen

Los sistemas de bicicleta pública constituyen actualmente elementos imprescindibles del transporte urbano, que están cambiando las pautas de movilidad en ciudades de todo el mundo. BiciMAD, inaugurado en Madrid en junio de 2014, es un ejemplo de la última generación (sistemas multimodales adaptados a la demanda), de tecnología única en el momento de su introducción y un nuevo elemento de la movilidad urbana de Madrid.

La bicicleta pública es un tema reciente en la investigación académica, por lo tanto, muchas cuestiones no se han analizado profundamente todavía. Por lo tanto, la implantación de BiciMAD puede ser considerada relevante como mínimo en dos aspectos: a nivel local, como un modo de transporte nuevo (activo y ecológico) en el contexto específico de Madrid, y a nivel global, como una de las primeras grandes flotas de bicicletas con asistencia al pedaleo y como una configuración inteligente única que constituye una medida de gestión de movilidad avanzada.

La presente tesis doctoral tiene como objetivo general dar respuesta a este vacío científico. Abarca tres partes clave en la línea de investigación de (1) revisar las circunstancias que influyen la transición hacia el uso masivo de la bicicleta y explorar la evolución de sistemas de bicicleta pública en ciudades; (2) analizar un nuevo sistema de bicicletas con asistencia al pedaleo a través de encuestas entre usuarios y no usuarios y métodos estadísticos; y (3) sacar conclusiones para ampliar el conocimiento sobre perfiles de usuarios potenciales, el proceso de adopción de bicicleta pública e impactos en la movilidad para entender mejor el fenómeno de la bicicleta pública y el comportamiento de sus usuarios.

Para lograr el objetivo, se ha empleado una combinación de entrevistas personales y cuestionarios en línea para estudiar características de usuarios (y algunos no usuarios) en tres fases (2014: 1859 respuestas; 2015: 584; 2016: 534), incluyendo una encuesta panel de antes y después (205 respuestas). Se han aplicado métodos estadísticos (análisis factorial, análisis cluster, medidas de correlación) para identificar y tipificar grupos de (no) usuarios y revelar los determinantes y la evolución de su disposición a usar el servicio.

Para el análisis de bicicleta pública como un elemento nuevo del sistema de transporte urbano, se ha empleado la teoría de difusión de innovaciones, incluyendo la familiaridad con la bicicleta como uno de sus atributos. Los resultados indican que la difusión de la bicicleta pública es diferente de los procesos de adopción de las innovaciones típicas. Una de las conclusiones es que los que declaran una experiencia en el uso de la bicicleta en el centro de la ciudad están entre los primeros y últimos adoptantes.

Se han estudiado los impactos de BiciMAD en el comportamiento individual (selección modal, uso de bicicleta, etc.) y también en las pautas de movilidad urbana (cambio modal, número de viajes, etc.). Las conclusiones indican que BiciMAD ha contribuido al fomento del transporte activo y a la mejora de la cultura ciclista. También ha contribuido a aumentar la movilidad (el número y distancia total de viajes) y reducido el tiempo percibido de viaje, que puede ser considerado un impacto clave de la bicicleta pública.

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1 INTRODUCTION

Urban mobility nowadays is a key issue of transport policy and research. On the one hand, based upon the study of current urbanisation processes, forecasts¹ suggest that by 2050 two thirds of the total world population will live in urban areas. In the European Union, cities are already home to over 70% of the population. On the other hand, climate change is a crucial challenge to be tackled in the 21st century and cities have to face many disadvantages and externalities of motorised traffic, such as oil dependency, air pollution, congestions, deterioration in quality of life, accidents and equity problems.

The promotion of cycling is one of the sustainable urban mobility strategies that cities apply worldwide. Some countries that traditionally foster the use of bicycles have paved the way for many others. Commitment of the local government, level of development of bicycle infrastructure, as well as cycling culture of cities in The Netherlands and Denmark are the best practices. However, there are different ways of adoption, according to specialties and potentials of each urban area.

Market of electric power-assisted bicycles is increasing dynamically as an answer to the demand by an ageing society in Western countries, growing affordability (Fishman and Cherry, 2016) and expanding environmental awareness. In light of recent technology developments, it may be expected that electric and autonomous vehicle based e-mobility will further expand in cities in the near future (Hülsmann and Fornahl, 2013) to tackle challenges of climate change, limited resources and externalities of current transport patterns (Van Wee et al., 2012).

In the late 2000s and early 2010s, many cities have opted for the implementation of bike-sharing systems, an efficient way for the promotion of the use of bicycles in city centres by increasing cycling levels and contributing to normalise cycling (Ricci, 2015). In this field, the reference city is Paris, where the state-of-the-art bike-sharing scheme Vélib' was launched in 2007. Taking into consideration that in that year there were less than 100 bike-sharing programmes globally, it seems that local governments recently consider them must-have elements of their transport system, especially in Asia, Europe and recently North America: as of 2017, according to the grey literature², there are nearly 1200 programmes in operation worldwide. As an example of the latest generation, the fully pedelec (electric pedal-assisted bicycle) based BiciMAD was introduced in Madrid in mid-2014.

Recent new ideas and developments, especially novel ICT solutions enable the improvement of urban transport services, technologies and systems (Black and Van Geenhuizen, 2006; Weber et al., 2014) to meet sustainability goals. In this regard, innovative bike-sharing systems are examples of the latest generation schemes that are characterized by a new or improved technology and/or a significantly new set of configuration in comparison to the state of the art. BiciMAD – a new travel mode in Madrid, featuring unique advanced technology and smart service configuration – seemed to comply with these conditions by the time this research and PhD project was started.

¹ World Urbanization Prospects, The 2014 Revision, Highlights, United Nations, New York, 2014

² The Bike-sharing Blog, provided by MetroBike, LLC. Data collected and maintained by Russell Meddin. <http://bike-sharing.blogspot.com/> (accessed 4/5/2017)

Quick diffusion of bike-sharing and its smart development worldwide may be linked to some recent phenomena and new mobility concepts, such as:

- Mobility as a Service (MaaS), i.e. buying mobility services instead of means of mobility, the employment of ICTs to offer a wide scale of transport services without the need for private vehicle ownership (Kamargianni et al., 2016). Bike-sharing, especially state-of-the-art schemes of the 2010s are key elements of MaaS and the strongly related mobility-on-demand concept as an efficient first/last mile connection to public transport and as an individual travel option on short trips in urban environments.
- The concept of sharing economy, especially sharing cities, i.e. “the marriage of the sharing economy in urban areas” (Cohen and Muñoz, 2016: 89) is a collaborative and more sustainable consumption pattern (Light and Miskelly, 2015) that has changed – among others – how people travel, commute or work. Bike-sharing and other vehicle sharing schemes, in response to population growth and increasing urban density, help cities to tackle congestion, pollution and traffic efficiently in the city centre (Cohen and Kietzmann, 2014).
- Smart Cities and their mobility concept of smarter urban transport networks with the use of digital and telecommunication technologies for the benefit of inhabitants and businesses³. It is a long-term complex vision to make cities better in terms of environmental footprint and quality of life for citizens (Benevolo et al., 2016). Eco-friendliness of and recent ICT applications for bike-sharing make it even more attractive for smart cities.
- Initiatives to foster sustainable urban transport, i.e. measures taken by local authorities to promote low carbon emissions and energy-efficient vehicles in order to reduce greenhouse gas emissions (Carvalho et al., 2012). Global projects include – among others – PTx2 strategy⁴ (to double the market share of public transport worldwide by 2025) by UITP⁵ and urban mobility related objectives of the Europe 2020 development strategy⁶ of the European Commission. Bike-sharing is directly or indirectly contributing to the achievement of such goals.

As bike-sharing and particularly pedelec-sharing is a relatively new topic, many aspects, mainly those related to demand have not yet been analysed in detail. Innovation in transport (Marchau et al., 2008; Ongkittikul and Geerlings, 2006) and how innovative measures change user behaviour and travel patterns are also still under-researched topics. Thus, the present dissertation aims to contribute to these research gaps, especially about user profiles, with special attention to adoption of bike-sharing as an innovation in urban mobility.

³ <https://ec.europa.eu/digital-single-market/en/smart-cities> (accessed 4/5/2017)

⁴ <http://www.uitp.org/strategy-public-transport> (accessed 21/6/2017)

⁵ International Association of Public Transport (L'Union Internationale des Transports Publics)

⁶ http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/index_en.htm (accessed 21/6/2017)

The manuscript comprises three main parts that follow the conceptual line of (1) reviewing the circumstances that influence the transition towards the massive use of bicycles and exploring the evolution of bike-sharing schemes in cities, (2) analysing a recently introduced pedelec-sharing system (BiciMAD) through user and non-user surveys and statistical methods, and (3) making conclusions to extend the knowledge about potential user profiles, the bike-sharing adoption process and impacts on individual travel patterns and urban mobility in order to better understand the bike-sharing phenomenon and the related travel behaviour.

Detailed analysis of bike-sharing systems and BiciMAD as an example in terms of operation, financing, business model or other supply side issues falls outside the scope of this dissertation. Accordingly, only the most essential information is provided in this regard.

1.1 Research project

In terms of academic research, the implementation of BiciMAD in Madrid may be considered relevant in at least two aspects: (1) locally, as a new (active, eco-friendly, innovative) mode of transport in the specific context of Madrid and (2) universally, as the first large network of pedelecs in a Western city and a smart service configuration including unique mobility management measures. Taking into account that impacts of such intervention cannot be properly explored without observations before and after inauguration, TRANSyT-UPM⁷ launched a self-financed research project in early 2014 to study potential and actual users' intentions, perceptions, attitudes and behaviour.

As of the finalization of this work, three survey stages have been finished: one questionnaire before implementation to predict future user categories (in 2014) and two more after that to understand the diffusion of pedelec-sharing and its effects on travel patterns (in 2015 and 2016). Each survey phase has had the same basis but a slightly different approach, which allows participating researchers to employ different theories and methods in data analysis and make plenty of conclusions of interest for both scholars and practitioners. Survey techniques developed by TRANSyT-UPM in a previous research – the EU co-financed City-HUB project (Hernández et al., 2016) – have been applied to reach the targeted number of competent respondents in the sample.

Such a wide-scale survey has already resulted in a number of outcomes such as research training works, master's thesis, scientific publications and, in the present case, a PhD dissertation. Thus, this outcome focuses only on one specific line of research: user profiles before and after the introduction of a new mobility option in the city, with special attention to the actual user characteristics according to the time of adoption and changes of travel behaviour. This is presented in the context of innovative bike-sharing systems through the case of BiciMAD. Other already realized and potential exploitation of the survey data (by

⁷ The Transport Research Centre of Universidad Politécnica de Madrid. <http://www.transyt.upm.es/>

other researchers, as part of the same or other research projects) is presented in the last part of the manuscript.

1.2 Thesis structure

The dissertation is structured in the classical form of a monograph, but actually it is largely based on four key papers and a variety of other publications, including book chapter, journal article, conference contribution and presentation. Although it is essentially the outcome of a research project on BiciMAD by TRANSyT-UPM from 2014 to 2017, some of its contents synthesize findings of a research activity started in 2007 on urban mobility, cycling and cycle tourism; first as a master's student at the Corvinus University of Budapest, after graduation and nowadays as a research fellow at KTI Institute for Transport Sciences and an invited lecturer at Corvinus University of Budapest in Hungary, as well as in-between as a PhD student and pre-doctoral research fellow at Universidad Politécnica de Madrid in Spain.

Concerning the internal structure, the dissertation has three main parts (Figure 1):

Figure 1: Thesis structure with chapter and subchapter numbers

- Part I reviews the broad context, namely evolution of cycling, definition and diffusion of bike-sharing in urban mobility (Chapter 2); provides a more focused overview of the literature about the users of state-of-the-art bike-sharing systems, presents the specific case of innovative pedelec-sharing in Madrid, and, accordingly, defines the research questions and methods (Chapter 3);

- in Part II, results are presented in three chapters that are based on papers for publication: identification of underlying factors of bicycle use in Madrid and clusters of potential users of a bike-sharing system before implementation (Chapter 4); study of the adoption of bike-sharing as an innovation, using two key elements of the Innovation Diffusion Theory, namely adopter categories and adoption attributes (Chapter 5); analysis of the willingness and actual use of bike-sharing by measures of association, as well as its impact on travel patterns through mobility indicators (Chapter 6);
- Part III highlights key findings and answers research questions, provides specific and global policy recommendations, analyses compliances with other research outcomes, as well as discusses limitations and future research directions (Chapter 7).

Survey questionnaires are attached as annex to this manuscript.

As mentioned above, chapters 4 to 6 are scarcely modified versions of papers for publication, i.e. these parts may repeat some contents regarding the context (mobility in Madrid, technology of BiciMAD, etc.), the methodology (e.g. survey technique) and some interconnected results. All these parts have their own introduction (including motivation and literature review), as well as particular findings, which may make them readable even separately. However, the slight modification of each paper was intended to adjust them to the line of research defined in this Introduction.

Chapters discussing research questions have the form of a paper: all have an abstract style brief summary (“In this chapter”) at the beginning and a conclusion or summary at the end.

One can find the basis of the present thesis in a set of publications⁸ (and papers under review and/or accepted for presentation) as an external framework of the dissertation, see in the Annexes.

⁸ These are not directly referenced in the text.

PART I: CONTEXT

Part I: CONTEXT

- **Evolution of cycling in cities**
- **Definition, characteristics and diffusion of bike-sharing**
- **Case study**
- **Research gaps, research questions and methodology**

Part II: RESULTS

- Potential user profiles of pedelec-sharing
- Adoption of bike-sharing as an innovation
- Association of the intention-to-use and actual use
- Impacts on travel patterns

Part III: FINDINGS

- Key findings and answers to research questions
- Policy recommendations
- Compliances with objectives and other research results
- Limitations and further research directions

2 REVIEW OF THE EVOLUTION OF CYCLING AND BIKE-SHARING

In this chapter

Based on an extensive literature review, this chapter sets the broad context about the use of bike-sharing in urban environment nowadays. After a review of individual, social and policy related factors that have resulted in an increase of bicycle use, the definition, characteristics and evolution of bike-sharing is described. Due to its wide perspective and new approach, this is not only an introduction to the empirical research, but also an outcome of the dissertation, based on a specific research question.

Increasing popularity of the use of bicycles and bike-sharing is a visible trend in cities of the developed world. Cycling boom from the 1990s (Heins and Wazlak, 2010; Lanzendorf and Busch-Geertsema, 2014; Pucher and Buehler, 2005; Pucher et al., 2011a; Pucher et al., 2011b) seems to be a precursor of the bike-sharing boom of the late-2000s and the 2010s: as has already been mentioned, in 2016 there were ten times more bike-sharing systems worldwide than ten years earlier (Figure 2).

As of the end of the year. Source of data: The Bike-sharing Blog⁹, MetroBike, LLC

Figure 2: Number of cities with a bike-sharing system worldwide

To set the scene and identify key research gaps, a preliminary research question (RQ0) is formulated about the evolution of cycling and bike-sharing in this chapter, such as:

RQ0: What factors have contributed to the recent popularity of bicycle use and a quick global spread of bike-sharing schemes, and what is the current practice of bike-sharing in light of its evolution?

It is not common to define a “number 0” research question for the literature review, but here the answer is expected to be more than a mere introduction to the research topic before upcoming analytical chapters in Part II. First, it is likely to find interconnected phenomena, circumstances and procedures that have led to the prosperity of non-motorized two-wheelers in urban contexts. Second, it is to provide a new comprehensive definition of bike-sharing in light of its relation to other mobility options and its evolution.

Methods to answer RQ0 are twofold. On the one hand, a thorough systematic literature review has been carried out, highlighting three groups of factors that may have influenced

⁹ <http://bike-sharing.blogspot.com/> (accessed 17/6/2017)

the use of bicycles in the past two decades. To conduct the literature search (by the online engines of Web of Science¹⁰ and Google Scholar¹¹), keywords related to the three factors (e.g. individual motivation, society, policy *and* bicycle, cycling, bike-sharing) have been used. Snowballing procedure has been applied to extend the study (Wohlin, 2014). On the other hand, some parts of the definition of bike-sharing – namely its description in the context of the use of bicycles, rental schemes, e-cycles and other shared modes – is mainly the summary of the current practice and knowledge, on the basis of an overview of existing bike-sharing services (especially information on official websites). As this is a new approach in the literature about bike-sharing, parts of Chapter 2.2.1 without direct references include some new findings by the author.

Obviously, there are great differences in terms of cycling popularity in cities, from country to country and even within one country. Bearing this in mind, the review has a European perspective with an eye on connotations from other parts of the (Western) world.

2.1 Factors influencing the spread of cycling in cities

Utility cycling (i.e. seasonally or more frequently regular and at least partly multitudinous cycling done as a means of transport, and not a sport or leisure activity) has gained importance in developed countries recently, especially in urban and suburban areas. The rapid expansion (popularly: the cycling boom) seems to be the result of many interconnected factors, and nowadays also some probable upcoming steps may be outlined. However, it is difficult to make a comprehensive and up-to-date analysis on the basis of exact data, since cycling and its role is changing dynamically: by the time the data of cycling in European cities were homogenized and synthesized, most of them would have already been changed and, thus, not valid any longer. That is what one of the most recognised researchers of cycling, John Pucher (2011b) says, while arguing in favour of a new version of his prior article (Pucher et al., 1999), about the bicycle use in North America: “It is now over a decade later, and much has happened during the intervening years. Cycling infrastructure has grown dramatically in many cities, and more programs are now in place to encourage cycling [...]. Some cities report a doubling or tripling in cycling levels since 2000” (Pucher et al., 2011b: 451).

Lack of data is a classical barrier of the research on cycling. On European and global level, there is no harmonisation and no interconnectedness between different databases on lower levels (Ensink and Haubold, 2015). Another problem is not having data on bicycle use independently (Monzón and Rondinella, 2010), but with other means of transport, e.g. motorbikes or pedestrians¹². A publication of the European Commission (TRT, 2010: 27) states that “[u]nfortunately there are no reliable single international or European statistical

¹⁰ <http://www.webofknowledge.com/>

¹¹ <http://scholar.google.com/>

¹² For instance, the latest edition of the Barometer of the European Metropolitan Transport Authorities (EMTA) about urban mobility in Europe in 2015 provides data on “sustainable transport modes”, i.e. cycling and walking together.

reports showing modal share of bicycle use per country, related to all journeys”, and only a few steps have been taken forward in this field from then on. Comparison of the use of bicycles in countries with a research activity above average (in Europe, Australia, North America and China) requires data mining in many cases and allows the analysis with certain limitations.

As per the study of the Commission, based on data from 2003 to 2008, the highest rate of cycling in Europe was in the Netherlands (26% bicycle modal share in all journeys), Denmark (19%) and Germany (10%). The most recent data of ECF¹³, outcomes of a Eurobarometer research on the quality of transport based on face-to-face interviews in the 28 EU member states (see Figure 3) is from 2014. On a typical day, bicycle is the most often used mode of transport for 8% of respondents (car 54%, motorbike or moped 2%, urban PT 19%, train 2%, walking 14%). This indicates an increase of the share of cycling (that was 7% in a similar Eurobarometer survey in 2011), walking (13%) and use of automobile (53%), but a decrease in public transport (22%).

Including urban and non-urban mobility. Source of data: “Quality of Transport” report¹⁴, Special Eurobarometer 422a, p. 11

Figure 3: Bicycle modal share in EU28 countries

Eurostat¹⁵ does not collect the data of cycling regularly and systematically, the only related statement of its Highlights of the Panorama of Transport (Mahieu, 2009: 5) is that cycling (and walking) “do have their place in EU-27 cities”¹⁶, and a more important role in North European cities. The yearly statistical pocketbook of the European Commission, “EU transport in figures” does not include data about cycling mobility (only fatalities) as per its

¹³ European Cyclists’ Federation

¹⁴ “On a typical day, which mode of transport do you use most often?”, answer: “Bicycle”, surveyed in October 2014, N=27.868.

¹⁵ The statistical office of the European Union

¹⁶ The 28th member state, Croatia joined the European Union in 2013.

most recent version of 2016. UITP key statistics included data on cycling and walking together (30% in global short distance transport; private motorized vehicles: 55%, public transport: 15%) in its 2014 edition¹⁷, with no up-to-date information in current versions. Data about bicycle market and industry (CONEBI, 2016) shows that the number of European bicycle sales is constant since 2003 (approximately 20 million units per year) and has increased slightly (by 5%) from 2012 – the lowest point in ten years – to 2015. Sales of electric power-assisted bicycles, i.e. e-bikes and pedelecs are growing rapidly in Europe and have reached 1 million units in 2014.

A number of studies aimed to describe the role of bicycle in the urban transport system in the past years, concluding that cycling lost position in modal share during the last decades of the 20th century (Ligtermoet, 2009; Pucher and Buehler, 2008) and that there has been a renewal, a *renaissance* going on in the European, North American and Australian cities from the late 1990s (Pucher and Buehler, 2012; Pucher et al., 2011b). There is a recent burgeoning of studies about the growing market of e-bikes and pedelecs in Western countries (Astegiano et al., 2015; Fishman and Cherry, 2016; Fyhri and Fearnley, 2015; Haustein and Møller, 2016a; Jones et al., 2016; Lee et al., 2015; Plazier et al., 2017; Rios et al., 2016) and its complex trends in China (Cherry et al., 2016; Ling et al., 2015) as well.

Reasons and motives of the recent cycling boom may be studied from several points of view. Factors influencing bicycle use has been analysed quite actively in recent years (Chatterjee et al., 2013; Fernández-Heredia et al., 2014; Heinen et al., 2011; Macmillan et al., 2014; Muñoz et al., 2013; Panter et al., 2013; Pikora et al., 2003; Pucher and Buehler, 2012; Rietveld and Daniel, 2004; Saelens et al., 2003; Santos et al., 2013). Based upon a literature review including the above mentioned papers, the present study analyses the development of the role of cycling in urban and suburban areas on the basis of three aspects: (1) individual motivations – urban citizens and their organised or spontaneous groups, (2) social trends – urban-suburban society, urban development and urban mobility related issues, as well as (3) (transport) policy drivers – decision-makers and decisions. The enlisted factors not only explain why cycling has become popular and gained success worldwide, but also why this process takes place in our days and why do decision-makers nowadays opt for measures that promote cycling.

2.1.1 Individual motivations

Cycling is an efficient, eco-friendly, cheap and reliable means of transport, active and healthy mode of travel. Bicycle is a door-to-door vehicle in urban areas, available for almost everyone, everywhere, every time. It is faster than walking, public transport or motorised private vehicles on short trips and an efficient complementary mode as a first or last mile connection. It is space saving (compared to other vehicles) as well as easy to park and store. These characteristics make it attractive through the evolution, popularity and spread of *values, norms, attitudes and forms of behaviour supporting cycling-friendly lifestyle*. According to findings of intercultural research in social psychology, values are converted into action when

¹⁷ <http://www.uitp.org/key-eu-statistics> (accessed 31/5/2014)

they are relevant in a context and important to the individual (Schwartz, 2012). In this regard, keywords like sustainability (sustainable mobility, sustainable transport, etc.), social and environmental responsibility, eco-friendliness, carbon footprint, zero-emission vehicle, localism, healthy and active lifestyle, equality and equity nowadays are influencing travel patterns in developed countries. Cycling is one of the options to conduct such a modern way of life (Banister, 2008; Haq et al., 2008; Neuvonen et al., 2014; Van Acker et al., 2016). Although there are a few barriers and inconveniences of behavioural change towards a bicycle-friendly lifestyle – like bad weather conditions, topography or risk of accidents –, cycling is available on most days of the year (on almost a 7/365 basis for a growing number of enthusiast cyclists), new technologies of electric power assistance make it convenient in hilly areas, and health benefits¹⁸ exceed any risk of being killed or seriously injured (Pucher and Buehler, 2012). Additionally, the feeling of liberty and trendy (chic) fashion associated with cycling has made it one of the symbols of modern urban lifestyle, and cycling culture seems to be a determinant of quality of life in cities.

Increasing number of trips and share of utility cycling in urban areas is partly due to riding a bike as a sport or leisure activity, i.e. *recreational cycling and cycling tourism*. Experiences during leisure cycling trips, cycling day visits, cycling holidays and holiday cycling (Keeling, 1999) may foster casual or regular use of the bicycle as a means of utility transport. This is also how the infrastructure has been developed: cycling tourism paths were typically built, signed and marked before tracks and lanes for utility cyclists in urban and suburban areas. In most European countries, many low-traffic side roads, forest paths, river or lake embankments have been designated as part of a cycling tourism way, many disused railway lines have been converted into cycling and walking routes (greenways), and many touristic bike tracks have been constructed, where cycling tourism could become and actually became popular. From 2013, EuroVelo, the European cycle route network initiated by ECF forms part of TEN-T, thus its development is an objective on EU-level (Piket et al., 2013). Although elements of the EuroVelo network¹⁹ comprising 15 routes were defined as long-distance cycle routes (2000 to 8000 km each), most cyclists use it for local or short inter-urban journeys and cycling tourism is also concentrated on relatively small parts of these routes. That means that before adopting EuroVelo as part of the TEN-T, realization depended mostly on local or regional initiatives. As local governments are not necessarily able to (co-)finance such projects, a European-scale project definition and management (ongoing by ECF) may result in better conditions and more people on bike: both tourists and utility cyclists. Although a number of researchers have identified a positive effect of recreational cycling on utility cycling (Goodman et al., 2014; Lee et al., 2012; Park et al., 2011; Xing et al., 2010), there are conflicting findings as well (Lois et al., 2015).

¹⁸ According to the World Health Organization (Edwards and Tsouros, 2006), walking and cycling for transport are considered highly feasible ways to achieve the goal of accumulating at least 30 minutes of activity each day to tackle the challenge of dramatic increases in the frequency of chronic diseases, obesity and sedentary lifestyles in Europe.

¹⁹ <http://www.eurovelo.com/>

Acting for each other and for a community, i.e. *volunteering*, NGOs and other civil associations of cyclists have gained importance throughout the developed world and, nowadays, their activity is highly supported by online technologies. In many countries (e.g. in Central and Eastern Europe) these organisations were spreading explosively in the 1990s, after the political changes, and many people joined one to participate in civil projects or lobbying activities (impossible in some countries before). Accordingly, local, national and European cycling representations were formed or strengthened at the end of the 20th century and they have gained importance in both promoting the use of bicycle and taking part of decision-making processes on all levels. ECF is a key non-profit organisation in Europe, and there are some national associations, references in their field, such as the Dutch Cycling Embassy in the Netherlands, Cycling Embassy of Denmark, ADFC²⁰ in Germany or Cycling UK (formerly Cyclists' Touring Club or CTC)²¹. Despite some insights into the role of civil society in cycling (transport) related issues (Carley et al., 2013; Portney and Berry, 2014; Poutiainen et al., 2013), this is quite an under-researched topic.

2.1.2 Social trends

Cycling is traditionally considered a means of transport that is most popular among mainly young or middle aged low-status people with no access to a car (Lois et al., 2016). Nowadays this affirmation is true primarily in low cycling countries (Pucher and Buehler, 2012), while in Northern Europe – the Netherlands, Denmark and Germany (Pucher and Buehler, 2008), i.e. countries where urban cycling has the highest modal share worldwide – the use of a bicycle is not so dependent on gender, age or social class. Although reasons of gender differences are not explored completely and gender seems to be linked more to cycling culture than to bicycle use (Fernández-Heredia et al., 2014), a higher proportion of cycling women is correlated positively with the share of cycling in the transport system and vice versa (Aldred et al., 2016; Garrard et al., 2008; Pucher and Buehler, 2012). The world population is aging due to increased longevity, declining fertility and the aging of baby boom generations (Bloom et al., 2011), but in a safe and convenient environment elderly people also cycle, like in the above-mentioned countries. Research outcomes concerning socioeconomic status are often inconsistent or contradictory; however, equality also in this field is more common in the “cycling countries” (Pucher and Buehler, 2012). Accordingly, in countries where attitude, culture and transport policy all support cycling, socioeconomic and demographic status do not lead to inequalities in terms of bicycle use. In other words, changes of attitudes in many countries may lead to *equity*, i.e. a pro-cycling environment to make cycling attractive for people of any socioeconomic background. The best practices may be seen in countries that are key references of the promotion of cycling.

Reurbanisation is the dominant *urbanisation* trend in cities of the developed world (Haase et al., 2013; Rae, 2013; Rerat, 2012). Return to the inner city is the key process of urban migration nowadays (Rae, 2013). Although there are contradictions in the previous work, a

²⁰ German Cyclists' Association (Allgemeiner Deutscher Fahrrad-Club)

²¹ In Spain, a similar entity is ConBici (a group of associations in defence of cycling, founded in 1992) and its 60 local member associations, such as Pedalibre (association for cycle tourism and urban cycling) in Madrid.

recent study (Santos et al., 2013) concluded that population (with some territorial restrictions) and higher population density – i.e. typical characteristics of inner cities – are favourable for cycling. From another point of view: traditionally smaller extension of European cities, consequently shorter distances of travelling, contributes to having a higher proportion of cycling than in larger-scale North American cities (Pucher and Buehler, 2008). As per Bassett et al. (2008: 795) “[c]ompact, dense cities with mixed land uses that generate short trips” make Europe more successful in the promotion of urban cycling than Australia or North America. Other researchers (Newman and Kenworthy, 2006, 2011) – on the basis of the Marchetti Wall theory²² (Marchetti, 1994), studied in North American cities – concluded that the diameter of a walking city is approximately 5 to 8 km, a transit (i.e. public transport dominated) city 20 to 30 km, and an automobile city 50 to 60 km. Consequently, it may be deduced that the diameter of a cycling city is about 12 to 18 km. This is the scale of many European cities and towns, including for example the “cycling capitals” of the world, Amsterdam and Copenhagen.

According to the *peak car use* theory, due to several interconnected factors, such as relatively high fuel prices, slowing population growth, population ageing, increasing urbanisation (reversal of urban sprawl), growth of a culture of urbanism, policy intervention, the growth of public transport, as well as hitting the Marchetti Wall, level of growing trends in private car use and automobile dependency have decreased or slowed down from the late 20th and early 21st centuries (Newman and Kenworthy, 2011; Van Dender and Clever, 2013) or the trends even turned negative (Puentes and Tomer, 2008). Car access-focused urban design has also ceased in our time (Newman and Kenworthy, 2006). A key form of substitution, besides the use of public transport and walking, is cycling.

Cities are facing plenty of challenges in the field of transport. Air pollution, traffic congestion, physical and financial barriers of infrastructure development, insufficiency of the current infrastructure (lack of road capacity, parking problems, etc.) create externalities, such as reduction of life quality, health problems, growing economic and social costs of urban life, and increasing social inequalities. In line with all economic, environmental and social (equity) dimensions of sustainable mobility, tools to tackle these challenges are limitation of motorised transport, as well as promotion and stimulation of the use of public transport and non-motorised modes, like walking and cycling (Macmillan et al., 2014; Pucher and Buehler, 2012; Rietveld and Daniel, 2004; Santos et al., 2013). Thus, as part of a complex package of mobility management measures, especially for relatively short distance journeys and first/last mile connections (Kumar et al., 2012), cycling is one of the solutions for some *urban mobility problems*. Furthermore, electric power assistance may increase the role of cycles in tackling challenges by overcoming geographical barriers to cycling (e.g. greater distances, disadvantageous topography, climate), especially in ageing societies. Besides fully electric

²² Based on a former research of Yacov Zahavi, Cesare Marchetti made up the theory that human being is willing to travel not more than approximately one hour per day, due to anthropological and biological instinct or determination (Marchetti, 1994). In line with technology development, distances travelled in one hour have changed dramatically. Hitting the Marchetti Wall means that people living in a city designed for private cars – “Automobile Cities” (Newman and Kenworthy, 2011) – are not able to commute any longer within 60 minutes.

cycle — such as e-mopeds, e-scooters and e-bikes — pedelecs combine the advantages of e-mobility and active mobility by electric assistance to pedalling.

The development of cycling is restrained by a number of barriers (Clay, 2008), such as individual factors (e.g. lack of skill and confidence, no physical activity), social and cultural factors (e.g. car-oriented society), physical and environmental barriers (e.g. bad urban design, gaps in bicycle infrastructure, bad condition of cycling facilities) as well as safety concerns (unsafe road traffic, aggression of motorists, fear of crime, etc.). Key barriers of cycling are risks of accidents (Mayes et al., 1996), that is to say, real and perceived safety (Thomas and DeRobertis, 2013). Main determinants of fatalities and serious cyclist injuries are road design and condition, the motorist and the cyclist. Influencing factors are speed of motorised vehicles, the weight and design of motor vehicles, the lack of protection of cyclists, their visibility, vehicle control and alcohol consumption (Pucher and Buehler, 2012; SafetyNet, 2009). Proportion of cyclists is 10% in road fatalities in the European Union²³ and most of the serious accidents occur in urban areas. However, rates of injuries and fatalities show a decent reduction recently (Mullen et al., 2014), most probably due to specific transport policy interventions (e.g. infrastructure development, prevention campaigns, education) and primarily to the spread of cycling. This is a social phenomenon, the so called critical mass effect or the safety in numbers (Jacobsen, 2003). *Safety in numbers* means that the number and rate of cyclists is correlated positively with the growing safety of cycling (both real and perceived)²⁴. A recent systematic review of the literature indicates “the existence of a clear safety-in-numbers effect” (Elvik and Bjørnskau, 2017: 281). Accordingly, many cities have increased the modal share of cycling, and cyclists’ injuries reduced (Pucher and Buehler, 2012), but there are huge differences among countries: for instance, fatality rates per capita are 2 or 3 times higher in the United States than in most Western European countries (Buehler and Pucher, 2017).

2.1.3 Policy drivers

Objectives and targets of cycling have become part of the *European transport policy* in the beginning of the 21st century, due to a fundamental challenge of any transport related policy on EU-level: climate change. On a theoretic level, cycling is in line, first of all, with the elements of the “resource efficient Europe” target group of Europe 2020, such as decoupling economic growth from resource use, shifting towards a low carbon economy, promoting energy efficiency and modernisation. The role of cycling in achieving these targets is defined by transport policy²⁵: promotion of cycling is a means of obtaining a clean urban transport, by contributing to face congestion, air and noise pollution, as well as oil dependence.

²³ According to the 2016 edition of *Transport in Figures* by the European Commission. Countries with high modal share of cycling face the highest proportion of road fatalities of cyclists (by type of vehicle): the Netherlands 28%, Hungary 21%, Denmark 19%, Germany and Austria 14%. In Spain, it is 6%.

²⁴ The background is Smeed’s law. R. J. Smeed determined in 1949 that by the increase of the number of cars, the number of fatalities is growing (in absolute terms) but the number of fatalities per car is reducing (in relative terms).

²⁵ White Paper, *Roadmap to a Single European Transport Area, Towards a competitive and resource efficient transport system*, European Commission, 2011

Although cycling is not a focus point of the current transport policy²⁶, the Green Paper on urban transport²⁷ explicitly includes the development of cycling as a tool towards free flowing towns and cities as well as a greener, smarter, accessible, safe and secure urban transport.

Increasing the “value” of bicycle transport may also be measured by the changes of the cycling lobby’s viewpoints. The European representation of cyclists, ECF made a declaration in 2007 (in Berne) that cycling should be accepted as an equal mode of transport, and that “all relevant European policy documents – on transport, climate change, land use and spatial planning, public health and social issues – must make clear, specific reference to the advantages of cycling”. Undersigning cities of the Charter of Brussels by ECF in 2009 called upon all authorities worldwide and at all levels to strongly promote cycling and to incorporate cycling into all areas of policy. In two years, the Charter of Seville stated that “[n]owadays many cities are moving away from car-oriented transport policies and towards the concept of ‘cities for people’ by prioritising walking, cycling and public transport”. By this time, the objectives of ECF became rather specific, like gaining support from the national authorities or making Sustainable Urban Mobility Plans (SUMP) mandatory for large cities with more than 100.000 inhabitants (ECF, 2011). In 2012, in the Charter of Vancouver, the focus point was that, in line with having an increasing role in transport policy, cycling should form part of *all* sustainable transport policies and strategies. From 2013 onwards, aims are linked to intermodal mobility as well as the role of cycling in meeting urban trends such as energy efficiency, climate protection, public health, as well as individualization, digitalization, new lifestyles and increasing diversity, as per the Vienna Memorandum of Mayors’ Cycling Summit²⁸. In sum, the objectives of the European cycling lobby have changed dramatically in a few years, and it seems that the emphasis has shifted away from cycling *as a problem* to cycling *as a solution*. However, many cities are a long way off being cycling-friendly municipalities and therefore lobbying still has much to do to draw decision-makers’ attention to bicycle related issues. As a latest action at the moment of finalization of this PhD project, ECF has prepared a draft of a potential future European cycling strategy²⁹, which may be a step forward to further growth of cycling in the EU.

National cycling policies (or cycling related topics of national policies) are derived basically from the European transport policy. There are national cycling strategies (e.g. UK) and strategies for sustainable mobility (e.g. Spain) as well as action plans for increasing transport

²⁶ It is worth mentioning that former transport policies (such as the EU White Paper on Transport of 2001) did not pay explicit attention to cycling. Documents on European level even in the 2000s had to affirm the role of cycling such as these: “national framework for urban transport policy should consider cycling in an integrated context with other urban travel and land-use policies” (ECMT, 2004: 14); “[f]acilitating walking and cycling should become an integral part of urban mobility and infrastructure design” (EU White Paper on Transport of 2001: 8); “local and regional authorities should ensure that these modes [walking and cycling] are fully integrated into the development and monitoring of urban mobility policies” (EU Green Paper on Urban Mobility of 2007: 6).

²⁷ Towards a new culture of urban mobility, European Commission, 2007

²⁸ A document signed by 16 city mayors at the ECF Velo-City 2013 in Vienna. http://velo-city2013.com/wp-content/uploads/Vienna_cycling_summit_memorandum_Velo-city2013.pdf (accessed: 28/4/2017)

²⁹ https://ecf.com/eu_cycling_strategy (accessed 24/6/2017)

safety, including safety of unprotected travellers like cyclists. In cities (urban and suburban areas), *local strategies* or policies have been defined, taking into account the specialities of the municipality. At the end of the 20th century, European Commissioner for the Environment, Ritt Bjerregaard stated that “the worst enemies of the bicycle in urban areas are not cars, but longheld prejudices” (Dekoster and Schollaert, 1999). Obviously, most cities were not able to eliminate or avoid all prejudices, but most of them have taken steps towards a more bicycle-friendly city. Most successful cities in developing cycling are those that have a consistent, continuous and integral transport or cycling policy (Ligtermoet, 2009, 2010). “One key lesson is that no single strategy is sufficient [...] [c]ommunities must implement a fully integrated package of measures” (Buehler and Pucher, 2012: 42), including gender and age considerations, safety issues, promotion, traffic calming, integration with public transport, compact urban development, training, regulation, etc.

Europe’s leading position in the field of the promotion of cycling (versus e.g. North America) is only partly due to the topography of urban areas and longer average trip distances. A main reason is public policy (Pucher, 1997), meaning infrastructure built by any government level, bicycle priority over cars and campaigns fostering cycling. Most of the top bicycle-friendly cities have a *sustainable urban mobility plan* and/or local cycling strategy, (co-)finance infrastructure projects, launch transport safety and cycling promotion campaigns as well as paying attention to the reduction of socioeconomic and demographic inequalities in the field of bicycle use.

Local or national governments, typically in cooperation with NGOs, promote cycling by *events, campaigns, competitions* or other marketing tools. There are international or European-scale events, such as European Mobility Week and Car-free Day in September of every year or Earth day on 22th April. Critical Mass, a demonstration of cyclists on urban roads usually takes place on these dates. “Bike to work” and “Bike to school” are few-week-long competitions of workplaces, schools and individual utility cyclists. Bicycle-friendly organisations (workplaces, school, public institutions, etc.) are rewarded in many cities. Opening city centres or a few roads to cyclists and other non-motorised transport modes during weekends and holidays is common in South American cities but there are European and Northern American examples as well. There are tenders for the (co-)financing of cycling-friendly infrastructure projects and other initiatives (e.g. bicycle fleets in companies). In some countries, e.g. UK or Belgium, companies can pay a price per km to their employees if they go to work by bike or there is tax deduction on a national level.

NGOs and other lobbyists forced local and national governments to modify the *traffic rules* of cycling. In Europe, most of these are based on the Vienna Convention³⁰, with some supplementary regulations added by the signing parties, such as equipment to ensure cyclists’ visibility (e.g. reflectors), minimum age for cycling, standards for children’s bicycle seats and helmet legislation (SafetyNet, 2009). Besides basic and traditional concepts (bicycle track, bicycle lane, etc.), special infrastructure elements, traffic signs and traffic lights have become part of the rules, and some of them have been specified, e.g. speed of bikes or

³⁰ Vienna Convention on Road Traffic, UN Economic and Social Council, Vienna, 8 November 1968

priority in crossings. New elements of bicycle infrastructure have been defined, such as advanced stop boxes/lines, shared lanes or parking and P+R facilities. A key and still controversial topic is helmet legislation. Cycling associations oppose them, since it does not reduce the proportion of head injuries, and a mandatory helmet wear seemingly makes cycling less popular (Pucher and Buehler, 2012).

Share of cycling decreased before the crisis even in The Netherlands, Denmark or Germany. However, this crisis is not the one of the early 21st century, but the one of the 1970s³¹. In these three countries, from the level of 50–85% of 1950, due to the rapid advance of private car use (Ligtermoet, 2009), share of cycling fell to 14–35% to 1975. After that, through transport policy decisions based on environmental, energy and safety concerns, the level of cycling started to increase again, and became 20–43% in 1995 (Pucher and Buehler, 2008). Crisis was not the only but an important factor in these changes. Cycling has been a *beneficiary of the crisis* of the 2000s, as well: households, companies and politics were having difficulties, and the bicycle was a solution for some of them. Families had increased costs due to new credit conditions, many people lost their jobs, incomes were lowered due to the austerity of companies and governments, etc. People had to sell the third, second (or the only) family car and had to find a cheaper mode of transport, e.g. bicycle. That was the time when companies in Belgium or the UK, instead of financing expensive company cars, started to motivate and reward people for going to work by bike and they began to purchase bicycle fleets. For local governments, also facing serious financial problems, promoting cycling was a *quick win*, an easy and cheap way of infrastructure development (compared to public transport or other road infrastructure projects). For example, bike-sharing systems, a key topic of the present study, are relatively cheap and even quick and easy to be installed and implemented. In Paris, first 10,000 bikes and 700 stations were put in operation within six months after signing the contract (Midgley, 2011). Furthermore, cycling is linked to positive keywords like modern, up-to-date, state-of-the-art, smart, chic or trendy, which make it a top item of urban development initiatives nowadays.

2.2 Definition and evolution of bike-sharing schemes

There are different ways to improve the conditions of cycling in urban mobility. Infrastructure development is not the exclusive but probably the most spectacular way of its promotion. For many people, campaigns, events or other short-term policy measures cannot mean such a concrete and durable solution for the improvement of cycling conditions and the rise of awareness like the construction of a bicycle track or the installation of bike racks. The efficiency of the huge variety of measures that promote cycling is still an under-researched topic.

³¹ The first period when cycling gained popularity was also during a crisis, at the end of the 19th century: “Between the late 1880’s and early 1900, the United States experienced a bicycle craze with millions of Americans buying and riding two-wheelers. [...] The peak years of bicycle popularity were also years of severe depression” (Tobin 1974: 838–840). However, that time people with low income could not buy a bicycle.

Thanks to modern urban design and civil engineering concepts, as well as adapted traffic rules, a wide range of facilities may be constructed or designated nowadays, such as:

- bicycle route facilities: standalone paths, cycle tracks, bike lanes, contraflow lanes on one-way streets, bicycle boulevards, adapted shared road, etc.,
- parking (end-trip) facilities: racks, locks, bike cages, parking stations, etc.,
- integration with other modes of transport: bike racks on buses, adapted space on rail cars/buses, B+R facilities, etc.,
- bike-sharing systems, i.e. a combination of an urban mobility service and a physical and/or digital infrastructure (a network of docking stations and/or a fleet of bicycles available through positioning and smart locking by an online application).

Although cyclists are participants of road transport, bicycles are human-powered and not motorised vehicles. Consequently, bike-riders are slower and more unprotected than others on the road (but obviously faster than pedestrians). Its infrastructure is closer to the motorised rather than pedestrian traffic but many circumstances justify having an independent or even separate path for cyclists. A classical antagonism of cycling infrastructure development is *separation* or *integration*, i.e. how to redistribute the roads: separate or integrate cyclists with motorised road traffic. Response of urban designers and civil engineers depends on peculiarities from city to city, from mobility culture to mobility culture. However, it seems that integration has gained significance recently, which can make cycling infrastructure development relatively cheaper and faster than before. Criteria and policy concerning separation and integration is quite clearly defined in some European cycling-friendly countries nowadays, first of all, in The Netherlands (Pucher and Buehler, 2012) and Denmark, which can make cycling safer on any kind of infrastructure.

Taking a bicycle on public transport is another controversial issue of cycling related measures. Regional and long-distance trains and ferries transport bicycles on-board as a general rule (folding bikes may be carried also on buses and other urban transport means) and usually there are options to carry bicycles as luggage on buses and planes, as well. However, in urban transport, only rail systems (suburban train, metro and light rail services) provide for the carriage of bicycles, sometimes with time restriction (off-peak or only non-working days) or other limitations (sufficient free space, no wheelchairs on board, etc.). Other public transport services rarely offer bicycle transportation on-board or by providing bike racks, since there are concerns about passenger safety and risk of accidents. Furthermore, capacities of buses and other urban public transport vehicles are limited and in dedicated on-board spaces other passengers (e.g. with reduced mobility or with a baby pushchair) have priority. Front bike racks have been applied in some North American and Australian cities but not in Europe. On-board bike transportation on regular urban bus services is rare (e.g. on some bus lines in hilly areas of Budapest, Hungary).

There are no such controversies about the worldwide success of another measure, namely bike-sharing, thanks to its global diffusion in a relatively short time, widespread popularity and spectacular recent IT development. This is one of the most complex bicycle systems (a combination of a transport infrastructure and a mobility service), which integrates private

and public transport characteristics, providing not only a first or last mile connection to many people, but responding to the demand of many target groups in its service area, such as residents who do not own bicycles or do not have bike storage facilities, as well as casual cyclists and tourists. Recent developments make this eco-friendly service a highly innovative mobility management tool that answers various demand related challenges.

In this subchapter, a new approach to the definition of bike-sharing is presented: its relations and context, as well as its history from the 1960s.

2.2.1 Bike-sharing: a comprehensive definition

Bike-sharing, public bicycle share system (PBSS), public-use bicycles (PUBs), rental bike, cycle hire, bicycle transit, smart bikes, are different names³² 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” (Gris Orange Consultant, 2009: 2). It “involves the provision of a pool of bicycles across a network of strategically positioned ‘bike sharing stations’, typically distributed in an urban area, which can be accessed by different types of users (i.e. registered members or occasional/casual users) for short-term rentals allowing point-to-point journeys” (Ricci, 2015: 28). Recently, there is a growing market for the fully online application based dockless or stationless bike-sharing systems as well (Fishman, 2016). In the present study, the term “bike-sharing” is used to name the above defined service and system. As the case study is about a fully electric pedal-assisted fleet, pedelec-sharing is also used as a subcategory of bike-sharing.

Some benefits of bike-sharing systems are (Anaya et al., 2012; Ferrando et al., 2007; Fishman et al., 2012a; Shaheen et al., 2010):

- flexible and increased mobility options;
- emission reductions;
- increased physical activity and health benefits;
- reduced traffic congestion and fuel use;
- greater environmental awareness;
- improved road safety, especially for cyclists;
- increased cycling levels, promotion of the use of bicycles;
- increased use of public transport and alternative modes;
- individual financial savings;
- lower implementation and operation costs (in contrast of, e.g., shuttle services);
- minimum amount of land is necessary;
- improved accessibility;
- support for multimodal transport connections through enhanced transport choices;

³² Its most common name is bike-share or bike-sharing in the US and Australia, cycle hire in the UK and public bicycle in China related literature.

- better support of local economies and tourism;
- enhanced image and liveability of cities.

Bike-sharing combines pros of a private cycle and a public transport service, offering not only a near zero emission, but also a healthy alternative to motorized or other sedentary vehicles. To properly define bike-sharing and to place it in the urban mobility system, its further relation to other modes and forms of use are described below.

2.2.1.1 *Public and private characteristics*

Bike-sharing is “an individual mode of public transport” (Dell'Olio et al., 2011: 89), incorporating characteristics of a public transport service and a private means of transport. In this term, it is similar to other shared modes (especially, car-sharing) but different as an active mode of mobility.

As a private mode, shared bikes are strongly similar to regular bicycles. However, due to its public character, it is usually adapted to special requirements: bike-sharing systems usually include heavy bikes (instead of traditional urban bicycles) to resist intensive usage and vandalism, unique components to avoid theft, tracking devices (GPS, RFID) to be localizable, simplified setting mechanisms to be easily adaptable to the needs of any user, etc. Shared bikes feature many of the advantages that make a bicycle attractive and competitive with other modes of transport (efficiency, eco-friendliness, reliability and predictability of travel time, physical activity, and relatively economical price and costs). Furthermore, it lacks drawbacks like the need for storage space, risk of theft and maintenance requirements.

In other terms, it is more similar to a public transport service. Public bike-sharing is not a door-to-door service and bicycles are available at a network of stations in a distance of 300 to 600 meters, i.e. stop distance of an urban bus or tram line. However, there is neither service frequency (no timetable; but not all the systems operate on a 24/7 basis) nor pre-defined itinerary: bike-sharing users may ride any time and choose any route between two stations, without the need for passing by other stops. Similar to bicycles, bike-sharing is also a seamless transport service but what makes a difference, it is not only physically but also often administratively linked to public transport (fares, access, etc.). Bike-sharing is open to the public, but not all cities provide the service to the general public, e.g. tourists or non-residents might not be allowed to ride a shared bike or only under the same conditions as local citizens.

Some systems are partly or completely financed by public funds, which may generate loss to the society as in the case of other public services. In most cases, systems are sponsored or subsidized by private companies, like other public transport services (advertisement on vehicles, at stations, etc.) or even in another manner (e.g. by selling the naming rights of the service, see Santander Cycles in London³³). There is public control on the service, not only as an authority to enforce the law but also as a competent authority to properly provide a public service.

³³ Formerly: Barclays Cycle Hire

Urban bike-sharing is designed nowadays as an element of the urban mobility system, comprising public transport characteristics, such as:

- bike-sharing is a public response to travel demand,
- bike-sharing is a service and infrastructure for public use (Anaya et al., 2012),
- bike-sharing systems meet quantitative (number of bicycles and stations defined to mobility needs) and qualitative requirements (safety and security, comfort, aesthetics, etc.),
- having network characteristics (as a system of docking stations within an urban area),
- efficiently contributing to urban mobility flows (to achieve co-modality),
- cooperating with other transport modes (e.g. as a first/last mile connection, through integrated access conditions).

Unlike public transport, bike-sharing is not a collective, but a shared individual mode of transport, i.e. users cannot ride the same vehicle simultaneously; they may make use of a public fleet of vehicles at the same time.

Considered a first/last mile service, bike-sharing is gaining significance in transport planning to provide people with better connectivity to public transport with environmental, health and mobility benefits for individuals and society (Griffin and Sener, 2016). According to recent research, one of the major benefits of bike-sharing is positive impact on the use of public transport (Ma et al., 2015), especially rail and metro services. Bike-sharing tends to be more substitutive in larger and denser cities, as well as more complementary in small to medium size and less denser cities (Martin and Shaheen, 2014; Shaheen et al., 2013; Shaheen et al., 2014).

2.2.1.2 *Bike-sharing vs. individual cycling*

During their evolution (see below), bike-sharing bicycles have become different from regular bicycles due to security concerns, and then fleets have been developed to be adaptable to the context of a city, easy-to-manage by operators and bicycles have been improved to be flexible to some extent and easy-to-use by an average user. Average bike-sharing bicycles are robust, vandal-resistant and weigh more than regular bikes and come with special built-in accessories for both costumers (lights, rack, basket, etc.) and operators (e.g. GPS localizer). In some aspects, all these items may make it safer (Martin et al., 2016): e.g. robust design discourages fast and reckless lane splitting; solid structure and wide tyres resist more to potholes; and integrated lights (with automatic switch-on in many systems) increase visibility. Recent developments, especially smart locking technologies facilitate the application of unique, but lighter and more streamlined bicycles for large bike-sharing schemes, such as the mobile app based dockless Mobike in Shanghai (China).

As mentioned above, the infrastructure of cycling has been improved worldwide to promote zero-emission cycling as opposed to polluting cars, to create safer conditions for vulnerable road users (e.g. children and elderly people) and to encourage cycle tourism in order to stimulate the local/regional economy. In addition, several other programmes of cycling measures have been carried out over the past decades; nevertheless, there are still several

barriers to cycling that remain largely unstudied. In this sense, the term barrier can refer to many different types of obstacles for cyclists, such as:

- individual factors: e.g. lack of skills and confidence, sedentary lifestyle, no physical activity, ownership of bicycles,
- social and cultural factors: e.g. car-oriented culture, lack of bicycle promotion (e.g. in early age),
- safety concerns: unsafe road traffic, aggression of motorists, fear of crime, etc.,
- physical and environmental barriers: e.g. distance, exposure to weather, bad urban design, gaps in bicycle infrastructure, bad condition of cycling facilities, lack of integration between cycling and other means of transport.

Research findings indicate that bike-sharing may provide a solution for some of these barriers (Griffin and Sener, 2016), such as no need for space for storage, secure parking on street as well as how it may be used in case of specific trip chain characteristics (taking not all the trips in a chain by bike, e.g. returning as a passenger in a car) and distance (one may take part of the trip by public transport – with no need to carry bicycle on-board – and then change to bike-sharing).

2.2.1.3 *Bike-sharing vs. bike rental*

Bike rental is traditionally a service for tourists in cities. Bike-sharing may replace it in case of a tourist-friendly service configuration, including easy access and competitive prices. Casual use without registration is not allowed in some schemes, e.g. service conditions of Bicing, the partly pedelec-based bike-sharing of Barcelona clearly says: “What are not Bicing and electric Bicing? They are not public bicycle rental systems for tourism and recreation. They are modes of transport and ideal complements to the conventional public transport of the city. Their aim is to serve short daily trips that are made in Barcelona”³⁴.

On the one hand, competitive character of bike-sharing and rental is discussed only by promotional and informational communications³⁵, arguing that rental companies usually offer a wide selection of bicycles (type and frame size) both for adults and children, equipment (including helmets and child seats), and additional services (provision of tourist information, guided tours, etc.), as well as advance reservation options and standard hourly or daily fees. In this case, tourists may face problems with bike-sharing due to special service conditions (e.g. no on-site registration, only certain credit cards are accepted to pay deposit), limited availability of bicycles at nearby stations, temporary restrictions (e.g. closed docking stations due to events), one size for all heavy bikes, lack of kid-carrying options, unpredictable final costs, and pressure to return the bicycle in a certain period of time to avoid extra fees. (However, bike rental services may also make users pay extra charges for delays in returning bicycles.)

³⁴ <https://www.bicing.cat/es/informacion/que-es-bicing-y-bicing-electrico> (accessed 3/5/2017)

³⁵ E.g. <http://www.bikeroar.com/articles/city-bike-vs-rental-debate> (accessed 21/6/2017)

On the other hand, in a monumental city centre fully covered by the bike-sharing network and short distances between attractions, bike-sharing is an option without the shortcomings of rental bikes (especially security issues, namely that users have to lock it safely whenever stopped, as well as the need to take it anywhere, i.e. one cannot take a long walk or hop on public transport). Furthermore, urban tourists usually take short rides between long stops (visit to a monument, walk in a park, have lunch, etc.) and most bike-sharing schemes are intended especially for travelling in the city centre for not more than 30 minutes.

The first specific study on the relation of tourism and bike-sharing (Kaplan et al., 2015) is aimed at evaluating market potential for tourists, as well as understanding bike-sharing attractiveness, frequency and purpose of use. The review of the limited literature on tourism demand in bike-sharing concludes that it may be a sustainable solution and contribute to protect scenic, sport and historical conservation areas as a substitute for or complementary to public transport. Furthermore, domestic and international tourists tend to form a large demand group for such systems.

2.2.1.4 Electric power assistance in bike-sharing

Using electric power-assisted bicycles in bike-sharing is a new phenomenon in urban mobility and only limited knowledge is available about experiences on technology, costs, impacts and user behaviour. E-bike-sharing and pedelec-sharing are responses to challenges in the promotion of bike-sharing in a city, such as geography and land use (hilly topography, low density areas, long distances, etc.), as well as society and lifestyle (ageing population, low cycling culture, sedentariness, etc.). Although a costly inversion by cities, emerging technologies, especially solar power stations and use of alternative energy for battery charging may make these schemes more sustainable both in environmental and economic terms. It is expected that electric power assistance in bike-sharing is an affordable and efficient alternative to motorized modes (e.g. motorcycles) and a complementary service to public transport in cities with some of the above-mentioned barriers to traditional cycling and bike-sharing.

Recent emergence of the topic is reflected by an increasing research interest from 2014. Study of the first e-bike-sharing of North America in the University of Tennessee, Knoxville (Ji et al., 2014; Langford et al., 2013) indicates that the most influential factors in the decision about using the service are speed and convenience, and that speed and comfort make them more attractive than regular bicycles. E-bike-sharing is replacing mainly walking in Knoxville; however, there are only two stations (one of them fully solar-powered) with a capacity of seven e-bikes and three regular bicycles each in a university campus that is hilly and geographically spread out (found less attractive for the use of a regular bicycle).

Both e-bikes and bike-sharing systems are rapidly growing in China, thus a mode choice survey and a multinomial logit model has been used to identify the factors that may influence modal shift to bike-sharing and e-bike-sharing in Beijing (Campbell et al., 2016). Conclusions show that, in comparison to traditional bike-sharing, e-bike-sharing would attract individuals with specific socioeconomic backgrounds (males of young to middle age, with low income and educational levels). In the context of a megacity, bike-sharing may have

success in areas of high density and diversity of attractions, where people may take short trips. The e-bike-sharing choice seems to be more tolerant to trip distance and also to environmental conditions (precipitation, temperature and poor air quality). Both modes tend to draw users from walking, cycling and regular e-bike, and e-bike-sharing may replace trips by bus, as well.

Survey among a representative sample of university students examines factors that may influence the use of an e-bike-sharing system in Mons (Belgium). The project (Ioakimidis et al., 2016; Rycerski et al., 2016) reveals that besides weather conditions, insufficient cycling infrastructure and convenience of other modes (mainly public transport and regular bicycles) may hinder the introduction of the scheme. System design is in the focus of some other contributions about future e-bike-sharing schemes, namely location of charging stations to integrate pedelecs into the bike-sharing system of Munich (Paul and Bogenberger, 2014) or effects on the low voltage network through a simulation (Thomas et al., 2015).

2.2.1.5 Bike-sharing and other shared modes of transport

Vehicle sharing systems have been implemented in many cities worldwide to solve the first/last mile problem and fill the gap between the advantages of private vehicles and public transport (Kaspi et al., 2014). Shared modes are used both as individual modes for short trips and as part of longer intermodal trips, usually as the first or last mile connection to public transport in urban and suburban contexts. Most of these schemes (nearly all bike-sharing systems and most of the other vehicle sharing schemes) are one-way, i.e. users may pick up a vehicle close to their trip origin and drop it off later next to their destination. The research community has been quick to review the early history, impact and prospects of sharing systems (Nair et al., 2013; Shaheen and Cohen, 2007; Shaheen et al., 2010).

Bike-sharing and some less frequent similar cycle sharing schemes (e.g. a tricycle sharing pilot test in the Madison BCycle bike-sharing programme, Wisconsin, US; the combined e-kick-scooter and pedelec-sharing system in Kaposvár, Hungary) are different to other systems in being human-powered (active) travel modes, with benefits for the society and environment by less air and noise pollution, less greenhouse gas emissions, and less congestion, as well as better individual and public health by increasing physical activity to avoid obesity, diseases and time and cost of their treatment (Deenihan and Caulfield, 2014; Johansson et al., 2017; Pratt et al., 2014).

Unlike the above sharing systems of a fleet of vehicles available in a network of stations, ridesharing is a communication technology-based carpooling, i.e. one-time shared rides on very short notice by mobile apps and social networks, a controversial phenomenon in many cities. Smart app based dockless systems have a similar concept, with some first examples

worldwide, such as in Shanghai (China), Austin (Texas, US) and a pilot programme in Cambridge (UK), called “Uber for bikes” by the media³⁶.

2.2.2 Generations and global diffusion

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 were more than 800 programmes in 56 countries worldwide, more than half of them introduced in the 2010s. The latest data by The Bike-sharing Blog shows that there are nearly 1200 urban and non-urban systems at the end of 2016 (Figure 4), with approximately 2.3 million bicycles worldwide (1.9 million in China) and 11,000 pedelecs. Besides pioneer Europe, bike-sharing is gaining popularity worldwide, especially in Asia, where the biggest programmes are in operation (as of 2016, the biggest one is the Hangzhou Public Bicycle system in China, with approximately 70,000 bicycles), the US and Australia.

Figure 4: Number of bike-sharing systems by continent at the end of 2016

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

³⁶ Uber for bikes: how ‘dockless’ cycles flooded China – and are heading overseas. <https://www.theguardian.com/cities/2017/mar/22/bike-wars-dockless-china-millions-bicycles-hangzhou> (accessed 4/5/2017)

China’s “Uber for bikes” startups are being taken for a ride by thieves, vandals, and cheapskates. <https://qz.com/919739/chinese-bike-sharing-startups-like-fofo-and-mobike-are-being-taken-for-a-ride-by-thieves-vandals-and-cheapskates/> (accessed 4/5/2017)

trips, etc.) and also to the intelligent technologies that make them easy-to-operate and easy-to-use. ITS solutions make the integration of bike-sharing and other urban transport systems efficient from both the user's (route planning, fees, 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 (or no docking at all), smart redistribution, advanced pedalling technology, bicycle localization and tracking, smart access, and online apps. Towns and cities that introduce a bike-sharing scheme nowadays opt for one or more of these items.

As mentioned above, popularity of bike-sharing is obviously linked to the *renaissance* of cycling in Western countries and to its traditional popularity in countries like China. Reasons have already been analysed from various viewpoints by scholars.

Employing insights from diffusion theory, Parkes et al. (2013) have identified some key drivers of the recent fast global spread of bike-sharing: entrepreneurship in both the public and private sector; business models (especially in Europe) that allowed local governments to tackle sustainability issues like congestion and pollution through a public service financed by private entities; its fast and mass adoption thanks to its obvious advantages for users, in contrast to some other mobility management measures, such as congestion pricing or public transport projects; as well as the facilitator role of reference cities like Lyon (Vélo'v, 2005), Paris (Vélib', 2007) and examples on a more local basis (e.g. London for the UK and Montreal in Canada). Global tendencies have shown that success of bike-sharing is dependent on political, policy and public support, and that sustainable systems are established in a positive cycling culture and an environment of pro-cycling policy (e.g. reflected by measures like the provision of good quality bicycle infrastructure) and increasing bicycle use levels (Ricci, 2015).

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. In the following section, basic information of bike-sharing generations is provided, including some information on user profiles of the first three generations.

2.2.2.1 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 zone or all along the centre of a city. Safety and security of the bicycles is not ensured at all.

The first free-bike system was launched without consideration for transport policy by a local government. The anarchist movement Provo created the so called “white plans” in Amsterdam 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). 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.

2.2.2.2 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 deposit, which is reimbursed to the user upon returning the bicycle to a station (as in the case of shopping carts). 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, Naksø in 1993 (DeMaio, 2009). Subsequently, the first participating large city was also in Denmark; City Bike (Bycyklen) in Copenhagen was launched in 1995 (Pucher and Buehler, 2012) followed by other cities like Sandnes (Norway, 1996), Helsinki (Finland, 2000) and Aarhus (Denmark, 2005), which 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 non-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 users of the coin-deposit systems were young adults in their 20s or 30s. Customers of Bicyklen were not only residents: as a first example of bike-sharing in a large city, Bicyklen³⁷ became a tourist attraction to be “visited” (used) during a stay in Copenhagen (Haines and Skinner, 2005).

2.2.2.3 *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, etc.), magnetic stripe cards or smart cards. Identification of the user (registration) is common in all schemes of this generation, which increases the security of bikes and the responsibility of the users. 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 programmes 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 walks, 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:

³⁷ Bicyklen of Copenhagen was upgraded to a 4th generation pedelec-sharing in 2014.

24%, trips to school or university: 15% and shopping: 27%). One out of two subscribers (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 (Haines and Skinner, 2005; Zanussi, 2003) was intended for regular use by residents, tourists became the main demand group in the first years of operation. Most of the users were young adults (45% between 21 and 45 years old).

2.2.2.4 Fourth generation: multimodal demand responsive 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) such as: (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 card integration with other transportation modes (public transport, car-sharing, etc.) or no smart card (identification by mobile apps); (4) advanced pedalling technology, electric 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; one 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.

As seen above, cycling has gained huge popularity during the 2000s and 2010s, and its promotion was supported by urban transport policy in many countries worldwide, popularly known as the cycling 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), London (Santander Cycles, 2010) and New York (Citi Bike, 2013) also introduced their specific large scale system (DeMaio, 2009; Kumar et al., 2012; Midgley, 2011; Parkes et al., 2013; Pucher and Buehler, 2012). As mentioned above, the introduction of Vélib’ in 2007 was the starting point of the worldwide bike-sharing boom.

Some conclusions may be drawn about these recently implemented systems:

- 1) Modern bike-sharing systems incorporate high-level *IT solutions*. As most of them have been launched in the past years and both hardware and software are relatively easy, a continuous updating to state-of-the-art technologies is feasible and rational. Mobile devices are available for the majority of inhabitants of cities in the developed world. These devices are beginning to integrate many functions and services related to transport, including the latest bike-sharing systems.
- 2) Recent developments have led towards *flexibility*: flexible (e.g. portable) docking stations, flexible user interface (online kiosks, mobile apps), flexible (e.g. user-based) redistribution, flexible registration and payment, etc. Such a high level of demand responsive improvements may make bike-sharing a “semi-private” system (e.g. by integrating workplaces, schools or even blocks of houses, providing a door-to-door or “gate-to-gate” transport alternative). It is a form of promoting the use of private

bicycles, by improving its conditions and eliminating its barriers (difficulties of storage, problems of security, lack of adaptation of workplaces and schools, etc.).

- 3) Another way of taking into account the demand is to improve bike-sharing schemes in line with *target group specifications*. It may affect physical design, such as adapting the current one size bicycle to the needs of other users (e.g. children), integrating options for transportation of people (e.g. baby seat) or goods (cargo bikes), or including pedal assistance for people who ride a bike with difficulties in hilly areas or even in any circumstances (e.g. elderly people). Or it may affect the service, such as systems that award users who pick up a bike at an overcrowded station or drop it off at an empty one. (These users are ready and able to walk, instead of using the nearest station.)
- 4) A relevant step may be the high level of *integration with other transport modes*, bike-sharing systems providing a first/last mile connection. As per Midgley (2009: 23), “[t]hese ‘smart’ bike-sharing systems provide the missing link between existing points of public transportation and desired destinations, offering a new form of mobility that complements the existing public transport systems”. In everyday use, that would mean that travellers could rely on shared bikes as part of the public transport system, i.e. they could reserve a bike for a section of their trips, pay the fee by an integrated mode on an integrated platform, or opt for a combined travel pass. Integration with the private car is also a topic to be widely considered in the future (park-and-bike schemes).

2.3 Characteristics of bike-sharing systems

A general structure for the study of bike-sharing system characteristics was defined by the project consortium of OBIS (Optimising Bike Sharing in European Cities), a project co-financed by Intelligent Energy Europe from 2008 to 2011. The project (1) enlisted the characteristics of bike-sharing systems, (2) created a structure for the analysis of any bike-sharing systems and (3) defined key attributes and indicators for the study of the efficiency of a system (Büttner et al., 2011). In the upcoming chapter of the present study, points (1) and (2) are applied, that is to say, the case study will be described in line with the proposed structure.

According to the OBIS project, bike-sharing systems are influenced by *endogenous* and city specific *exogenous* factors (Table 1). The latter are hard to be managed by (transport) policy measures, since they are difficult to be changed or modified, such as city size and density, climate, mobility behaviour, safety and security or factors like demography, economy, geography, finance or politics. The OBIS Project, on the basis of case studies realised in European cities, came to some general conclusions about exogenous factors: in larger cities it is more likely to have a high-tech, 7/24 system; in warmer countries it is more likely that the bike-sharing system operates 365 days a year; and small and medium cities offer longer periods free of charge.

Endogenous factors are divided into *physical design* (components and service) and *institutional design* (business model: service providers and contracts, costs and financing), reviewed in detail in the following subchapters.

Table 1: Exogenous and endogenous factors of bike-sharing schemes

EXOGENOUS FACTORS	ENDOGENOUS (POLICY SENSITIVE) FACTORS			
	Physical design and service		Business model	
	Components	Service	Service providers and contracts	Costs and financing
— City size	Bicycles (robust, unique design, one size for all, advertising space)	Size and density (no. of bikes, docking points, etc.)	Operators (local government or authority, non-profit group, university, transport agency, advertising company, street furniture provider, bike sharing business)	Capital costs (infrastructure, implementation)
— Climate		Registration (one-time, daily, weekly, monthly, yearly)	advertising company, street furniture provider, bike sharing business)	Running costs
— Mobility behaviour				
— Population density		Information (websites, apps, maps, terminals)	Contracts (ownership, responsibility, contract length)	Operational financing sources (charges, advertisement on infrastructure)
— Safety and security	Docking stations (low-tech, high-tech, advertising space)	Target groups (commuters, tourists, leisure users, business)		
— Demographic factors		Availability (24h or limited, seasonal)		Subsidies (direct subsidies, advertisement contracts, sponsorships, parking enforcement or congestion charges)
— Economic factors		Charges (period free of charge, increasing or decreasing price per time unit)		
— Geographic factors and topology	Access technology (card-based, RFID, code-based, key, staff in charge)	Public transport integration (information integration, physical integration, access and charges)		
— Existing infrastructure				
— Financial situation				
— Political situation				

Adapted from The OBIS Handbook (Büttner et al., 2011: 17, 28)

2.3.1 Physical design and service

2.3.1.1 Components

Bicycles have become unique (and not only uniquely painted anymore) during the evolution of bike-sharing, and they differ substantially from private use bicycles. Although there are

some differences from vendor to vendor (from designer to designer), basic characteristics are unique design, robust construction, durability, weatherproofness, ease-of-use, one adaptable size for all, resistant to vandalism or thefts (Büttner et al., 2011; Midgley, 2011). Heavy bikes usually come with airless, puncture resistant tyres, front and rear lights, an adjustable seat, and can shift a few gears. Some systems offer lock as well. If the user would like to stop on route between docking stations, however, docking stations are the safest and most secure places to lock the bikes. Since theft and vandalism is present in all systems³⁸, bicycles are becoming more and more unique (e.g. customised, not interchangeable parts) and more and more robust (Pucher and Buehler, 2012). GPS and/or Radio Frequency Identification Unit (RFID) are every time more common components of the bicycles to allow localization or tracking.

A *docking station* may be (a) fixed-permanent, (b) fixed-portable (easily portable modular stations), (c) flexible or free-placement model, where bikes need to be locked to any stationary object in the service area, typically at crossroads and there are dockless or stationless systems. Concerning the technology, stations may be low tech, with bicycles locked to the station by a lock of the station or a lock on the bicycle, offering static information about the service and the system. Some systems operate manually with personal attention and users have to identify themselves to the staff (Dell'Olio et al., 2011). High tech stations include several docking points and a kiosk (rental terminal), which has a computer, integrated with a card reader terminal. State-of-the-art technologies make possible the installation of a station without need for construction, easily placing it on the ground. These stations are powered by solar energy and house all the wires for their operation (DeMaio, 2009). In some small cities the handling is manual (supervised by a staff), but most of the bike-sharing systems are automatic.

In high tech stations, computer *software* has some back-end functions (invisible for the user), like monitoring, redistribution planning, defect management, customer data management, as well as billing. Most frequent front-end functions (in interaction with the customer) are registration, rental management, provision of information, customer data management and payment.

2.3.1.2 *Service*

Characteristics like *scale*, *scheme size* and *density* of a bike-sharing system depend on exogenous factors of a city. Scale is due to city characteristics and city size as well (Table 2). Large cities introduce bike-sharing systems in the dense zones, like a city centre, with an approximate distance of 300 to 600 metres between stations. Systems in low density zones take into account a longer time of use. The number of bicycles per inhabitant differ significantly, e.g. in Paris 9.6 (per 1000 inhabitant), in Barcelona 3.7, in Vienna 0.4 (Midgley, 2011).

³⁸ During the first two years of operation of Vélib' (Paris), 7,800 bicycles were stolen and another 11,600 destroyed or vandalised. Replacement of a bike costs approximately 400 euros (Pucher and Buehler, 2012).

Table 2: Type and scale of bike-sharing systems in relation to city size and density

City population	City density	System type	Scale of bicycle-sharing network coverage
> 200,000	High	Automatic	Throughout the city
	Low	Automatic	In the city centre or high density areas
50,000 – 200,000	High	Automatic	Throughout the city
	Low	Manual	At public transport stations and public facilities (community centres, sport facilities, etc.)
< 50,000	High	Automatic	At main activity centres (main public transport stations, commercial centres, health centres, etc.)
	Low	Manual	At public transport stations and public facilities (community centres, sport facilities, etc.)

(IDAE, 2007: 84; Midgley, 2011: 7)

Target groups (persons and trips) are characteristically mixed, but in some cases there is a dominant group, like systems optimised on tourists (e.g. the free bike-sharing BUGA in Aveiro) or trips to work or school (e.g. Bicing in Barcelona). The systems in large cities are optimal for tourists, since most of them operate in the monumental zone. Nevertheless, tourists may face relatively high usage fees, lack of information or difficulties of access. In order to satisfy all groups of local inhabitants, a broad operation area and a dense network of stations is required.

Daily and yearly *service availability* is influenced by climate, demand and costs of redistribution. Most systems operate on a 24/7/365 basis but some of them are closed during the winter season or even during night hours. In large cities, there are non-stop schemes, some of them operating with fewer bicycles during low season.

Most of the systems nowadays make prior *registration* mandatory, even before the first use at the kiosk or at a customer service office. On the one hand, this prevents thefts and vandalism and, on the other hand, ensures the payment of usage fees. Registration may be free of charge or has a time-based *fee* (one-time, daily, weekly, monthly, seasonal, yearly, etc. registration). In some systems, users have to pay a deposit as well. Customers pay the fees directly at the kiosk (by cash or credit/debit cards) or a bank account is linked to the bike-sharing smart card. Most of the systems are free of charge for the first 30 minutes of use (that means approximately 6 to 8 km, which usually makes possible to reach any other docking station within the service area). Fees of further use increase exponentially every 30 or 60 minutes. That is to say, someone intending to use a bicycle during several hours without docking would rather opt for a traditional bike rental. Taking into account that most systems are free or nearly free, operators cannot finance the service exclusively by user fees, other *incomes* (e.g. advertisement) and *public subsidy* is needed, like in the case of any public transport service.

Information provision related to bike-sharing systems is static (information boards, folders, etc.) or, recently, there are also IT-based forms of information provision. Most systems have a website, mobile apps or applications at kiosks. In latest schemes, the information is up-to-date or even real-time, and provides data about the availability and location of bicycles, route options and the operation of the system.

Efficient *integration with public transport* is a challenge of any bike-sharing scheme. Integration of the provision of information has been done in most cities, especially where bike-sharing is operated by a PT company. There is physical integration or physical connection of the independent systems (docking stations at or near public transport stations) and functional integration (bike-sharing complementing public transport, e.g. during night hours or at zones where there is no public transport stop) as well. Fare integration means the harmonisation of fees and/or the use of a unique smart card (or other travel document). There are various examples worldwide, such as the system of Hangzhou (China), where public transport users have the right to use a shared bike for 90 minutes, instead of the regular 60 minutes (Fishman et al., 2013).

2.3.2 Business model

2.3.2.1 Service providers and contracts

First bike-sharing schemes were launched by local governments and the service was provided by a transport operator or the government itself. Later, both the complexity of the service and the structure of financing (PPP or joint structure) required the participation of the private sector. Nowadays, small-scale systems are operated by municipal governments, local authorities, universities (if it is operated on a campus) or non-profit groups (associations, cooperatives). *Operators* of large-scale schemes are (quasi-governmental, publicly or privately owned) transport agencies, advertising companies, street furniture providers or other for-profit public service providers, or even bike-sharing businesses (Bührmann, 2007; Büttner et al., 2011; DeMaio, 2009; Pucher and Buehler, 2012).

The “owner” of the service area, such as a local government or, in its representation, a public transport agency, as well as a university at a campus is one of the *contracting parties* in any service contract. Bike-sharing systems operated by a municipality or a university tend to be less flexible, since these organisations are not adapted to manage a service provision or to take financial responsibility for it. However, direct management provides higher influence and control.

Non-profit associations (e.g. Gothenburg) have a background in the field of cycling or public transportation, or they are founded especially for the operation of such a system. Responsibility is shifted to them from the local government; however, they depend strongly on the public sector in financial terms. If the service provider is a public transport company (e.g. Deutsche Bahn, Germany), bike-sharing may take integral part of a complex transport service, which is public and not profit-oriented.

Bike sharing businesses (C'entro in bici, in Ferrara, Italy; Bicincittà, in Italian towns, incl. Rome, Parma; nextbike, in Germany and Austria) have permission and right from the local government, but they operate the bike-sharing system independently, by own incomes. On the one hand, if a local government does not have financial resources to launch a system, this is one of the most feasible solutions. On the other hand, financial sustainability of bike-sharing schemes is in question in this case, since these businesses do not receive any subsidy, and in case of bankruptcy, bike-sharing also breaks down.

The most popular model (to date) is a service contract with advertising and street furniture providers. These companies receive revenue generating rights for the operation of the bike-sharing system. The largest firms (Clear Channel Outdoor, JCDecaux, Cemusa) earn profit from the exploitation of billboards, bus shelters, kiosks and the bicycles themselves. In Barcelona, there is a special contract: Clear Channel Outdoor, considered to be the largest service provider worldwide, has been contracted not on the basis of advertisement rights but on service fees, financed by on-street parking (Büttner et al., 2011; DeMaio, 2009; Midgley, 2009).

Not additional advertising revenue but rather a better public image and brand in the target market are aims of companies that (co-)finance bike-sharing systems in a sponsorship-based model (Cohen and Kietzmann, 2014). Some systems are publicly owned and operated by a public entity (e.g. MOL-Bubi in Budapest, operated by the Budapest Centre for Transport and sponsored by the Hungarian multinational oil and gas company MOL) or a private company (e.g. the operation of Santander Cycles in London is contracted by Transport for London to the private operator Serco Group and sponsored by the British bank Santander UK of the Spanish Santander Group).

Contract types are classified in four categories, depending on the provider of the infrastructure and the service (see Table 3). The typical has only one provider (Option A1).

Table 3: Contract types of bike-sharing systems

	Infrastructure	Operation
<i>Option A1</i>	Contractor	
<i>Option A2</i>	Contractor A	Contractor B
<i>Option B</i>	Contractor	Municipality
<i>Option C</i>	Municipality	Contractor

(Büttner et al., 2011: 26)

2.3.2.2 Costs and financing

In general, bike-sharing schemes are not self-supporting: *incomes* from registration and usage fees are completed by private and public sources. Scale and structure of *costs* depend on the peculiarities of each system, population density, service area and fleet size (DeMaio, 2009). Approximate capital (infrastructure and implementation) costs are EUR 2500–3000 per bike and annual operating (running) costs EUR 1500–2500 per bike (Büttner et al., 2011). The latter strongly depends on the number of users and dockings. Since the main service related income is the registration fee (due to free usage during the first 30 minutes), the system needs to be co-financed by direct or indirect subsidies, advertising contracts, sponsorships, on-street parking incomes or congestion charges.

After some failures in the implementation of bike-sharing and some system closures (a recent example is Pronto Cycle Share of Seattle, USA, in early 2017), a dispute has emerged about the affordability of bike-sharing systems in some cities (Ricci, 2015). Although unsuccessful

operation might have other reasons, such as policy issues on safety (helmet requirement in Brisbane and Melbourne, Australia) or land use (difficulty to set up new stations where potential users need them in San Diego, USA), the most common challenge is funding (e.g. Toronto). This is primarily due to the lack of a thorough consideration of costs and financing before implementation; the same has happened in the case study city, Madrid, where a public entity had to take over the operation from a private company to avoid unnecessary losses and exorbitant future costs.

2.4 Findings about urban cycling and bike-sharing

In parallel with the growing modal share of cycling in urban areas of the developed world, literature related to cycling is expanding continuously. In this introductory chapter, a review has been done to understand the recent evolution of cycling in cities, as well as to present the history and characteristics of a special form of bicycle use, namely bike-sharing.

Own edition

Figure 5: Catalysts of the cycling boom

Figure 5 summarises the factors that have been analysed here to highlight some phenomena that have led to current levels of cycling in Western cities. These factors not only explain (1) why cycling has become popular and gain success worldwide, but also (2) why this process takes place in our days and (3) why decision-makers opt for measures that promote cycling.

These seem to be interconnected and reinforcing each other. In some cases, there may be a cause and an effect and/or a temporal relation (urbanization>peak car use>urban mobility problems, NGO activities>transport policy and traffic rules). The phenomenon of “critical mass” has been mentioned in this chapter, as a concept of transport safety (Marshall and Garrick, 2011) and a European-scale event (Blickstein and Hanson, 2001; Furness, 2007). It is also a way of measure for the spread of cycling in urban and suburban areas: if the number of cyclists or the share of cycling crosses a threshold, it becomes a substantial and constant (but not necessarily dominant) element of the urban mobility. Cities applying up-to-date mobility management tools make steps in this way. However, measures and results are different from city to city, and both the starting point and the objectives are different in, for instance, cycling capitals like Copenhagen or Amsterdam, or newcomers of the promotion of cycling like Madrid.

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 (integrated smart access cards or online access). The evolution of bike-sharing is presented in Table 4.

Some practitioners claim that an enhanced version of the fourth generation – namely a system with solar-powered stations (Gaegauf, 2014), electric assistance to pedalling, application-based user access or similar improvements – forms the fifth generation. However, this is not a widely accepted approach in academic research and there is no relevant publication on the definition of a new generation. Thus, although flexible improvements of the supposed fifth generation may mean a modification of many elements of bike-sharing technology and service configuration, the question is whether the complexity of these improved details can reach the level of a new generation. The first three steps between generations (from the first to the fourth) have affected the principles of the systems and not only their characteristics. That is why a fifth generation is still a question of the future.

Concerning the next steps in the lifecycle of bike-sharing schemes, one thing seems to be certain, even after a few years: “there will be a lot more of it” (DeMaio, 2009: 52). Thus, this dissertation aims to analyse in the following chapters an example of the latest generation to highlight impacts and characteristics of potential and actual users.

Table 4: Evolution of bike-sharing generations

Generation	1 st	2 nd	3 rd	4 th
	Free-bike system	Coin-deposit system	IT-based smart card system	Demand responsive multimodal system
Year	1965*/1976	1995	1998	2005
First introduction (large-scale)	Amsterdam (NL)*, La Rochelle (FR)	Copenhagen (DK)	Rennes (FR)	Lyon (FR)
Area	Flexibly defined	Defined service area		...and/or flexibly defined
Bicycle	Bicycle			
Type	One-size urban bicycles (distinct design, colour, etc.)	Heavy bikes		...and/or pedelecs/e-bikes (smart bikes)
Lock	Unlocked bikes	Locked bikes (physical locking)	Locked bikes (computer-controlled)	Locked bikes (computer controlled or smart dockless lock)
Tracking	No tracking			GPS localization and/or tracking
Station	No stations	Fixed docking stations		...and/or flexible stations and/or no station
Kiosk	No kiosk		Kiosk (user interface technology)	...and/or online kiosk
Docking technology	No technology	Mechanical technology	Smart technology	State-of-the-art smart technology (e.g. solar power) or no docking
Access	No access control	Coin access	Stripe card / magnetic card	Smart card / mobile device
Registration	No registration		Registration (identification) and/or deposit	
Fee (access)			Annual or temporal fee and/or deposit	
Fee (per use)	Free of charge		<30 min.: free (exceptions); >30 min.: fee to pay; fees for casual users	
Apps	No apps			Online apps (real time availability)
Redistribution	No redistribution	Basic redistribution	Advanced redistribution	Smart (automated or user-based) redistribution
PT integration	No integration	Some physical and functional integration	...and some fare integration	Towards full horizontal (on short distances) and vertical integration (as a first/last mile connection) with other modes; substitutive to public transport in large and dense cities and complementary in small to medium size and less denser cities
Role in urban transport	Mainly individual mode		Individual mode for short trips in a city centre and/or first/last mile connection in suburbs and on longer trips	
Present and future	Still present as a system for small communities (e.g. workplace, university campus)	In extinction	May be present in small and medium size towns that have already implemented it	Already existing systems will be upgraded to this level, new schemes to come

*Introduction of White Bikes of Amsterdam cannot be considered a (transport) policy measure; they represent the first well-known idea of bike-sharing. Adapted (DeMaio, 2009: 49-52; Kumar et al., 2012: 6; Martin and Shaheen, 2014: 323; Midgley, 2011: 4; Pucher and Buehler, 2012: 191)

3 CASE STUDY, RESEARCH OBJECTIVES AND METHODOLOGY

In this chapter

The case of BiciMAD, the innovative bike-sharing system of Madrid is described here. Upon that, research gaps are identified, research questions are formulated and a proper methodology is defined. Although literature review is presented both above and in upcoming chapters, here a synthesis is provided to highlight the under-researched topics about bike-sharing demand.

An initial research question (RQ0) has been formulated above to study the thesis that worldwide spread of urban cycling and bike-sharing in the 2000s is a timely phenomenon due to interconnected recent factors. This has set the broad context of this PhD research. On this basis, first a specific case of innovative bike-sharing systems is presented (BiciMAD of Madrid) and a concise overview of a relatively under-researched field (the demand side topics of innovative bike-sharing systems) is provided here to identify questions for further research. Methods for data collection and analysis are selected accordingly.

It is worth mentioning here that, due to the structure, upcoming chapters also include brief and more focused descriptions of the current knowledge about specific bike-sharing related topics and, as a consequence, identification of research gaps (see Chapters 4 to 6). This is in line with what is going to be described in this chapter. The same applies to the methodology; in this section, a detailed description of survey techniques and only an overview of analytical methods and theories are provided. Chapters of Part II include more information on methodology.

3.1 Case study: pedelec-sharing in Madrid (BiciMAD)

Madrid is not a "cycling city" and its cycling culture is relatively low (Muñoz et al., 2013). Some exogenous factors (see below) make cycling less attractive than in reference cities like the European cycling capitals or municipalities where bicycle use has gained huge popularity recently. Catalysts of cycling (analysed in Chapter 2) have also reached Madrid. Thus, positive trends of cycling may have been observed in recent years. The local government has realised some pro-cycling policy measures, like 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 (Ayuntamiento de Madrid, 2013).

In 2010, modal share of cycling was 0.3% in Madrid (Monzón and Rondinella, 2010). Based on a traffic count in May 2012, 0.6% of people moving inside the M-30 ring road (city centre) were cyclists³⁹, 0.8% right before the introduction in 2014 and 1.7% in 2015 (López Lambas and García Martínez, 2015). A longitudinal standard data collection of the local government (by traffic counts in 15 streets of the inner city, Figure 6) also indicates that there is a significant increase in use of bicycles but the share of cycling is still low in global terms. On this basis, it is estimated that cycling represented 0.7–0.9% of the total mobility of local residents and 1.0–1.3% of their trips inside the municipality in 2016 (Kisters et al., 2016).

³⁹ Data of the local government (Ayuntamiento de Madrid) referenced by *En bici por Madrid* blog, <http://www.enbicipormadrid.es/2013/01/el-uso-de-la-bici-crece-un-28-en-2012.html> (accessed 15/6/2014).

By traffic counts in 15 streets. Data source: Kisters et al. (2016)

Figure 6: Evolution of the share of cycling in Madrid city centre

One of the most ambitious measures is to implement a bike-sharing scheme (BiciMAD) in three phases, first in the monumental area and central residential and commercial zone. Inauguration was foreseen for May 2014, however, in spite of the installation of stations and kiosks in due time, the project was delayed more than one month and it was opened on 23 June 2014. Due to IT problems and privacy concerns, casual use became available in autumn 2014.

BiciMAD is a state-of-the-art bike-sharing system. It comprises all characteristics of a fourth generation scheme. It has been implemented at a moment when many experiences could have been gathered from other cities, as well as when bike-sharing technology development is one of the most ambitious challenges of urban transport engineers. BiciMAD makes the difference to its predecessors due to having all of the following properties:

- It is the first city centre-wide large bike-sharing system with exclusively electric pedal-assisted bicycles⁴⁰. A city centre with difficult topography for cyclists, like the one of Madrid, is a proper place for a global test of such a solution.
- All bicycles may be localized by GPS, in order to avoid thefts.
- A price per each use is applied (€0.5 / 30 min. for subscribers) to avoid trips by bike-sharing instead of walking or public transport and to refinance some part of the expensive operation of an electric power-assisted system.
- The redistribution of bicycles is partly user-based. Users who return a bike to a station with a high proportion of free docks (with less than 30% occupancy) are awarded a discount of €0.1.

⁴⁰ The pedelec-sharing system of Copenhagen (GoBike, Bycyklen, <https://bycyklen.dk/>) was opened to the public a few months before BiciMAD, on 31 March 2014; however, there were only 250 pedelecs in 20 stations (in contrast to the initial fleet of BiciMAD with 1580 pedelecs in 123 stations). Expansion of Bycyklen to become a *large* network started after the approval of long-term funding by the local government in August 2014. The full Bycyklen system consists of 1860 pedelecs and 105 stations.

- The system is fully supported by online applications, available from most mobile devices.

Classification of the OBIS Project (see Chapter 2) is applied for the description of BiciMAD. The information about the future system is based on the official website of the project⁴¹ and communications by local authorities and the operator. Chapters 4 to 6 enter into further details about the innovative and demand responsive characteristics of BiciMAD.

3.1.1 Exogenous factors in the city

To make a brief review of basic data about Madrid, official and up-to-date statistics of the local government's website⁴² has been checked. The information is summarized in Table 5.

Table 5: Exogenous factors of a bike-sharing scheme in Madrid

Factors	In Madrid
City size	604.3 km ² (municipality), 42.0 km ² (inner city)
Population density	5229/km ² (in total, 3.16 million inhabitants) in 2016. The bike-sharing system was introduced in the dense city centre (15,000 to 30,000 inhabitants per km ²) of approximately 850,000 inhabitants.
Climate	Mediterranean climate, with a mean daily temperature of 14.6°C and an average yearly precipitation of 436 mm. Number of precipitation days: 63. Mean yearly sunshine hours: 2769.
	According to the last comprehensive transport survey in the future catchment zone (inside M-30 ring road) in 2014, there was a low modal share of cycling (0.8%) but high share of walking (54.4%) and public transport (30.1%) in comparison to other large cities. Accordingly, there is a relatively low share of individual motorised modes in the bike-sharing catchment area (Figure 7).

Mobility

Data source: Travel survey by TRANSyT-UPM

Figure 7: Modal share in Madrid city centre in 2014

⁴¹ <http://www.bicimad.com/>

⁴² Áreas de información estadística. <http://www.madrid.es/> (accessed 25/4/2017)

Factors	In Madrid
	This is a destination of daily commuting from the Community of Madrid (Wang et al., 2015), with approximately 6.5 million inhabitants and an area of 8030 km ² . Like in other European cities, the number of fatalities has decreased in a ten years perspective (2006: 50 road fatalities, 2016: 35).
Safety and security	Madrid is one of the five safest European capitals, 46% of the citizens not victimised in the past 5 years (Nyíri, 2005) ⁴³ . Madrid is 51 st on Mercer's Quality of Living Rankings 2017 (out of 231 cities) and is not among the top cities in terms of personal safety. According to a survey by the European Commission ⁴⁴ , local people's perceived safety in the city and in their neighbourhood is slightly below average in a European comparison, very similarly to the "bike-sharing capital" Paris.
	Despite recent developments, bicycle infrastructure is still insufficient in the city centre: there is an East-West bike lane axle (Calle Alcalá-Calle Mayor), a short South-North section (Parque del Retiro-Calle de Serrano) as well as paths in the university campus "Ciudad Universitaria". Furthermore, the local government designated a cycling boulevard ("M-10") of "ciclo-carril"; however, these are shared lanes on high-traffic avenues and other streets of the city centre (Figure 8). The cycling boulevard forms part of a project for the realization of new bicycle routes (mostly shared lanes or bike lanes), carried out in parallel to the implementation of bike-sharing. Outside the city centre, more infrastructure is available; some especially for leisure and sport purposes ("Anillo Verde", "Madrid Río").

Existing bicycle infrastructure

Source: Kisters et al. (2016: 146)

Figure 8: Designated shared lane for cycling in Madrid

⁴³ However, some BiciMAD stations were vandalised before and after inauguration and the system was hacked during the first days of operation. The operator had to take security measures to avoid illegal use.

⁴⁴ Quality of life in European cities 2015. Flash Eurobarometer 419. European Union, January 2016

Factors	In Madrid
	From 2015, cycling infrastructure has been developed by the extension of a basic network (“Red Básica”) and pro-cycling improvement of some streets of the inner city. It is foreseen that the residential priority area (some central neighbourhoods where non-residents have limited access) will be expanded towards other central districts, which may largely improve cycling conditions. In 2016, there were 292 km of bicycle routes and 161 km of “ciclo-carril” as well as 1167 public bicycle parking facilities with a capacity of 12,576 places (Kisters et al., 2016). Bicycle route network in 2017 may be seen in Figure 10.
Geographic factors	Hilly topography, elevation differences up to 200 m.
Demographic factors	Ageing society, due to life expectancy (83 years), relatively high mean age (43 years) and low nativity in the whole country. 86% of the inhabitants have Spanish nationality. Sex ratio: women 53%, men 47%.
Economic and financial factors	In spite of a long period of crisis and recession, economic situation is not an obstacle of cycling development.
Political situation	Commitment to the promotion of cycling is a recent attitude of the local government. Campaigns and events have been carried out (FestiBal con B, Talleres de bici urbana, etc.) in past years and a guide has been published in several languages. The government’s website contains basic information about the cycling in the city: recommendations, rules, maps, etc. In 2008, a conceptual document (“Plan Director de la Movilidad Ciclista”) established the urban cycling policy of Madrid. An update has been published in November 2016 (Kisters et al., 2016) to adjust cycling promotion activity and criteria of measures to the current situation in the city.

Source: Kisters et al. (2016: 17)

Figure 9: Poster of a local campaign about respect towards other road users in Madrid

Factors	In Madrid
	Besides some awareness-raising campaigns of the government — e.g. to improve road traffic culture after the implementation of bike-sharing (Figure 9) —, cycling associations and groups (En Bici Por Madrid, ConBici, Bici Crítica, etc.) are also actively promoting the use of bicycle and lobbying the government.

Light blue: designated shared lanes of cycling (“ciclo-carril”); red: bike lanes or paths; green: tracks for sports and leisure.
Source: Mapa de la Bici⁴⁵

Figure 10: Bicycle infrastructure in the BiciMAD catchment area

⁴⁵ Portal web del Ayuntamiento de Madrid, <http://www.infobicimadrid.es/> (accessed 4/5/2017)

Map of Madrid city centre inside the M-30 ring road. Source: BiciMAD official website⁴⁶

Figure 11: Network of BiciMAD docking stations as of early 2017

⁴⁶ <https://u.bicimad.com/mapa> (accessed 11/5/2017)

3.1.2 Endogenous factors of the bike-sharing scheme

BiciMAD was started on 23 June 2014. The establishment of a bike-sharing system was foreseen years before, but the Municipality had financial constraints due to the crisis of the late 2000s. After two years of operation, BiciMAD was taken over from a Spanish transport company, BonoPark, by a publicly-owned local public transport entity, EMT in 2016.

3.1.2.1 Components

Madrid is the first city worldwide to introduce a large bike-sharing network of fully electric-power-assisted bicycles (pedelecs), which would make it “practical, easy and ecological” (as per the local government) as well as encourage use in the hilly city centre. In theory, the bicycles have an electric pedal assistance up to 25 km per hour. Bicycles of BiciMAD (1580 in 2014; 2028 in early 2017) are heavy bikes: robust, unique and one size for all. All of them may be localized by GPS. Further details of the bicycle technology are described in Chapter 5.2 about the innovative characteristics of BiciMAD.

Station nr. 86, at Plaza de Cibeles. Source: Madrid official tourism website⁴⁷

Figure 12: BiciMAD docking station: kiosk, docks and pedelecs

Initially, there were 123 docking stations with 3120 racks. In 2017 there are 165 stations with 4116⁴⁸ (4128⁴⁹) racks, see Figure 11 and Figure 12. Installation of new stations and bicycles in further areas of potential large demand is foreseen by the Air Quality and Climate Change Plan 2017–2020. Extension towards all districts of the municipality is also under evaluation by the public operator (Kisters et al., 2016).

⁴⁷ <http://www.esmadrid.com/alquiler-de-bicicletas-en-madrid> (accessed 17/6/2017)

⁴⁸ <https://www.bicimad.com/index.php?s=que> (accessed 25/4/2017)

⁴⁹ EMT, ahora también sobre dos ruedas. http://www.emtmadrid.es/Ficheros/dosier_bicimad_baja.aspx (accessed 25/4/2017)

BiciMAD infrastructure comprises a high-tech kiosk allowing any operation (registration, pick up/drop off, payment, account recharge, information) of the system. Access cards are also available at the kiosk (subscriber's code may be purchased also at "Línea Madrid" information offices, contacting 010 information line or the official website). Location and availability of bicycles, as well as reservation of end-trip docking racks is available through online applications and mobile apps.

3.1.2.2 Service conditions

Docking stations have been installed in every 300 to 500 metres in the inner city of Madrid. Bike-sharing density is 3.3 pedelecs per 1000 inhabitants in the operational zone. A foreseen extension toward other areas of the centre of Madrid was carried out in 2015/2016. The system operates on a 24/7/365 basis. The registration may be done personally at any of the stations or at an information office of the Municipality, as well as online or by phone call. Annual registration costs €25, for transport pass holders €15. Access cards may be purchased before the first use at the kiosk. Occasional users can buy an access card for 1, 3 or 5 days at the docking station (making a deposit of €150 in advance and paying the charge per use afterwards).

Differently from the majority of bike-sharing schemes, BiciMAD users have to pay for any ride, since the local government aims to avoid trips that could be done by walking. Fees are defined for the first two hours (see Table 6), after that, users pay a "fine". All fees include costs for insurance, both for accidents and third party.

The target group of the system was not explicitly defined before implementation. People making any kind of trips (shopping, going to work, leisure, tourism, etc.) in the service area could become users of the system. A minimum age of 14 years has been established.

Table 6: BiciMAD fees

	Yearly subscribers	Occasional user
Registration	€25 (for transport pass holders: €15)	free of charge (deposit: €150)
Fees		
<i>first fraction</i>	€0.5 / 30 min.	€2 / 60 min.
<i>further fractions</i>	€0.6 / 30 min.	€4 / 60 min.
<i>fine (after 120 min.)</i>	€4 / 60 min.	
Discounts		
<i>pick-up from a high-occupancy station (>70%)</i>		
<i>drop-off at a low-occupancy station (<30%)</i>		€0.1
<i>reservation of end-trip docking rack</i>		
<i>(not combinable with other discounts)</i>		

As of June 2017 (prices have not been altered since the inauguration of BiciMAD in 2014)

3.1.2.3 Business model

Initially, the local government signed a concession with the private company BonoPark for €25 million for 12 years. This company has built the pedelecs (the so called Booster Bikes), installed the docking stations and it was in charge of the operation. Besides the income from fees (expected much higher than in other cities), the Municipality intended to finance the operation by the updated public parking scheme (“SER”). Both projects (bike-sharing and public parking) formed part of the Air Quality Plan 2011–2015 of Madrid, aimed at reducing air pollution.

In only two years after inauguration, as the consequence of a request by the private operator to get an economic rebalancing of 3.6 million EUR due to vandalism and theft, the bike-sharing system has been taken over by a public company to avoid such conflicts, as well as to overcome other disadvantages of the contract and shortcomings of the operation in the first years. The operation by a public transport company may ensure a higher level of integration with the public transport system (especially in terms of physical integration, integrated access and payment platforms), in line with the aims of the Air Quality and Climate Change Plan 2017–2020. It is also expected that technology developments by the public operator will contribute to increase availability of pedelecs and reduce system failures (Kisters et al., 2016). All these improvements may result in better cost efficiency in comparison to the first years of operation.

3.1.2.4 Some data about the use of BiciMAD

Data on BiciMAD use is publicly available by the open data service of the local government (Datos Abiertos⁵⁰). Here, three figures are presented and a brief description is provided:

Aggregate number of active subscribers from inauguration to 31/05/2017. Data source: Datos Abiertos

Figure 13: Number of BiciMAD subscribers from July 2014 to May 2017

⁵⁰ <http://datos.madrid.es/>

- Aggregate number of subscribers reached 10,000 in August 2014, 20,000 in October 2014, 30,000 in February 2015, 40,000 in May 2015, 50,000 in September 2015 and 60,000 in January 2016. It peaked on 10 July 2016 by 67,304 (Figure 13). The average number of subscribers in the first five months of 2017 was 60,384.
- Number of subscribers with and without a PT pass is nearly equal.

Data source: Datos Abiertos

Figure 14: Number of daily trips by BiciMAD from June 2014 to May 2017

- The highest number of trips on a day was 15,308 (25/09/2015). The lowest — after the first days after inauguration — was 1493 (20/11/2016), see Figure 14.
- Average daily use from the implementation to May 2017 was 7184 rides. In the last full month before the finalisation of this dissertation, namely May 2017, there was a daily average of 9969 rides.
- Share of rides by occasional users is minimal (2.2% of the total number of rides from the beginning until May 2017). In relative terms, it reached its maximum on Friday, 3 April 2015 (13.1%). The single day with most rides by occasional users was on 20 September 2015 (745 rides). After initial low-demand days in November and December 2014, the lowest number of occasional rides was observed on 23 November 2016 (6 rides). Occasional users are more active on weekends and holidays: all the days with a share above 5% or 500 rides take place on Saturdays, Sundays or public holidays. In May 2017, there was an average use of 269 rides by occasional users.

Average number of daily rides by subscribers and occasional users from June 2014 to May 2017. Data source: Datos Abiertos

Figure 15: Average BiciMAD use by month and by day of the week

- There is a clear seasonality in BiciMAD use (Figure 15). In this term June, May and September are the top months of the year (with an average daily use of 9483, 9328 and 8774 rides, respectively, by subscribers and occasional users), i.e. months with cycling-friendly climate conditions during the academic year. Winter is the season with the fewest number of rides (January: 5291, December: 5706, February: 5996).
- There are more BiciMAD riders on the streets of Madrid on weekdays (Thursday being on top with an average of 7803 rides) than on weekends, especially Sunday (6074).

3.2 Identification of research gaps and specification of research questions

Bike-sharing has recently become a key topic of urban mobility and related research activity. According to a heuristic search on Google Scholar, from the initial number of 2 in 2005, the number of publications in a single year has reached its top in 2015, with 167 search results on “bike-sharing”, “bike-share” and “public bicycle” in the title of contributions. A synthesis has recently been done by Fishman et al. (2013) and an updated version by Fishman (2016). Findings of these systematic literature reviews also indicate a quick evolution of research activity: after a first statement that “peer-reviewed literature on bike share is limited and there are important questions yet to be examined in detail” (Fishman et al., 2013: 162), a conclusion of the second article is that global spread of bike-sharing “has spurred an enthusiastic response from transport researchers, which has led to a burgeoning of papers” and that “[t]he research community has been quick to examine the spectrum of issues associated with bikeshare, including user preferences and demographics, usage rate and geospatial visualisation, safety, redistribution options and technological innovation” (Fishman, 2016: 92, 109).

Due to the relative novelty of the issue, most scholars started to focus on the supply side characteristics and not those of demand. Top supply side topics are the following:

- system design, including decisions about the network, number and location of stations, fleet size, applied technology and other related issues (Garcia-Gutierrez et al., 2014; García-Palomares et al., 2012; Lin et al., 2013; Martinez et al., 2012; Romero et al., 2012; Wuerzer and Mason, 2016);
- rebalancing issues, to find the best practices about fleet management, a shortcoming of bike-sharing in terms of eco-friendliness, due to the employment of trucks for repositioning in most cases (Angeloudis et al., 2014; Dell'Amico et al., 2014; Di Gaspero et al., 2016; Faghih-Imani et al., 2017; Forma et al., 2015; Fricker and Gast, 2016; Lu, 2016; Raviv et al., 2013), usually by the application of mathematical models and programming;
- pricing, to define a proper fee system that makes each scheme attractive in light of local mobility management goals as well as contributes to a more efficient bike-sharing operation, especially in terms of incentivizing user-based redistribution (Goodman and Cheshire, 2014; Haider et al., 2014; Ruch et al., 2014; Waserhole and Jost, 2016); and
- most recently, as a response to the recent evolution of such schemes, e-bike-sharing and pedelec-sharing (Campbell et al., 2016; Fishman and Cherry, 2016; Ioakimidis et al., 2016; Ji et al., 2014; Langford et al., 2013; Paul and Bogenberger, 2014; Thomas et al., 2015).

Until the very recent years of the mid-2010s, studies related to the demand side characteristics were mainly for market rather than scientific research. During the realization of the present project many steps have been taken forward in this field. Initial reviews of the evolution and current practice (DeMaio, 2009; Midgley, 2009, 2011) and recent syntheses by researchers in the UK (Ricci, 2015), Australia (Fishman, 2016; Fishman et al., 2013) and the US (Shaheen and Guzman, 2011; Shaheen et al., 2010; Shaheen et al., 2013) are based on an increasing knowledge and research activity about bike-sharing users, their travel behaviour and actual or latent demand.

A limitation of this field of research is that data about users in many cases has not yet been collected, processed or analysed 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. Besides some above-mentioned publications about general findings (e.g. on North American schemes), some researchers have applied data mining techniques to explore user behaviour, travel patterns and trip characteristics (Come et al., 2014; Jäppinen et al., 2013; Vogel et al., 2011; Vogel and Mattfeld, 2011). There is a visible interest in specific topics on the basis of one or more case studies, such as safety and health issues, especially the controversial problem of helmet use (Basch et al., 2014; Bauman et al., 2017; Fishman and Schepers, 2016; Graves et al., 2014; Haustein and Møller, 2016b; Kraemer et al., 2012; Langford et al., 2015; Martin et al., 2016; Woodcock et al., 2014) or the relation of land use and bike-sharing use (El-Assi et al., 2017; Faghih-Imani et al., 2014; Tran et al., 2015; Zhang et al., 2017).

The present PhD project also addresses topics about the demand of bike-sharing, namely implications of its implementation to understand user (and non-user) behaviour as well as impacts on travel patterns. As mentioned above, research about the introduction of BiciMAD may be of utmost interest on local (as a new travel mode in Madrid) and global level (as the first large pedelec-sharing network in a Western city). Hence, research gaps are also twofold. First, bike-sharing is a completely new element of urban mobility in Madrid, thus, only very limited research has been completed so far and there are essential topics that have not yet been examined (e.g. impacts). Second, BiciMAD – as a bike-sharing system of the latest generation – has a unique demand responsive service configuration, including one of the first fleets of pedelecs, without extensive experience in other cities and, consequently, no previous research.

Among many research topics to be considered in this context, factors that may influence the decision about starting to use bike-sharing have been investigated in recent years in different contexts. For instance, a specific group of potential adopters is examined by Kaplan et al. (2015), namely tourists, on the basis of an online questionnaire and sampling by social networks, applying Theory of Planned Behavior in the analysis. Despite far-reaching conclusions about the intention to use urban bike-sharing while on holiday (e.g. that positive attitudes towards bike-sharing are related to the place of residence in a cycling-friendly country), transferability of outcomes to the study of intentions by local people is limited.

Focus groups of 18 people representing three categories (non and infrequent cyclists; regular bicycle riders; bike-sharing subscribers) have been organized to identify barriers and motivators of the use of bike-sharing in Brisbane, concluding that service configuration improvement (easier and faster registration procedure, 24/7 operation), system integration (e.g. one access card for PT and bike-sharing), and incentives (e.g. increasing the free period) may make bike-sharing more popular (Fishman et al., 2012a). In addition to safety concerns (lack of proper infrastructure, driver behaviour, etc.), a long-time controversial issue of cycling promotion in Australia, namely mandatory helmet use is also discussed. In spite of an initiative to provide some users with helmets in Brisbane, helmet use law is obviously decreasing spontaneous use. An online questionnaire among approximately 800 users of bike-sharing in Brisbane and Melbourne, a focus group of 30 people and 60 respondents from a survey panel have been synthesized to understand the decision about the use of bike-sharing (Fishman et al., 2014b). Convenience of car use and distance to frequent origins and destinations (especially home and work) are found as the most influential barriers. A logistic regression model was employed to identify facilitators (Fishman et al., 2015b), indicating that better bicycle infrastructure and a more extensive bike-sharing network may be useful for an efficient promotion, and certain socioeconomic background and convenience of active modes are important predictors of bike-sharing usage.

Findings of a case study about the implementation of bike-sharing in Dublin show that some socioeconomic characteristics (middle and higher income earners, young males) are linked with adoption, and changing social norms may contribute to a better diffusion of bike-sharing among other potential users than any other promotional effort. In this regard, Murphy and Usher (2015: 120) conclude that “[t]here is a need for further research in this

area to better understand barriers to entry for these schemes and attitudes towards cycling among different income groups more generally and specifically within the context of bicycle-sharing schemes”.

Although a number of further studies have been carried out to understand intention-to-use, barriers and facilitators of use, as well as socioeconomic background of potential and actual users (Chen and Lu, 2016; DeMaio and Gifford, 2004; Efthymiou et al., 2013; Hampshire and Marla, 2012; Wang et al., 2010; Webster and Cunningham, 2013), potential user groups have not yet been explicitly identified, especially in the special case of pedelec-sharing.

As a consequence, at least two questions may be raised in relation to the implementation of bike-sharing. First, to extend the knowledge about potential users before inauguration.

RQ1: What is the profile of potential users before the implementation of bike-sharing in light of their socioeconomic characteristics, background in cycling and attitudes towards smart configuration of the new urban mobility service?

Second, to understand the decision about starting to use the service in light of previous intentions and to identify barriers and motivators in this context.

RQ2: What is the relation of the intention to use bike-sharing prior to its implementation and the final decision about becoming a user?

Despite a growing interest in actual bike-sharing user characterization, “there is little available evidence” (Murphy and Usher, 2015: 123) about the profile of bike-sharing users. Syntheses by Fishman (2016) and Ricci (2015) came to the conclusion that characteristics of bike-sharing users are different from the general population (mainly male, white, younger, employed, with higher income, etc.) and there are case studies that may be interpreted in certain contexts or with some limitations on a global level. Nevertheless, analysis of the adoption and profile of people who became clients after inauguration has largely been overlooked by the research community.

Exceptions include the article, based on an intercept survey among early adopters, by Shaheen et al. (2011), which has concluded that the difference between users and non-users is statistically significant. They also analysed the perceptions about the scheme by potential users and persistent non-users. On the one hand, although reviewing literature on innovation adoption and identifying five key variables of bike-sharing adoption (travel behaviour, sociodemographics, psychographics, bike-sharing perception, bike-sharing conditions), this research has not entered into details about differences among adopters. On the other hand, their case study is about the bike-sharing system of Hangzhou, the largest

network (in terms of fleet size and number of stations), in the specific context of a city in China, where cycling popularity has declined steadily in the past two decades.

Adoption of e-bikes has been examined more actively (Dill and Rose, 2012; Fishman and Cherry, 2016; Wolf and Seebauer, 2014) with some implications in e-bike-sharing related research (Ioakimidis et al., 2016; Ji et al., 2014; Rycerski et al., 2016), but without an analysis of users and their characteristics in light of adoption attributes.

In response to this research gap, the following question may be formulated:

RQ3: Are there differences between the adoption of bike-sharing as a new travel mode in the city and other types of innovation? If so, which are the characteristics of users in terms of innovation adoption?

Impacts of bike-sharing on urban mobility (individual travel patterns and changes of modal share) is one of the most researched topics about bike-sharing from the beginning. Each of the essential systematic reviews of the literature and state of the practice (DeMaio, 2009; Fishman, 2016; Fishman et al., 2013; Midgley, 2009, 2011; Pucher et al., 2011b; Ricci, 2015; Shaheen and Guzman, 2011; Shaheen et al., 2010) study the effects of bike-sharing as a key issue. However, there are many gaps, for instance, in the comparison of bike-sharing use, system management data and impacts on safety, health, economics, cycling, modal shift, vehicle ownership, etc. (Parkes et al., 2013).

A summary of the current knowledge is presented in Chapter 6. Three main conclusions may be drawn: (1) that there is lack of evidence whether existing bike-sharing schemes have achieved their objectives (Ricci, 2015), (2) modal shift from individual motorized modes is lower than expected (Fishman, 2016), i.e. bike-sharing tends to draw from public transport and other sustainable modes (Martin and Shaheen, 2014; Shaheen et al., 2013; Shaheen et al., 2014), and (3) it has a positive overall impact on active travel (Fishman et al., 2015a).

Some first results have been published about the influence of BiciMAD on travel behaviour by an independent project (Anaya and Castro, 2017) and in a paper in which the author was a contributor (García Martínez et al., 2016), but verification of the above global findings has not yet been done by the observation or surveying of a panel of users and non-users. Therefore, the last research question may be as follows.

RQ4: What is the impact of pedelec-sharing on individual and urban travel patterns?

These research questions are examined in the upcoming chapters in the specific context of Madrid and answered among the concluding remarks.

3.3 Thesis methodology

To understand users' perceptions about and attitudes towards pedelec-sharing as a new travel mode in the city as well as to observe their travel patterns during the project, methods of data collection and subsequent analysis have been determined. Survey techniques and sample size have been defined after a thorough consideration of available financial and human resources of the project, experiences with the employed tools in previous research activities as well as a minimum response rate needed for building up a database for both cross-sectional and longitudinal analysis. On this basis, qualitative and quantitative frameworks and methods have been chosen for proper examination of the above specified research questions.

3.3.1 Sampling and survey techniques

TRANSyT has recently developed and gained experience with a combined method of personal intercept interviews and online surveying (Hernández et al., 2016) to explore the opinion of potential or actual users of a transport service or infrastructure. It was employed for the first time in the EU co-financed research project City-HUB to study user perceptions of transport interchanges, followed by its application to analyse bike-sharing user profiles in the present project.

3.3.1.1 Survey methodology

This combined technique includes a series of steps in each survey phase, as follows:

1. a definition of the survey objectives, a proposal of the main topics and an initial survey plan were outlined;
2. a draft questionnaire was developed and edited by a survey development tool (in this case in SurveyMonkey⁵¹, a cloud based web survey development service, allowing prompt basic data analysis by charts and tables, as well as exporting options to data processing software);
3. a pilot survey was carried out in each survey phase, pilot sample representing different age, gender, social background and transport habits;
4. on the basis of pilot responses and recommendations, the questionnaire was refined in content and graphic design as well as adjusted to time limits;
5. once the final version had been fixed, cards with individual access codes (URL and/or QR code) to the web-based questionnaire were printed (see Figure 17 and Figure 18);
6. 30 to 120 sec. onsite introduction of the project and distribution of access cards — at or near a BiciMAD station (Figure 16) — was carried out by interviewers (university students) after a short training and presentation by the project coordinators;
7. some basic information of the person invited to participate in the survey (age, sex and special features, such as disability, holding large bag, group of people) and the

⁵¹ <https://www.surveymonkey.com/>

circumstances (location, date, time, weather conditions, etc.) was noted by the interviewer.

2nd survey phase (June 2015). Photos by the author.

Figure 16: Presentation of the research project and distribution of access codes at and near a BiciMAD docking station

8. access card distribution was managed and controlled by the coordinators through personal visits and mobile applications;
9. after the access codes had been handed over, respondents had approximately two weeks to fill in the online questionnaire before the survey was closed;
10. in the 2nd and 3rd phase, respondents of the previous phase(s) who provided their contact data were invited by e-mail to participate again to build up a panel sample;
11. interested people were expected to fill in the questionnaire by any mobile device or computer with internet access, typing in the personal code in the online survey platform;
12. a prize was drawn among respondents with completed responses⁵².

This method synthesises the benefits of two methods (Babbie, 2010): (1) personal interviews: directness of the personal contact; the interviewer can keep records of observations about respondents; more representative sample; and (2) online surveys: more confidential and honest due to anonymity and privacy; almost any type of question may be asked; and relatively cheap.

⁵² See the project website <http://bicimad.transyt-projects.com/>

ENCUESTA SOBRE EL USO DE LA BICICLETA EN MADRID

TRANSyT, Centro de Investigación del Transporte de la **Universidad Politécnica de Madrid**, está realizando durante el mes de mayo de 2014 una encuesta para estudiar el uso de la bicicleta y la opinión de los ciudadanos sobre la implantación de un sistema público de préstamo de bicicletas en la ciudad de Madrid (**BiciMAD**).

Por favor, rellene nuestro cuestionario utilizando el siguiente enlace e inserte su número de encuesta:

es.surveymonkey.com/s/bicimad

Número de encuesta:

1000

Participará en el **SORTEO** de una **TABLET** o una **CAJA REGALO DE FIN DE SEMANA** de valor equivalente

Por favor, visite www.bicimad.transyt-projects.com el **30 de mayo 2014** para saber si su número de encuesta es el **GANADOR**

El plazo para realizar la encuesta es de **DOS SEMANAS** desde la fecha de entrega de esta tarjeta.

¡MUCHAS GRACIAS POR SU COLABORACIÓN!

Figure 17: Survey access card of the 1st phase (2014)

ENCUESTA SOBRE EL USO DE LA BICICLETA Y EL SERVICIO PÚBLICO DE BICICLETA EN MADRID

PARTICIPA, OPINA Y

GANA UNA TABLET

o una **CAJA REGALO** de fin de semana de valor equivalente*

*Según la elección del ganador del sorteo de premio

Puedes rellenar el cuestionario utilizando el siguiente enlace e insertando el código:

Tu código personal:

«F1»

es.surveymonkey.com/s/bicimad

El plazo para realizar la encuesta es de **UNA SEMANA** desde la fecha de entrega de esta tarjeta.

¡MUCHAS GRACIAS POR TU COLABORACIÓN!

Contacto:
www.bicimad.transyt-projects.com
bicimad@caminos.upm.es

Figure 18: Survey access card of the 2nd phase (2015)

3.3.1.2 Time period

The survey was conducted from April to June 2014, June 2015 and June/July in 2016. In each phase, a pilot questionnaire was administered to survey development experts and frequent cyclists or bike-sharing users. Feedback was used to finalize contents, improve the questionnaire and eliminate internal logical errors of the online survey.

Interviewers distributed cards with access codes during the first half of May 2014 (50% on weekdays and 50% on weekends and holidays, including the International Workers' Day), during the first two weeks of June 2015 (58% on weekdays and 42% on weekends) and during ten days in mid-June 2016 (60% on weekdays and 40% on weekends). The online questionnaire was open to responses from the first day of access card distribution until two weeks after all the access codes have been handed over. Prize draw took place within a few days after the survey had been closed.

3.3.1.3 Survey area

In line with the geographical coverage of the initial BiciMAD operational zone, its foreseen extension and potential catchment area, access codes have been distributed in the “Almendra Central” (city centre inside the M-30 ring road). For previous mobility surveys – based on considerations to group the central area into homogeneous zones with similar population, socioeconomic division and mobility – TRANSyT divided this area into 16 sample zones. Out of these, 11 cover the initial operational zone and nos. 12 to 16 (see Figure 19) belong to the extension and primary catchment area. The final survey plan included 12 zones (11 of the initial operational zone + nos. 12 to 16 as one area).

Madrid map adapted from Wikipedia⁵³

Figure 19: Survey zones

⁵³ https://es.wikipedia.org/wiki/Autopista_M-40#mediaviewer/Archivo:Mapa_m-40_-_m-30.PNG (accessed 28/4/2017)

In the ex-ante survey phase, two interviewers were assigned to each of the above-mentioned zones and they were advised to stay in a limited number, i.e. two or three busy public places, especially next to already installed or future docking stations. However, they were allowed to find other proper places in their assigned zones in order to make the personal intercept part (presentation of the project and distribution of access codes) more efficient and reach potential bike-sharing users of different attributes.

In the next two survey phases, interviewers were appointed to mini-zones (12 in 2015, 17 in 2016) of two or three stations of different types, such as stations in the initial or extension zone, with or without direct connection to metro, next to a tourist attraction or a recreational zone, on a low traffic or busy street and high or low capacity station.

3.3.1.4 Sample and target groups

Since BiciMAD in theory is for any people living, working or visiting the service area, the population of the survey is quasi-infinite. As the first survey aimed to identify latent needs and this is the second real-life application of the surveying method (and the first about the use of bike-sharing), samples of 1,000 responses in the first BiciMAD operation zone and 200 responses in other parts of the catchments area were expected. Bearing in mind costs of surveying, human resources, response rates and data quality of the first stage, the next two phases targeted a reasonable sample of 200 total responses from the same survey zone. These phases included responses from a panel sample as well.

These targets mean that the expected response rate was 10% (per access codes distributed), a reachable target on the basis of previous experience in applying similar survey techniques in Madrid. Consequently, 12,000 cards (1,000 per zone) were distributed in order to certainly cross the threshold of 1,200 responses in the ex-ante survey; 2,000 actual users and potential users were contacted personally in the next phases (Table 7). In this classification, actual users are both *frequent users* (that is, yearly *subscribers* of BiciMAD) and *occasional users* (who use BiciMAD eventually or, at least, tried it out). *Potential users* (i.e. *non-users*) are individuals who have never ridden a BiciMAD bicycle.

Table 7: Number of responses by survey phase

Phase	No. of access codes distributed	Potential user	Actual user	Response rate	E-mail provided	Potential user (panel)	Actual user (panel)	E-mail provided (panel)	Total responses
May/June 2014	12000	1859*	–	15.5	923	–	–	–	1859
June 2015	2000	25	403	21.4	407	63	93	152	584
June/July 2016	2000	30	302	16.6	309	62	140	186	534

*Including 20 respondents who entered the online questionnaire by a non-personalised access code (“999” or “1000”). Some of them participated in the upcoming phases as panel respondents. A total of 48 tourists are also included.

Interviewers were instructed to address people of both sexes, all ages (youngsters below 25 years of age, middle-aged between 25 and 60 as well as the elderly), travelling by different

transport modes (pedestrians, cyclists, car-drivers, public transport users) and different motivations within the survey area (residents, visitors, tourists, etc.). They had to stop people randomly in the survey site. In the second and third survey phases, they had to contact both actual users (75%) and non-users (25%).

Response rates of 15.5, 21.4 and 16.6 percent have been achieved in 2014, 2015 and 2016, respectively, i.e. the target of 10% has been reached in each phase. Users are more participative than non-users: for instance, response rate by actual BiciMAD users was 26.8% and by non-users only 5% in 2015.

Respondents were encouraged to participate in upcoming phases of the project, i.e. to leave their e-mail addresses. In this way, half of the participants of the first survey could have been contacted in 2015, and more than 90% of later respondents agreed to be part of the future phases. In the *panel survey*, response rates of 16.9 and 15.5 percent have been achieved in 2015 and 2016, respectively. Finally, a survey panel of 205 individuals could have been examined. They are respondents who completed the questionnaire in the 1st phase, as well as in the 2nd and/or 3rd survey phase, i.e. before and at least once after the implementation of BiciMAD.

3.3.1.5 Basic socioeconomic information about the sample

Sample size and response rates of the three survey phases have been presented above. Here, general information of the survey sample may be seen in Table 8. The panel sample is presented and described in detail in Chapter 6 (Table 20).

Some basic observations about the sample may be outlined as follows:

- Men are overrepresented in each survey phase (actually they were 47% of the population of Madrid during these years, according to the statistical database of Madrid municipality⁵⁴). As there is only little evidence about gender influence on online survey participation (Smith, 2008), more information would be necessary to understand why women were less participative in these surveys.
- Young people tend to be more responsive in this survey (actually, average age of Madrid citizens was 43.5 years in 2014⁵⁵, 43.8 in 2015 and 43.9 in 2016). This seems to be explained by their greater familiarity with online tools, such as survey websites and a supposed greater interest in cycling and bike-sharing in the low cycling context of Madrid⁵⁶. The low participation of elderly people is reflected also by the extremely low rate of pensioners (the actual rate of people above 65 years of age in Madrid was 20.2% in 2014 and 20.5% in 2015 and 2016). Increasing age in the panel sample is partly due to the passage of time between survey phases.

⁵⁴ <http://www-2.munimadrid.es/CSE6/jsp/menuBancoDatos.jsp> (accessed 21/6/2017)

⁵⁵ On 1 January.

⁵⁶ A study about cycling demand in Madrid (CONECTA, 2015) has found that the group of “Rejectors” (who refuse the use of bicycle as a transport mode, average age: 42.4 years) are older than “Urban bikers” (who are frequent cyclists, 35 years) and “Potentials” (who are potential future riders, 37.5). Women are in the majority among “Rejectors”. This is a fact that may partly explain their lower interest in participating in the survey, as well.

- A vast majority of respondents have higher education degrees. It may be supposed that they are more open to relatively long and complex questionnaires, which are usually associated with a lower response rate in web-based questionnaires (Galesic and Bosnjak, 2009). Students are much less present in the 2nd and 3rd stage than in the ex-ante survey.
- Maybe reducing influence of the financial crisis (that strongly affected Spain) explains lower unemployment rates, greater household incomes and increased access to a car in the 2nd and 3rd phases. (The registered unemployment rate was 14.3% in May 2014, 12.8% in June 2015 and 9.6% in June 2016 in Madrid.)

Table 8: Sample characteristics by survey phase

Year		2014	2015		2016	
Survey phase		1st	2nd	2nd panel	3rd	3rd panel
Sample size		1811	428	156	332	202
Female:Male		47:53	34:66	41:59	39:61	40:60
Average age		34.6	35.3	36.5	36.9	39.3
(Standard deviation)		(12.8)	(11.0)	(12.2)	(10.5)	(10.8)
Education	Higher	72.2	80.6	77.0	83.1	81.7
	Secondary	26.1	18.5	23.0	16.9	17.8
	Student	28.1	13.3	19.9	10.6	6.9
Occupation	Employee	55.7	61.4	64.1	70.5	67.8
	Entrepreneur	2.3	15.4	2.6	14.2	16.3
	Unemployed	9.0	8.6	10.9	3.6	8.4
	Pensioner	2.2	0.9	1.9	0.6	0.5
Household size (nr. of persons)	1	10.2	16.4	12.2	18.1	16.3
	2	27.2	40.0	25.0	39.4	42.1
	3	26.9	19.9	24.4	20.8	20.3
	4	26.5	15.4	29.5	16.3	15.3
	More	2.4	8.3	8.9	5.4	6.0
Household income (€)	–1300	25.1	23.6	25.0	17.2	16.3
	1300–2500	38.5	39.0	38.5	37.9	40.1
	2500–	36.4	37.4	36.5	44.9	43.6
Bicycle ownership		70.9	56.5	73.7	56.6	71.3
PT pass		48.3	46.3	51.2	49.4	47.0
Driving license		79.0	85.1	82.7	84.3	87.6
Access to car		52.5	54.7	59.6	56.3	61.4
Access to motorbike		12.0	14.3	13.5	12.1	10.9

% of respondents

In conclusion, global socioeconomic trends (e.g. ageing society, changes on the job market) seem to be reflected by the survey, but the random sample is not fully representative of the key target group of BiciMAD (population of Madrid) and this may be true for the others as well (commuters, visitors, tourists, etc.).

3.3.2 Theories and statistical methods for data collection and analysis

An original data collection has been realized for the research project about BiciMAD users, thus survey design is partly based on the objectives of this PhD project (see original questionnaires as annexes). Each survey has three main parts:

- (1) “YOU AND THE BICYCLE”⁵⁷: urban mobility and especially cycling patterns (bicycle use and evaluation of factors that influence cycling);
- (2) “YOU AND BICIMAD”: intention to use bike-sharing (ex-ante survey), adoption of bike-sharing and motivation of use and non-use (2nd and 3rd survey phase), as well as appraisal of BiciMAD characteristics;
- (3) “PERSONAL DETAILS”: demographic and socioeconomic information.

Each survey phase had a large number of common questions but a different focus from phase to phase. The first survey aimed to explore the background of potential users in cycling to understand factors that may influence the use of bicycles in Madrid and reveal the opinion about service configuration prior to implementation in order to find common characteristics of potential users. Although the primary target group of the survey was the population of Madrid (and its suburban area), a slightly modified questionnaire was administered to Spanish-speaking tourists as well. The second phase put the emphasis on the diffusion of bike-sharing as an innovation to understand the adoption process. Finally, the third phase included further questions to assess the impact of bike-sharing in Madrid.

To meet the above aims, many survey items had to be answered by rating on a Likert-type (or Agree-Disagree) scale, a psychometric tool to obtain respondents’ preferences and degree of agreement. Likert-type scales have been extremely popular in questionnaires of social science research in spite of their limitations and bias (Revilla et al., 2014). Number of response categories is a classical issue (Weijters et al., 2010). The use of at least 20 categories is recommended by many psychometrists (Birkett, 1986) and there has been a long dispute about the reliability of scales with or without a neutral point (4 or 5, 6 or 7, etc. categories). In the present survey, both are applied⁵⁸: Likert-type scales of six categories (0 to 5, with no neutral point) are employed in the first two phases and five categories (1 to 5, with a midpoint) in the third. To make data homogeneous in this term, this kind of evaluation of perceptions (or level of agreement) has a standardised numerical interpretation of 0 (totally disagree or similar) to 5 points (totally agree or similar) in the quantitative analysis. That is to say, Likert-type scales with five categories of 1 to 5 are all standardised to a scale of five categories of 0 to 5. In the third survey phase, Likert-type scales are applied also for Importance-Performance Analysis (Martilla and James, 1977), a marketing research technique to measure the level of satisfaction; however, results by this approach are presented in other outcomes of the research project, e.g. García Martínez et al. (2016).

⁵⁷ USTED Y LA BICICLETA; USTED Y BICIMAD; DETALLES PERSONALES (see the questionnaires in the Annexes).

⁵⁸ Appraisal of this recently developed survey method is ongoing and TRANSyT applies different approaches for a proper evaluation and further improvement.

For the analysis of RQ1 and RQ4, including further research on bike-sharing related attitudes, survey items have been formulated by inspirations from theories that serves to understand voluntary behaviour – especially Theory of Reasoned Action (TRA, M Fishbein and I Ajzen, 1975) and Theory of Planned Behavior (TPB, I Ajzen, 1985, 1991) – without the direct application of any of them. An explicitly applied framework is Innovation Diffusion Theory (IDT), to study adopter profiles in regard to RQ3. The theory by Everett Rogers, dating back to the 1960s, “has become the most influential model of dissemination across fields” (Schoenwald et al., 2012: 18) and it is a frequently and multidisciplinary employed approach, see reviews by (Greenhalgh et al., 2005; Lyytinen and Damsgaard, 2001; Meade and Islam, 2006; Sahin, 2006). In the present case, it is used as a framework to study the adoption of bike-sharing as a new travel mode in Madrid. It is employed critically to adjust the theory to the reality, making modifications or doing extensions if necessary. A detailed description of IDT and its application is provided in Chapter 5.

Basic and advanced statistics are the basis of any analysis in this dissertation. The multivariate exploratory technique of factor analysis is used for data reduction. To organise observed data and classify the sample in certain contexts, the multivariate data exploration tool of cluster analysis is applied. For such techniques, the advanced analytics software packages STATISTICA and STATGRAPHICS have been used, with some control calculations in SPSS. A panel sample of bike-sharing users and potential users is analysed for answering RQ3 and RQ4. As not all respondents were identifiable by their original access codes in the second and third survey phase, algorithms have been defined for matching personal data. Due to the above-mentioned slight modifications of the content and scales from phase to phase, standardization of responses had to be carried out before analysis.

Table 9 is a summary of the expected outcomes in relation to research questions, survey phases and methods. In the chapters presenting research results, some further information on methodology is described to set the context about calculations and qualitative assessments.

Table 9: Relation of research questions, survey phases, methods and expected outcomes

	Research question	Survey sample	Methods	Expected outcomes
0	<i>What factors have contributed to the recent popularity of bicycle use and a quick global spread of bike-sharing schemes, and what is the current practice of bike-sharing in light of its evolution?</i>	-	Literature review	-Classification of the phenomena that have driven to the current burgeoning of cycling and bike-sharing worldwide -New comprehensive definition of bike-sharing in light of its characteristics and evolution
1	<i>What is the profile of potential users before the implementation of bike-sharing in light of their socioeconomic characteristics, background in cycling and attitudes towards smart configuration of the new urban mobility service?</i>	Ex-ante (2014)	Factor and cluster analysis	-Identification of underlying factors of bicycle use in Madrid -Analysis of the <i>a priori</i> evaluation of BiciMAD -Understanding the characteristics of potential user and non-user groups
2	<i>What is the relation of the intention to use bike-sharing prior to its implementation and the final decision about becoming a user?</i>	Panel (2014–2016)	Measures of association	-Quantification of the association between intention-to-use and actual use -Revealing motivation of use and barriers to start riding BiciMAD
3	<i>Are there differences between the adoption of bike-sharing as a new travel mode in the city and other types of innovation? If so, which are the characteristics of users in terms of innovation adoption?</i>	2 nd and 3 rd phase (2015–2016)	Innovation Diffusion Theory as a framework for analysis	-Identification of adopter characteristics (by time of adoption), including personal history in cycling -Understanding bike-sharing diffusion in Madrid
4	<i>What is the impact of pedelec-sharing on individual and urban travel patterns?</i>	Panel (2014–2016)	Mobility indicators	-Identification of changes of individual travel patterns: modal shift, number and duration of trips, by trip purposes -Understanding the effect of bike-sharing on urban mobility

PART II: RESULTS

4 IDENTIFICATION OF FACTORS THAT AFFECT BICYCLE USE AND POTENTIAL BICIMAD USER PROFILES

In this chapter

Three topics are presented here: (1) a detailed overview of the sample for ex-ante analysis, (2) identification of underlying factors that influence the use of bicycles, as well as opinion about the latest technologies and characteristics of BiciMAD before implementation, and (3) potential user and non-user profiles of bike-sharing, as a result of a cluster analysis.

Recently, there has been growing interest in the study of cycling patterns in Madrid. Factors for successful bicycle promotion were examined by a survey of approximately 3000 respondents in the university campus “Ciudad Universitaria” (Fernández-Heredia et al., 2014). Findings indicate that frequency and type of use (experience in cycling) makes a difference, and there are four (latent) variables: physical determinants, exogenous restrictions (risk of accidents, vandalism, safer infrastructure), pro-bike (economical, healthy, ecological character and fun of cycling), and convenience (efficiency, flexibility). A sample of 224 individuals was analysed to identify cycling habits and other psychological variables affecting utility cycling (Muñoz et al., 2013). A key conclusion is that cycling experience (e.g. recreational rides) may increase positive attitude towards the use of bicycles and decrease the importance of barriers. Factors of direct benefits (reliability, comfort) and long-term benefits (health, quality of life, eco-friendliness, flexibility) have been found as drivers of the decision about frequent cycling, as well as physical conditions, external facilities and individual capacities as potential barriers. An extensive research has explored the role of experience in utilitarian cycling (Rondinella, 2015; Rondinella et al., 2012). A comparison has also been done to highlight different commuting patterns in Madrid and another city with a different cycling environment and policy through semi-structured interviews (Lois et al., 2016).

In this context, as a first study about the users of the bike-sharing scheme in Madrid, the present chapter focuses on the profiles of potential clients of a pedelec-sharing system by an ex-ante questionnaire about mobility patterns, perception of future service configuration and technology and a brief new insight into the factors that may influence the use of bicycles in Madrid. The latter is not an original approach to understand cycling habits and underlying factors in Madrid (as in the above-mentioned studies), but to include information about cycling patterns and attitudes into the analysis of potential users’ profiles.

Following a description of the sample, advanced statistics are applied to identify underlying factors that may influence respondents’ cycling habits, and perceptions of two key elements of the BiciMAD service configuration (namely pricing and advanced pedalling technology) are examined. On this basis, a clustering of potential users is presented.

4.1 Characterization of a sample of potential users

The number of completed responses in the ex-ante survey period (i.e. before the implementation of BiciMAD) is 1859. The number and proportion of tourists among respondents is quite low⁵⁹. This is due to the realisation of the survey only in Spanish, difficulties to fill in the online survey (e.g. roaming charges, no internet connection in the hotel), lack of interest and the low number of tourists in some of the survey zones, especially in residential neighbourhoods.

⁵⁹ Without the responses of tourists, a total of 1811 responses are analysed in most parts of this chapter.

With regard to the motivations of staying in the survey zone, most respondents are residents, followed by leisure, work and study purposes (Figure 20). Respondents are 53% male and 47% female. The age of the youngest is 8 and the oldest respondent is 87 years old (Figure 21). Since the survey was filled in online, young people were more willing to answer; accordingly, the median is 32 years of age. Most of the respondents have university degrees or completed secondary education. They are typically employed (56%) or students (28%). The proportion of unemployed people (9%) and pensioners (2%) is lower than their rate in society: as mentioned above, unemployment rate was 14.3% in May 2014 and the rate of 65+ years old residents was 20.2% in 2014, according to the statistical database of Madrid municipality. Most respondents live in a family of 2 to 4 persons.

Figure 20: Trip purposes of ex-ante respondents in the survey zone

Ex-ante sample (2014), n=1811

Figure 21: Number and age of ex-ante respondents

A huge majority of respondents (97%) can ride a bike⁶⁰ but 3 in 10 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 out of 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 school⁶¹, and approximately 60% never do shopping or visit friends or relatives by bike. Nearly 50%

⁶⁰ Peculiarly, 2.5–3.6% is the proportion of respondents who do not know how to ride a bicycle by filtering them by a wide range of socioeconomic characteristics (level of education, household size, income level, etc.), except the case of sex: 1.05% of male and 5.01% of female respondents report that they cannot ride a bike.

⁶¹ Trips to work or school are analysed together, based on the fundamental similarities between regular travel to school and to the workplace (Keserü, 2013).

has a PT pass and PT is the typical transport mode for going to work, going out in the evening and visiting friends. Most of the respondents (79%) have a driving license. One out of two respondents has access to a private car.

Ex-ante sample (2014), n=1811

Figure 22: Mode choice by trip purpose before the implementation of BiciMAD

Respondents had to report their typical mode choice by four trip purposes (Figure 22). Responses about two trip purposes may be biased in terms of travelling in the city centre: mode choice for shopping may be influenced by the fact that some people go shopping to malls outside the city centre, as well as visiting friends and relatives may mean trips outside Madrid (e.g. to their hometowns), suggesting the presence of non-urban trips, especially by car or public transport. Thus, two trip purposes – about utility trips to work/school and to go out with friends in the evening – are further analysed in the dissertation (see Chapter 6). On these trips, a majority of respondents (70% to work/school and 71% to go out) rely on sustainable modes, with the only difference being that more people cycle (6% and 2%) to work/school and more take PT (50% and 55%) to go out. Use of individual motorized modes, especially automobile, is significantly higher here than in other survey samples (22% and 20% vs. 11%, see Chapter 3, Figure 7).

4.2 Analysis of factors that influence the decision about the use of bicycles

The survey addressed some specific questions about the personal attitudes towards factors that may influence the decision about 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 infrastructure).

All the questions are in line with the factors analysed in previous chapters and are quantified on a Likert-type scale from 0 (not important at all) to 5 (very important), see Table 10.

Table 10: Rating of the factors influencing bicycle use prior to BiciMAD implementation

Factor	Classification	Rating
Bicycle tracks or lanes	<i>Policy (infrastructure)</i>	4.57
Safe parking facilities	<i>Policy (infrastructure)</i>	4.29
Public transport integration	<i>Policy (infrastructure)</i>	4.16
Access and parking facilities in public spaces (cultural centres, shopping centres, etc.)	<i>Policy (infrastructure)</i>	4.01
Eco-friendliness	<i>Individual (concepts)</i>	3.97
Climate	<i>Individual (attitudes)</i>	3.92
Flexibility (e.g. parking anywhere)	<i>Social (urban mobility problems)</i>	3.86
Risk of accidents	<i>Social (real and perceived safety)</i>	3.83
Adaptation of workplaces/schools	<i>Policy (competitions, campaigns)</i>	3.60
Speed limits (30 km/h)	<i>Policy (traffic rules)</i>	3.45
Topography	<i>Individual (attitudes)</i>	3.42
Price (cheaper than other modes)	<i>Individual (equity)</i>	3.42
Lifestyle (fun)	<i>Policy (benefits of the crisis)</i>	3.42
	<i>Individual (attitudes)</i>	3.21

Likert-type scale from 0 to 5. Ex-ante sample (2014), n=1811

Some questions are adapted to specific conditions of cycling in Madrid. Topography is a relevant issue, as streets are hilly in the city centre, i.e. it is a potential barrier to cycling for many people. Climate may also be a similar challenge in a low cycling culture, due to the hot summers and cool winters in Madrid. Road infrastructure (bicycle tracks or lanes, 30 km/h speed limit on streets, etc.) is a key condition: many people could find bicycles to be inefficient or to have an increased risk of accidents in peak hours without proper space for cycling. Respondents had to express their opinions about 13 variables⁶² that may influence the use of bicycles in Madrid (Figure 23).

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. Respondents consider bicycle infrastructure as the most important: safe bicycle routes, parking places and efficient integration with public transport. In contrast, individual factors — such as economical character of the use of a bicycle or cycling-related lifestyle — are less relevant. However, environmentally-friendly characteristics are quite appreciated.

Infrastructure is crucial for any target group, e.g. men and women, young and elderly people, cyclists and motorists. Obviously, there are some differences in the evaluation, e.g. senior citizens (60+) consider the price of cycling or the accessibility of workplaces or schools less important. For women, the use of bicycles tends to depend more on weather conditions, risk of accidents or the integration with public transport than for men.

⁶² Some other potential variables may be addressed by other surveys or data collection techniques, e.g. a combination of questionnaires and vehicle tracking to understand the speed of BiciMAD and its relative speed to other modes.

Likert-type scale from 0 to 5. Ex-ante sample (2014), n=1811

Figure 23: Intention to use BiciMAD and rating of influencing factors

Frequent utility cyclists (i.e. people who bike to work or school at least once a week) have the same main priorities as others (especially infrastructure development) but they do not consider external factors, like the weather or hilly streets, relevant about cycling. For them, flexibility and modernity of cycling (i.e. it fits into their lifestyles) are some of the most rated factors. Ratings of people who intend to use BiciMAD on a frequent basis are very similar to those of frequent cyclists, excepting 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 bicycle forms part of their lifestyle. This is something that the government and the operator have to consider for an effective promotion of bike-sharing (e.g. by awareness-raising about its benefits in a hilly context).

According to the preferences of respondents, key of the promotion of cycling in Madrid is infrastructure development: traditional barriers to cycling – like climate, topography and risk of accidents – are considered less important than bicycle routes, safe parking and integration with public transport. People seem to appreciate eco-friendliness of cycling but riding a bike is still not considered as an expression of a modern lifestyle in Madrid.

Some questions addressed general features of cycling and some important issues about infrastructure and intermodality. However, interpretation of a lower number of variables, and a better understanding of (unobserved or not identified, secondary, aggregate, underlying) factors seemed to be useful for further analysis in the following stage of the study. Accordingly, an exploratory factor analysis has been carried out (see Table 11) with varimax raw rotation and principal components extraction and eigenvalues greater than 1. Variables with loadings greater or equal to .50 were retained on a factor. 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 underrepresented in the survey). Consequently, here the total number of analysed responses is 1694.

Table 11: Loadings of factors that influence the use of bicycles in Madrid

Factor (eigenvalue; % of total variance)	Variables	Factor loadings	Factor name
1 (3.94; 30.36)	Safe bike-parking	.80	“Parking and intermodality”
	Access (public centres)	.79	
	PT integration	.70	
	Adaptation of workplaces	.66	
	Bicycle routes	.62	
	Speed limit to 30 km/h	.53	
2 (1.40; 10.70)	Topography	.82	“External factors”
	Climate	.72	
	Risk of accidents	.66	
3 (1.90; 14.67)	Flexibility	.80	“Advantages of cycling”
	Price (cycling is economical)	.78	
	Eco-friendliness	.76	
	Lifestyle (fun)	.53	

Ex-ante sample (2014), n=1694

Three factors have been identified (that explain 55.74% of the variance in the original data):

- *Parking and intermodality*: variables linked to parking the bike (in public spaces, at commercial, cultural and other public institutions and 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 due to the effort required on hilly streets) 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 risk of accidents of cyclists as unprotected road users.
- *Advantages of cycling*: characteristics of using a bicycle that puts it in a favourable position compared to other transport modes, such that cycling is an economical, environmentally-friendly and flexible means of transport, offering a door-to-door mobility option, easily parkable almost anywhere.

4.3 Potential users' perceptions of the demand responsive characteristics

In spite of the officially announced inauguration foreseen for the 1st May 2014, most respondents (53%) had no idea about the BiciMAD project during the survey period, taking place in May 2014. (As mentioned above, BiciMAD was finally inaugurated in late June 2014.) One of the possible reasons of this ignorance may be that the project was first drafted by the cycling mobility plan of Madrid in 2008 and financial constraints during the crisis caused the project to be postponed. Another reason is that there was no relevant public participation in the planning of the project and there was 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 local people, the issue of public acceptance of the bike-sharing system and 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 rarely ride a shared bike: most frequently for recreational trips, sometimes going to work or doing shopping. Leisure and sport is the top motivation for the reported future occasional use (36.5% of all respondents) as well, followed by shopping. The less important reported 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 efficient 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 fees (lack of free period), limited service area in the first project phase, lack of proper infrastructure and inefficiency of shared "ciclo-carril" lanes (instead of visually or physically separated bike tracks or lanes) in the city centre as well as the behaviour of motorists.

Some 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 pedelecs, and (2) the fee 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; however, by the time of the personal intercepts (to invite people to take part of the survey), most of the BiciMAD stations and pedelecs had already been installed.

4.3.1 Electric pedal assistance

All bicycles of BiciMAD are pedelecs (electric power-assisted bicycles), thus 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 out of the 22 kg total weight), stopping if the rider is not pedalling or a speed of 18 km/h⁶³ 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 also be a barrier, (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, and (4) elderly people (quite usual in an aging society like the one in Madrid) would not easily opt for regular bicycles.

According to the survey, less than 1% of bike owners have an e-bike or pedelec. Peculiarly, a similar proportion, 0.96% was the share of EPACs (electric power-assisted cycles⁶⁴) in the sale of bicycles in Spain in 2013⁶⁵. Most of them have other bicycle(s) as well (urban bike, folding bike, etc.). All of them bike more often than the average: all e-bike/pedelec owners have ridden a bicycle at least in the past month (one third even on the same day) and most go to work/school by bicycle on a regular basis. They rate the importance of barriers below the average: climate 3.67 (average 3.92), topography 2.92 (3.42), risk of accidents 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%) has 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 more importance to the advanced pedalling technology (3.7 points) than those who would 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 power-assisted, as they are keener 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 one of the first city-scale bike-sharing systems 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.

⁶³ By experiences of actual use, maximum assisted speed has been increased to 25 km/h. However, ex-ante survey respondents evaluated the original configuration.

⁶⁴ Electric power-assisted cycles or EPACs are e-bikes, pedelecs, e-mopeds and e-scooters.

⁶⁵ From then on, EPAC sale has increased significantly: from 10,000 in 2013 to 18,000 (1.7% of all bicycles sales) in 2014 and 25,000 (2.3%) in 2015. Source of data: EUROPEAN BICYCLE MARKET 2014, 2015 and 2016 edition by COLIBI Association of the European Bicycles Industry and COLIPED Association of the European Two-Wheeler Parts' & Accessories' Industry .

4.3.2 Fees, discounts and online apps

The government of Madrid decided to apply a fee 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 hand, it is aware that a fee per each use may keep many people away from using BiciMAD. In this context, decision-makers opted for a relatively low yearly fee of €25 (London €112, Budapest €61, Barcelona €47.16, Brussels €32.6, Paris €29 in 2014) and a relatively low fee per each use of €0.5 per 30 minutes for registered users (that is usually free of charge in other cities).

Before implementation, it seemed to be the most controversial issue about BiciMAD. Although the yearly subscription fee is considered acceptable by respondents, fees per use are apparently refused (Figure 24).

Likert-type scale from 0 to 5, ex-ante sample, incl. tourists (2014), n=1859

Figure 24: Evaluation of fees and related applications before BiciMAD implementation

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 per use) and people who walk to work (1.95) would hardly accept the costs per use. Fees for occasional users are also rejected by the respondents. Tourists rate it better than local residents who would use bike-sharing

occasionally (2.5 and 2.3, respectively). Maybe this 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 user-based redistribution by reducing the fees if a bike is picked up from a saturated station (>70% of occupancy) or returned to a low occupancy one (<30%). Surveyed people evaluated this discount much more positively than the fees. Nevertheless, 13% of the people who wish to use BiciMAD would not walk more than 3 minutes and 52% do not plan to walk more than 3 to 5 minutes to find an available bicycle, even for a discounted fee. That means that they would like to find an available bike at the nearest or the second nearest docking station (having a station in a distance of 300 to 500 m). It is also much appreciated that mobile apps help to locate a bicycle or to reserve an end-trip docking rack. These applications may reduce the fees by letting people know the availability of bikes and docks.

4.4 Identification of potential 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, soon to be implemented in Madrid, as well as properties of future users (and non-users). Socioeconomic characteristics and factors that influence cycling have been analysed.

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 a 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 bike-sharing, who will reject its use and who may be targeted by campaigns and other measures after implementation.

Analysed variables are related to socioeconomic status (gender, age, education, occupation), mobility patterns (means of most frequent trips, cycling habits, attitudes towards cycling) and bike-sharing attitudes (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 a relatively homogeneous group – following the advice of a recent study on public transport service quality evaluation by users in Spain (De Oña et al., 2014) –, the technique of cluster analysis is employed. Taking into account its relative advantage in comparison to other (e.g. hierarchical) methods and that the number of clusters may be specified in advance, the heuristic centroid-based technique of K-means clustering has been chosen. Its linear complexity, ease of interpretation, simple implementation, quick

convergence, adaptability to sparse data and, especially, applicability to large datasets (that is the case here) makes this partitional algorithm a proper technique for the identification of potential user groups (Jain, 2010; Jain et al., 1999; Likas et al., 2003; Rokach and Maimon, 2005). Three clusters are expected by the analysis, in line with the three user categories of BiciMAD: subscribers, occasional users and non-users.

Euclidean distances between clusters (Table 12) indicate moderate differences among clusters, which seem to be explained by the lack of full representativity of the sample (e.g. young and active people are overrepresented) and that there are similarities across clusters in other terms as well (e.g. there are only slight differences in the knowledge about BiciMAD prior to its implementation). Some topics are represented by a group of items in the analysis (e.g. there are separate items for the typical transport mode: walking, bicycle, PT, car and motorcycle, other), i.e. differences on a graphic representation of means (Figure 25) are obvious particularly only in case of variables that independently address topics in the clustering (e.g. global evaluation of BiciMAD).

Table 12: Euclidean distances between clusters of potential BiciMAD users

Clusters	1	2	3
1	0	.22	.17
2	.47	0	.19
3	.41	.43	0

Euclidean distances below diagonal,
squared Euclidean distances above diagonal

Figure 25: Plot of cluster means

Table 13: Clusters of potential users and non-users of BiciMAD

Variables	Cluster 1: “Fans”	Cluster 2: “Vacillating and indifferent”	Cluster 3: “Opponents and/or frequent cyclists”
Cycling last time	Not in the last 4 weeks	Not in the last year	Less than 4 weeks ago
Most important cycling related factor	Parking and intermodality	Advantages of cycling	Parking and intermodality
Sex	Slightly more women	Slightly more men	Men and women equally
Age	20–40	In their 20s	30–50
Education	Mostly secondary education or still studying	Secondary or higher education	Higher education
Occupation	More students and inactive	Mostly students	Employed or self-employed
Transport mode	Mostly PT users	Car and PT users	More cycling and walking (average in car and PT use)
Information about BiciMAD	Heard more about BiciMAD	Heard less about BiciMAD	Heard about BiciMAD
Attitude towards BiciMAD pricing policy	Relatively positive	Indifferent (but more negative)	Very negative
Global evaluation of BiciMAD	More positive	Rather negative	Quite negative (more negative than others)
Willingness to use BiciMAD	Will use (frequently and/or occasionally)	Occasionally	Less intention to use, maybe occasionally
Group size	735	446	513

Ex-ante sample (2014), n=1694

As expected, three clusters have been identified (Table 13), as follows:

- *Opponents and/or frequent cyclists (30.3% of the sample)*: On the one hand, this is a homogeneous group: these are the people who would not use BiciMAD and it would be difficult to convince them. On the other hand, 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 pedestrians (who may not “need” bike-sharing). Non-cyclists are average car or PT 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 out of two have never heard about it). They are the

more negative about the pricing structure, i.e. they strongly criticize both the annual registration fee and the fee per use. Only a few of them would register as a frequent user and this is the group where occasional use has also the lowest chance.

- *Vacillating and indifferent (26.3%)*: 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 (more negative than the average), they would like to use it occasionally. 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 PT in Madrid. Also the use of motorised modes (car and motorcycle) is above average.
- *Fans (43.4%)*: 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 the 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 are crucial for them, closely followed by external factors. The majority have not ridden a bicycle in the past month or even longer.

Although the three groups basically correspond to the three user categories of BiciMAD (Fans: subscribers; Vacillating and indifferent: occasional users; Opponents and/or frequent cyclists: non-users), there are different intentions within clusters, meaning that the identified groups outline complex user (or non-user) profiles.

4.5 Findings about potential bike-sharing users

In Madrid, exogenous factors make the promotion of cycling and bike-sharing difficult: first, a city centre full of slopes and second, 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. Seemingly, young people (up to 40) are more open to the use of bike-sharing than middle age or elderly people in Madrid. Also this challenge is faced by introducing a fleet of pedelecs, a type of bicycle suitable at almost any age and any level of fitness.

Furthermore, the local government decided to introduce a unique fee structure to achieve goals on the basis of mobility management considerations: each user has to pay per each use (including subscribers) in order to avoid that people stop walking or using public transport and there are discounts to incentivize user-based redistribution, i.e. to improve efficiency and eco-friendliness.

The identification of three groups of users and non-users through the present study may help the service provider to adapt system configuration to the needs and expectations of

other potential users more efficiently. One aspect to be considered (prior to the implementation of such systems) is the lack of information that makes people indecisive about their intention to use bike-sharing 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 or smart redistribution incentives). 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 fee system may be observed after a few years of operation, i.e. if it will really avoid a modal shift from walking or public transport to bike-sharing; if riders will actually make use of redistribution related discounts and really help to rebalance the system; and also if a fee per each use will not discourage potential users (motorists, pedestrians and public transport users) from becoming bike-sharing clients.* 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 mainly 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 reject it).* Road infrastructure development by 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 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, managed or even operated by a local or regional public transport provider).

5 DIFFUSION OF BIKE-SHARING AS AN INNOVATION VECTOR IN MADRID

In this chapter

Innovation Diffusion Theory (IDT) is adapted and applied as a framework to identify adopter profiles and analyse attributes that influence the time of adoption of BiciMAD as an innovation in Madrid, including an additional attribute: cycling familiarity. Empirical results are presented to understand how an innovation (in terms of technology, service configuration and on the level of a city) is spread. Conclusions show that bike-sharing is an innovation vector in urban mobility, a smart technology adopted quickly by all adopter categories, namely 1) lifestyle cyclists, the venturesome and technology enthusiast Earliest adopters, 2) dedicated cyclists, the rational and deliberate Early majority, 3) leisure cyclists, the skeptical and peer-dependent Late majority, and 4) fairweather cyclists, the prudent Laggards.

Innovation is one of the key topics in Europe in order to tackle major societal challenges, such as ageing population, health, migration and internal mobility, urbanization, effects of climate change, and reduced availability of resources. Two specific drivers stimulate innovation in the transport sector (Wiesenthal et al., 2011): (1) the ambition to improve quality of both products and services, increase market shares, enter into new markets, add flexibility and reduce costs in the production processes, as well as (2) regulatory and fiscal policies. Innovative Union, an initiative of the Europe 2020 strategy to achieve a smart, sustainable and inclusive growth, addresses some specific transport related objectives: reducing greenhouse gas emissions through interoperable and intelligent traffic management systems across all transport modes, more efficient urban transport with less congestion in smart cities, and deployment of Intelligent Transport Systems (ITS) to equip Europe with seamless door-to-door travel and effective logistics.

In the research of innovation, rate of adoption (the relative speed with which an innovation is adopted, i.e. a way to analyse an innovation or to compare various) can be explained by the differences of perception of certain attributes of an innovation. Understanding the decision about the adoption of a new technology or service in the highly innovative transport sector is, in terms of transport research, a specific question of travel behaviour. Although many aspects of individual decision-making on travelling (mode choice, routing, etc.) have already been addressed by researchers and there has been significant progress in travel behaviour research recently, questions about how travellers (or users of a service related to passenger transport) perceive characteristics of an innovation and how they then react have not yet been studied extensively. In their widespread review on innovation attributes, Tornatzky and Klein (1982) came to the conclusion that there is a need for more research in this area, that we certainly do not know all there is to know about innovation characteristics and that this line of research should not be abandoned. Furthermore, most studies of the literature on innovation diffusion focus on determining the characteristics of general adopter categories, rather than how innovation properties affect their rate of adoption by members of a social system (Rogers, 1995). After decades, at least in the field of transport research, there are still gaps in the study of innovation characteristics and their perception by (potential) users.

In the context of urban mobility, innovation is motivated mainly by environmental and sustainability issues, policymaking and legislation as well as technology changes and ICT (Klasing Chen et al., 2014). Recent history of bike-sharing reflects all these motivations by being a service of a non-motorized shared vehicle, namely bicycle, i.e. a highly egalitarian and sustainable mode of urban transport which has few fossil fuel implications (Kenworthy, 2007), representing the latest technology (e.g. smart access by mobile devices), and getting considerable attention by decision-makers that is reflected by a quick recent global spread. Currently cities look for smart solutions, e.g. a high quality and more efficient transport system to manage new challenges of sustainability (Albino et al., 2015), and bike-sharing is one of the most promising and most popular ITS tools applied recently.

As mentioned in previous chapters, in spite of its more than half-century-long history, bike-sharing is relatively new as a common element of urban mobility. Due to that and the highly

innovative, adaptive and demand responsive character of its recent implementation in cities worldwide, there are many questions to be addressed by researchers to understand the bike-sharing phenomenon. Apparently a quick response has been given by the research community and some relevant topics have already been studied, but — in spite of its unprecedented spread worldwide and fast success in some cities — circumstances of its diffusion as an innovation (especially on urban level) has not yet been explored. The present chapter aims to contribute to its research by the analysis of BiciMAD as a novel bicycle technology, a unique set of configuration and, especially, a new travel mode in Madrid.

5.1 Framework for the study of bike-sharing adoption

Despite growing interest in public sector innovation⁶⁶ (Hughes et al., 2011; Nam and Pardo, 2011; Petkovšek and Cankar, 2013; Sørensen and Torfing, 2012; Weber et al., 2014), there is general lack of knowledge about innovations in systems of public use⁶⁷ and the catalyst role of public sector in innovation by private firms, including urban (public) transport services and technologies like bike-sharing. Types of innovation are also defined mainly for the business enterprise sector, such as:

- The four types by the Oslo Manual (OECD/Eurostat, 2005): product innovation (a good or service that is new or significantly improved); process innovation (a new or significantly improved production or delivery method); marketing innovation (a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing); and organisational innovation (a new organisational method in business practices, workplace organisation or external relations). In this context, a bike-sharing scheme may be identified as a product innovation, i.e. a new or improved element of urban mobility.
- The types of innovation by Clayton Christensen (Christensen, 2013; Christensen and Overdorf, 2000): sustaining innovation (that make a product or service perform better but does not affect existing markets) that may be either evolutionary (expected improvement of a product or service) or discontinuous (an unexpected innovation that does not affect existing markets); and disruptive innovation (that create an entirely new market through the introduction of a new kind of product or service). In this case, bike-sharing may be disruptive (if introduced for the first time with a significant impact on urban mobility) or evolutionary (if improved significantly, e.g. by upgrading an existing system from a 2nd to a 4th generation service configuration).

The literature defines three phases of an innovation (Moreno and Suriñach, 2013): 1) the invention process (a new idea is conceived), 2) the innovation process (the new idea is

⁶⁶ There is clear intention to foster public sector innovation on EU level as well, see Powering European Public Sector Innovation: Towards A New Architecture. Report of the Expert Group on Public Sector Innovation. DG for Research and Innovation, Brussels, 2013.

⁶⁷ “Innovation is also important for the public sector. However, less is known about innovation processes in non-market-oriented sectors. Much work remains to be done to study innovation and develop a framework for the collection of innovation data in the public sector.” (OECD/Eurostat, 2005: 16)

developed into marketable products or services), and 3) the diffusion/adoption process (the new product or service is spread across the potential market). This part of the dissertation is focused on the last phase, where the impact of the innovation-induced change takes place. A new approach is presented to understand the adoption of bike-sharing as an innovation: Innovation Diffusion Theory is applied as a framework for the first time to study specific research questions about bike-sharing diffusion.

5.1.1 Innovation Diffusion Theory

In the broad context of diffusion, acceptance, adoption and perception of innovations, many theories have been developed to understand people's behaviour and thoroughly explored worldwide in a wide variety of literature of several research fields (e.g. Alomary and Woollard, 2015; Attuquayefio and Addo, 2014; Sahin and Thompson, 2006; Williams et al., 2011; Wills et al., 2008; Yucel and Gulbahar, 2013), especially in ICT, health and education related studies. The theories vary from the "incredibly influential" (Tan, 2013) Theory of Reasoned Action (TRA, M Fishbein and I Ajzen, 1975), throughout its expanded or modified descendants like Theory of Planned Behaviour (TPB, I Ajzen, 1985, 1991), Technology Acceptance Model (TAM, FD Davis, 1989), extended TAM (TAM2, V Venkatesh and FD Davis, 2000), Combined TAM and TPB Model (C-TAM-TPM, S Taylor and P Todd, 1995), Unified Theory of Acceptance and Use of Technology (UTAUT, V Venkatesh et al., 2003) to theories of other background like Motivational Model (MM, FD Davis et al., 1992), Innovation Diffusion Theory (IDT, EM Rogers, 1995, first edition published in 1962) or Social Cognitive Theory (SCT, A Bandura, 1986).

Innovations are not adopted by all individuals at the same time and research on diffusion of innovation aims to explore how a new idea is spread among members of a social system. A widely accepted approach is the categorization in the Innovation Diffusion Theory. It states that perceptions of the characteristics of an innovation by potential adopters influence their adoption decisions. This approach has been widely supported for a variety of innovations (Ilie et al., 2005), and it seems to be an appropriate basis for the analysis of the adoption of bike-sharing as an innovation in the city. As it considers a larger number of variables than other models (e.g. TAM), it provides a richer perspective for research, as well.

On the basis of observations, IDT classifies adopters in five "ideal" categories according to their innovativeness (Rogers, 1995):

- *Innovators (venturesome, 2.5% of adopters)*: They are eager to try new ideas and risk-taking is almost an obsession with them. Innovators have a key role in the diffusion process by launching the new idea in the social system. The enthusiasm in innovations might lead them out of a local circle of peers and into more cosmopolite social relationships than the average.
- *Early adopters (respectable, 13.5%)*: They tend to be more integrated into the local social system than innovators. They are considered as opinion leaders, "the individual to check with" before adopting an innovation. Their role is to decrease uncertainty about an innovation by making judicious decisions, adopting it and inform peers about the evaluation through interpersonal networks.

- *Early majority (deliberate, 34%)*: They are more innovative and adopt new ideas before the average. They are not considered as opinion leaders but interact frequently with their peers. Their position in the diffusion of innovation (between early and relatively late adopters) makes them an important link in the process. They deliberate some time before the adoption of a new idea and their decision takes more time than in earlier adopter categories.
- *Late majority (sceptical, 34%)*: They adopt new ideas just after the average, after being persuaded and/or pressured enough by peers. Adoption of an innovation may be an economic necessity or answer to an increasing social pressure.
- *Laggards (traditional, 16%)*: The last group of people in a social system to adopt a new idea. Their point of reference is the past and they must be relatively certain that an innovation will not fail before they afford it by their limited resources. They are the most localites in all adopter categories; many are near isolates in social networks and possess almost no opinion leadership.

Distribution of adopter categories nearly approach normality and takes the form of a well-shaped curve, which consists of five areas: Innovators (the first 2.5% of adopters), Early adopters (13.5%), Early majority (34%), Late majority (34%), Laggards (16%). In spite of some critiques on the shortcomings of this categorization — that the assumption of normality may be far from reality for many innovations and its arbitrariness (Peterson, 1973), there is no empirical or analytical justification of why adopter categories should be the same for all innovations (Mahajan et al., 1990) — it is still a reference point of the classification of adopters in diffusion research and many scholars have applied or reconsidered it (e.g. Bach, 1989; Bernstein and Singh, 2008; Valente and Rogers, 1995).

The relationship between the attributes (characteristics) and the adoption (implementation) of an innovation is a classical issue of the innovation related literature (Tornatzky and Klein, 1982). The key attributes that most research analyses are the five of IDT (Rogers, 1995): relative advantage, compatibility, complexity, trialability and observability (Table 14).

According to IDT, at least half (49 to 87%) of the variance in rate of adoption can be explained by these five attributes.

Table 14: Perceived attributes according to the Innovation Diffusion Theory

Perceived attribute	Definition: "The degree to which..."	Application
<i>Relative Advantage</i>	an innovation is perceived as being better than the idea it supersedes	<ul style="list-style-type: none"> -the nature of innovation determines the specific type of advantage (economic profitability, social prestige, or other benefits) -potential adopters want to know the degree to which a new idea is better than an existing practice -one of the best predictors of an innovation's rate of adoption
<i>Compatibility</i>	an innovation is perceived as consistent with existing values, past experiences, and needs of potential adopters	<ul style="list-style-type: none"> -an innovation can be (in)compatible with 1) sociocultural values and beliefs, 2) previously introduced ideas, 3) client needs for the innovation -an idea that is more compatible is less uncertain to the potential adopter -the rate of adoption of a new idea is affected by the old idea that it supersedes -less importance in predicting the rate of adoption than relative advantage
<i>Complexity</i>	an innovation is perceived as relatively difficult to understand and use	<ul style="list-style-type: none"> -complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption -as it is the only attribute negatively related to the rate of adoption, ease of use or simplicity (the opposite of complexity) may be applied -any new idea may be classified on the complexity-simplicity continuum
<i>Trialability</i>	an innovation may be experimented with on a limited basis	<ul style="list-style-type: none"> -the personal trying-out of an innovation is a way to give meaning to an innovation -earlier adopters perceive trialability as more important than do later adopters -later adopters are surrounded by peers who act as a kind of vicarious trial (hence their own personal trial is less crucial for them)
<i>Observability</i>	the results of an innovation are visible to others	<ul style="list-style-type: none"> -some innovations are difficult to observe or describe to others -technology-based innovation has a hardware (material or physical object) and a software (information base for the tool) component -innovations in which the software component is dominant are not so apparent to observation and usually have a relatively slower rate of adoption

Adapted from Rogers (1995)

According to the theory, some other variables also affect the rate of adoption (Figure 26):

- the type of innovation decision (optional, collective, authority): individual decision-making speeds up adoption;
- the communication channels: the relationship between communication channels (e.g. mass media or interpersonal channels) and the attributes of an innovation may interact to make the adoption faster or slower;
- the nature of the social system (e.g. norms, degree of communication network connectedness);
- the extent of change agents' promotion efforts in the diffusion of innovation: the relationship with rate of adoption may not be direct or linear.

Figure 26: Variables determining the rate of adoption of innovations according to the Innovation Diffusion Theory

In the evolution of the application of Rogers' theory over more than fifty years, some other aspects of innovation characteristics have also been studied. Attributes like flexibility, reversibility, cost-efficiency, risk (Kolbe and Iverson, 1981), cost, communicability, divisibility, profitability, social approval (Tornatzky and Klein, 1982), image, voluntariness (Moore and Benbasat, 1991), economic advantage, effectiveness, reliability, divisibility, applicability, commutuality, radicalness (Dearing and Meyer, 1994) have further been discussed in health, education, IT and general innovation related studies. The 'additional' characteristics are obviously related to one of the five attributes, e.g. image (how the use of an innovation enhances one's status in the social system), voluntariness (the degree to which an innovation is optional to use) and profitability (the level of profit to be gained by the

adoption) as aspects of relative advantage; communicability as a topic of observability (how aspects of an innovation may be conveyed to potential users); or divisibility as an issue of trialability (if the innovative service or product can be tried on a small scale prior to adoption). Taking into account the recommendation of Rogers on limiting the core attributes to the five originally proposed and that most scholars still accept this recommendation (Atkinson, 2007; Sahin, 2006), it seems reasonable to ignore the application of any (criticized, outdated, consequently rejected or simply additional) other characteristics as an individual category of perceived attributes in traditional fields of diffusion research.

5.1.2 Specific research questions about the diffusion of bike-sharing

There might be some doubts about the direct application of IDT in a specific case, i.e. if any of the five attributes and its perception need further consideration, especially in a research about a previously understudied field, namely transport and mobility, and its specific topics like passenger transport or travel behaviour. For instance, the subject of the present study, bike-sharing, is a unique element of the urban transport system that combines properties of a private bicycle (cheap, environmentally-friendly, active mode, space-saving, etc.) and a public means of transport (integrated into the transport system, available for the general public, reliable, secure, etc.) and, as such, has a strong linkage to the characteristics of cycling. In this context, is there any special attribute of cycling that may have influence on the decision about using a bike-sharing service as an innovative element of the urban transport system? For instance, does bike ownership or experience in cycling affect the use of a recently introduced bike-sharing service? There might be doubts about adopter categories, as well, e.g. is it possible to differentiate the five ideal types in case of an innovation like a new bike-sharing system in a city and do these categories include the supposed percent of adopters? Answers to these questions may contribute to the discussion about time of adoption and perceived characteristics, as well as to better understand bike-sharing and cycling related travel behaviour.

Adoption of an innovation has been rarely addressed in specific fields of transport related research, e.g. Mallat et al. (2008) applied a combination of TAM and IDT (amended by factors based on empirical findings) to study mobile ticketing service adoption in public transport and Sigurdardottir et al. (2014) employed IDT to identify adolescents' intended time-frame for obtaining a driving license and buying a car. Only first insights have been provided into the diffusion of cycling and bike-sharing: e.g. Wolf and Seebauer (2014) and Seebauer (2015) about technology adoption of electric bicycles, Parkes et al. (2013) about the global diffusion of bike-sharing programmes and Hazen et al. (2015) about the prediction of bike-sharing adoption using the Technology Acceptance Model. Nehme et al. (2016) examined two theory constructs of IDT, namely perceived compatibility of bicycle use and stage in the innovation-decision process to understand utility cycling adoption. Furthermore, recently there has been an interest in the study of factors that influence people in their travel behaviour, especially in mode choice literature based on the Theory of Planned Behaviour. There is a strong interest, as well, in studying the shift of mode choice towards cycling in urban mobility throughout case studies (Habib et al., 2014; Heinen et al., 2011; Majumdar et al., 2015; Piatkowski and Marshall, 2015; Verma et al., 2016), especially in Spain (Fernández-Heredia et al., 2016;

Fernández-Heredia et al., 2014; Lois et al., 2015; Muñoz et al., 2016), including a study on the role of mode familiarity (Rondinella, 2015; Rondinella et al., 2012). Bike-sharing has also recently become an issue of great interest of transport research, but relatively little effort has been devoted to analysing demand side issues like mode choice or user perceptions.

Thus, there is the need, on the one hand, for the application of the theories on innovation diffusion in the field of transport to understand how personal characteristics and innovation attributes influence its time of adoption by users and if there is any further characteristic to be considered due to the specific properties of a transport mode. On the other hand, there is still room for further investigation in behavioural issues of cycling and especially the highly innovative bike-sharing services to explore what we do not know about the users and potential users. An extensive research (Rondinella, 2015) has found that higher levels of cycling use for utilitarian purposes (i.e. cycling familiarity) may lead to more positive levels of cycling consideration. On the basis of this conclusion, the present study intends to examine the role of individual frequency and history of cycling in the decision about bike-sharing adoption. For that, cycling familiarity is analysed in the adoption of bike-sharing, as an additional attribute to the five identified by IDT. Thus the theory is applied as a framework for a case study to identify adopter profiles (by time of adoption) of a bike-sharing system, including cycling familiarity as a possible attribute.

5.2 Presentation of the innovative characteristics of BiciMAD

BiciMAD is novel in, at least, three terms: as a unique vehicle at the moment of its implementation (*technology*), as an innovative bike-sharing system of the latest generation (*service configuration*), and as a new element in the urban mobility of Madrid (*travel mode*). All these three approaches are described in detail in this chapter to specify and characterize the subject.

This part of the research is explicitly based on surveys among *actual* users of BiciMAD. For that, specific questions have been included in the surveys carried out in 2015 (n=584) and 2016 (n=534). Only a few conclusions have been indirectly included in the present chapter about ex-ante respondents, i.e. potential users (2014, n=1811). This chapter focuses on the responses by frequent users (i.e. yearly subscribers) of BiciMAD. In this regard, the total number of respondents is 676, of which 392 are from the 2nd survey phase (2015) and 284 from the 3rd (2016).

There have been some limitations in the statistical analysis, due to the fact that the surveys served for a general analysis of bike-sharing usage and the content was partly modified after each survey phase. For instance, some questions had to be omitted in the 3rd phase due to time restrictions. Furthermore, attributes determined by IDT for the study of the diffusion of an innovation are not intended to serve merely quantitative analysis. In the present case, IDT sets the framework for the analysis of rate of adoption, which is a numerical indicator (the number of individuals who adopt an innovation in a specified period), but variables determining the rate may be interpreted according to the character of the innovation, i.e. not necessarily in a quantitative but a qualitative (or descriptive) way.

5.2.1 Novel technology

BiciMAD pedelecs have been developed especially for Madrid's bike-sharing system. On the one hand, in some aspects it is a conventional heavy bike of a bike-sharing system: it is a light and robust bicycle (weighing not more than 25 kg) with adjustable and non-removable seat, solid double-wall rims and antipuncture tubes, cowlings protecting components (control panels, cables, handlebars, etc.) and providing space for publicity, chain and mudguards, etc. On the other hand, it is innovative, differing from other systems due to its unique specification with some brand new mechanical (e.g. an exclusive aluminium frame for the built-in battery ensuring improved security against vandalism) and electrical elements (e.g. a battery management system with longer useful life, providing system information). Bicycles are equipped with a light and almost noiseless electric motor for pedal assistance on three levels, with a maximum engine power of 250W and a maximum assisted speed of 25 km per hour (as mentioned in a previous chapter, an original 18 km per hour was modified a few weeks after the implementation in order to ensure the integration of BiciMAD into the road traffic). The first fleet had three control options: pedal assistance (on/off), level of pedal assistance (low, medium and high), lights (on/off). From 2015, bicycles come with automatic lights. GPS is built in for the localization of bicycles in case of theft or other irregular use.

Source: Madrid official tourism website⁶⁸

Figure 27: BiciMAD pedelecs and docks

Bicycles are parked in fix stations (Figure 27) which comprise a modular docking point where smart charging of bicycles and downloading of information about bike properties and routes take place (for maintenance), as well as a terminal that gives access via touchscreen monitor to online registration and payment procedures (for occasional users), information about the network and routes, availability and reservation of docking points, etc. (for users). Registered users may pick up a bicycle by an RFID card without the need for any operation at the terminal. Services for users are available online as well. CCTV operates in each station for security reasons.

⁶⁸ <https://www.esmadrid.com/en/itinerary/madrid-two-wheels>; <https://www.esmadrid.com/bicimad> (accessed 18/6/2017)

An exclusive software manages BiciMAD, providing the maintenance department with real-time reports and notifications about the stations (availability of docks and bicycles, improper parking, maintenance and redistribution priorities, etc.), bicycles (state of repair, number and duration of trips, etc.) and users (available credit, number of trips, carbon footprint, etc.). Some special features, i.e. reservation of a dock at destination, access to information about dock availability at destination, and maintenance management (identification of problems and suggested action through user interaction) make it different to other systems.

5.2.2 Smart service configuration

As mentioned in Part I, e-bike or pedelec is not a new idea but e-bike-sharing is a relatively novel concept in urban mobility. Beside some other early applications and pilot programmes (cycleUshare in the university campus of Knoxville, Tennessee; a complementary pedal-assisted bike fleet of Bicing, Barcelona; a network of 20 stations of Bicyklen/GoBike in Copenhagen; etc.) Madrid was the first to introduce a city-centre-wide large bike-sharing fleet of pedal-assisted bicycles in Western countries. The main feature, the electric pedal assistance is, for example, a response to many potential barriers: age, inactivity, lack of storage space for private bike, hilly streets, low speed in the motorized traffic, etc. In a city like Madrid where topography and distance are variables that explain a key factor of cycling behaviour (Muñoz et al., 2013), e-bikes and pedelecs may contribute efficiently to an increased demand of cycling and bike-sharing.

Table 15: Answers of BiciMAD to the challenges of cycling promotion in Madrid

Challenge	Required answer	Solution
hilly city centre	provide assistance	fleet of pedal-assisted bicycles
insufficient cycling infrastructure	be safe and competitive with road traffic	
ageing population	be accessible for elderly people be attractive for a general public	
low cycling culture	be flexible	fully supported by online applications, available at stations and by mobile devices
relatively high share of walking and PT use in the city centre	avoid modal shift from other sustainable modes	fee per each use (incl. first 30 minutes)
	foster integration, encourage interchange	discount on yearly registration fee for PT users
		physical integration at stops and stations
environmental pollution by trucks (redistribution)	reduce necessity	smart rebalancing by users, incentivized by fee discounts
possible thefts	ensure tracking and/or localization	built-in GPS
possible vandalism	provide surveillance	CCTV at stations
	solid construction	anti-vandalism batteries incorporated into an exclusively designed aluminium frame

However, BiciMAD is unique not only as a fleet, but also as a set of service configuration and policy measures. This is due to what has been told about the recent generation of bike-sharing systems: multimodal demand responsive services are adjustable to the needs of a city (in terms of geographic, economic, demographic, political, etc. factors) in light of consumer needs or potential user characteristics. BiciMAD, as a unique bike-sharing service, was designed to give answer to many problems, challenges and needs (Table 15) of the city and local people. Special attention has been paid to mobility management issues, i.e. how to attract new customers and, at the same time, prevent a modal shift from walking and public transport to bike-sharing on short trips, as well as to environmental problems, i.e. how to reduce the use of motorized vehicles for bicycle redistribution.

5.2.3 Travel mode (innovation in the city)

At the moment of its implementation, BiciMAD was a new element of the transport system in Madrid (There was a pilot bike-sharing system of 300 bikes in the university campus “Ciudad Universitaria” from 2011 to 2013.) In spite of its low cycling culture, there is a great cycling potential according to the SUMP of Madrid: 82% of the local residents work in Madrid and 40% of the routes by motorized modes are shorter than 5 km. In this context, the local government decided to introduce BiciMAD as an ambitious mobility management measure: to provide citizens and tourists with a sustainable and efficient new transport mode in the city centre but avoiding a modal shift from other non-motorized or public transport modes.

On the one hand, offering an eco-friendly alternative to motorized vehicles – which had a share of 10.8% in the inner city (where the first phase of BiciMAD has been implemented) with more than 280,000 daily routes by private cars and motorcycles – was a priority for decision-makers. A bike-sharing system of the latest technology and especially a fleet of exclusively pedal-assisted bicycles might have been a costly solution compared to an already implemented, more uniformed technology or service configuration. However, in terms of marketing, it is also a “quick win” for the local government: a fully IT-based, smart system with demand responsive elements (e.g. discount for docking in a low-occupancy station) that needed no advertisement at all to become very popular in a period of a few months and exceeded even the ambitious expectations of having 40,000 subscribers in one year (see Chapter 3).

On the other hand, walking and public transport play a significant role in the mobility of Madrid, where an extensive metro and bus system operate and the modal share of walking is among the highest in European cities (Figure 28). Preventing a modal shift from these modes to a new one seemed a reasonable intention for the local government.

Data source: TEMS – The EPOMM Modal Split Tool (data from 2001 to 2015)⁶⁹

Figure 28: Modal split in European cities

In light of these considerations, it may be concluded that BiciMAD is not actually intended to be a first/last mile connection facility (that is walking) or a mass transport service but a special sustainable means of transport for routes of 2 to 6 km in the city centre (and by time, in the extension zones). The peculiar fee system, i.e. a fee of 0.5 euros per the first 30 minutes of use is also supposed to ensure that people keep walking and using public transport.

The modal share of cycling has been increasing in recent years in Madrid (see Chapter 3). It might be assumed that the bike-sharing service has served as one of the catalysts of such increase and despite its shortcomings (failures in IT services, maintenance, as well as unfavourable contracts and an unsustainable financing that led to the takeover of the service by the municipality from the private operator after two years), it has become a relevant and established element of the urban mobility system of Madrid.

5.3 Analysis of the diffusion of bike-sharing as an innovation

Above-presented survey data is used to study the diffusion of BiciMAD as an innovation vector in urban mobility. For such purpose, IDT is applied as a framework for the analysis of

⁶⁹ <http://www.epomm.eu/tems/> (accessed 31/1/2017)

two critical elements: adopter categories and perceived attributes of the bike-sharing service. The specific subject required some kind of modification and extension to the theory.

5.3.1 Adopter categories

There have been some challenges and difficulties for the classification of BiciMAD subscribers into adopter categories. Although bike-sharing might be considered a unique “product” (actually a combination of a public service and a private means of transport) and therefore adoption characteristics might be completely reconsidered, the ideal types of IDT have been applied as a common framework of the innovation related literature. The idea was, however, not to distribute frequent users (respondents) into the categories unconditionally, but to adapt the classification to the observations, if necessary. It had to be decided, as well, if any modification of the bike-sharing system might be considered significant enough to define a new idea and start a new process of diffusion.

An incomplete adoption at the time of the analysis is one of the key challenges; however, relevant changes took place only three months after the last survey phase. In autumn 2016, the municipality took control of the system from a private operator that led to improvements in safety, technical conditions and maintenance, which may lead to modifications of the service configuration in the future as well.

Another issue to be considered is that pre-registration was available, thus the service had a significant number of subscribers before implementation. Additionally, there was no advertisement of the project, only a few press releases and informal information (e.g. in the community media). Potential users were informed about it mostly by the installation of stations and bicycles on the streets a few weeks before inauguration. On the one hand, this is not exceptional in the case of a public service but somehow rare in the case of a completely new idea and a new mobility management tool in the city centre like bike-sharing. On the other hand, that might influence the earliest adoption by allowing more time for consideration to those who live or pass by the first installed stations and make first adoption highly dependent on the information sources of the individual.

Splitting the categories of Innovators and Early adopters and finding a date as a boundary seems impossible and pointless in light of the fast spread of subscriptions before and right after implementation. The first subscribers (weeks before the inauguration) took the risk of paying for an unknown service and those who started to use bike-sharing in the first months of its operation had to face some well-known failures (IT problems, unavailability of stations, vandalism, etc.), including at the moment of registration. These people not only behaved “hazardously” but obviously became opinion leaders in a short time, as well. Only 11% of the earliest subscribers relied on peers (friends or relatives) but they became a reference point for many later adopters (38% of Early majority and 44% of Late majority) in their decision about using the service.

Data (both official and survey) about subscribers is available only on a monthly (and not weekly or daily) basis. According to IDT, there are no pronounced breaks in the innovativeness continuum. Although months might seem arbitrary and quite large-scale

units (especially in the initial period), they also form a coherent and continuous system to properly delimit adopter categories. Seasons are and periodic changes affecting urban mobility (e.g. summer holidays in July and August) may also be assigned to months.

The core technology of BiciMAD remained unchanged during the data collection period but an intended and announced change affected the service both as a service configuration and a travel mode. By the geographical extension towards a greater area of the city centre, BiciMAD became available for more users and as a new urban mobility service in more neighbourhoods linked to more PT services and more valuable for some users (as in a greater operational zone one can achieve larger distances for the same price). As mentioned above, the changes affected the number of stations (165 instead of 123) and bicycles (from 1560 to 2028), as well.

Considering these circumstances, a decision was made:

- To use the data collected in summer of 2015 and 2016 to analyse the diffusion of innovation as a quasi-complete process. The time of the last survey, right before the public takeover of the operation, is not the perfect but an acceptable, almost ideal moment to close the data collection and subsequently identify adopter categories.
- That the diffusion process is considered as not being interrupted or finished during the subject period. As major changes take place in several steps (and is continued after the finalization of the present study) it means only the extension of an already generally known idea to new neighbourhoods nearby. The starting point of the system expansion is considered a potential boundary of adopter categories and not the ending of the diffusion (i.e. it is not the start of another innovation).
- To introduce the category of Earliest adopters to integrate Innovators and Early adopters. According to IDT, the two could be combined into a single category ("early market") to achieve symmetry in distribution but these are quite different types. Nevertheless, in this case, inseparability and common characteristics make sense to the definition of a new adopter category that combines venturesomeness and opinion leader role in the social system.
- That months are appropriate to delimitate adopter categories, in line with the category sizes defined by IDT, as follows:
 - Earliest adopters: months 1 to 3 (June to August 2014, 20.4% of adopters). It combines the ideal types of Innovators and Early adopters of IDT. The category includes adopters that subscribed before the inauguration and those who started to use the service right after, during the summer holiday period of 2014.
 - Early majority: months 4 to 9 (September 2014 to February 2015, 34%). Subscribers of the first autumn and winter, i.e. a working period and a full school semester. That time, some initial failures have already been fixed (especially the IT system and those of the stations and bicycles), as well as expansion has not already been launched.
 - Late majority: months 10 to 13 (March to June 2015, 30.4%). Geographical extension has already been started. A certain amount of experience (by

friends, relatives and other peers) might have been gathered and become available (press, community media, etc.).

- Laggards: months 14 to 25 (July 2015 to June 2016, 15.2%). One year after inauguration, the system has been established and has been expanded to some new neighbourhoods. Conditions of use and experiences of other users are available for everyone.

Share of subscription by month. 2nd and 3rd survey phase, n=676. Source of data about total subscribers: Datos Abiertos.

Figure 29: Adopter categories in light of the evolution of BiciMAD subscription from June 2014 to June 2016

Figure 29 shows that the distribution of survey respondents (red dashed line) is mostly in line with the percentage of new BiciMAD users (blue dots), with some exceptions due to a random sampling.

As a synthesis of the case study, some socioeconomic information, mode choice, relation to and opinion about cycling (Table 16), as well as knowledge about and evaluation of BiciMAD and motivation of subscription (Table 17) may be seen by the above defined adopter categories. These are also to present the profile of respondents that participated in the survey. The operational zone of the bike-sharing system in the city centre accounts for some rare outcomes of the survey, i.e. low percentage of car usage or that people go shopping on foot, etc.

Table 16: Characteristics of adopter categories: personal, socioeconomic and transport related information

N=676	Earliest adopters	Early majority	Late majority	Laggards
Theoretical size	16% (2.5% + 13.5%)	34%	34%	16%
Size in case study	20.4%	34%	30.4%	15.2%
Age	-average of 35.6 years (variability: 10.6 years) -Earliest adopters are a bit older, Laggards are slightly younger than the average -18 to 30: rather later adopters -30 to 40 and 50+: practically equal distribution in innovator groups -40 to 50: rather first adopters -in the survey, maximum of 71 and minimum of 13 years			
Sex	women adopt bike-sharing as an innovation later than men			
Education	-people with a degree (on any level of higher education) are overrepresented in the survey -no differences by level of education			
Occupation	-employees are more innovators than students, freelance and unemployed users			
Home	-4 out of 5 live in the first BiciMAD zone -about 5% live in the extension area		-2 out of 3 live in the first BiciMAD zone -15-20% live in the extension area	
Household size	no significant differences			
Income	people from households with higher income seem to adopt earlier			
Bicycle ownership	59%	58%	53%	56%
	-in total, 44% have no owned bicycle at home -those who do, typically have a mountain bike -half of the bicycle owners have more than one bicycle -3% e-bikes and pedelecs (compared to the total number of bicycles)			
	-more bike-owners but less multiple bike-owners than the average -other types of bicycles (urban bike, road bike) at home as well		-one out of two bike-owners have a mountain bike (above the average)	

N=676	Earliest adopters	Early majority	Late majority	Laggards
<i>Bicycle use</i>	-18% frequently (more than once a week) ride a bike, 37% never -one out of two goes to work/school by bike more than once a month, one out of four on a daily basis -bike is rarely used for shopping, visiting people and evenings out with friends -leisure is a motivation for almost all bike-owners (but not typical on a daily or weekly basis in any group) -an average of 13% go shopping by bicycle, 25% visiting friends or relatives, 18% going out with friends			
		-more frequency in riding a bike than in any other group -more bike-owners who go to work/school by bike on a frequent basis (more than once a week) than the average	-the highest proportion of non-riding (never) -go to work/school by bike less than the average	typically no frequent (daily or weekly) bike usage
<i>Opinion about factors affecting cycling</i>	<i>As it has been presented in Chapter 4, an outcome of the first phase of the same series of surveys, concluded that there are three key variables that may influence the decision about riding a bicycle in the city: 1) variables that affect cycling conditions and habits, such as climate, topography or safety (External factors); 2) variables linked to parking, related services and integration with other transport modes (Parking and intermodality); 3) characteristics of cycling that make it more favorable than other transport modes, e.g. flexibility and eco-friendliness (Advantages of cycling).</i>			
External factors	-the factor that users consider less relevant -Earliest adopters care less about climate, topography or risk of accidents than the average -for Laggards, climate is more, topography is less important than for others			
Parking and intermodality	-the most relevant factor for users, including the top item (namely bike routes) -Laggards consider parking issues (e.g. on public streets, at workplaces) and PT integration less relevant than others			
Advantages of cycling	-flexibility of cycling (e.g. door-to-door travel, parking almost anywhere) is highly evaluated by all groups, especially Early and Late majority -later adopters consider more the cheapness of cycling as well as if it fits to one's lifestyle -Laggards care the most about eco-friendliness of riding a bike			
<i>Typical transport mode (by trip purpose)</i>	-high percentage (an average of 45%) of bike or bike-sharing to work/school -almost 75% of the trips are made by non-motorized or public transport modes -shopping and other daily issues done by foot -going out in the evening typically by PT (40%) and on foot (24%) -running errands on foot (58%) and by bike (29%), earlier adopters even more by bike or bike-sharing than the average -car use typically for trips outside the bike-sharing system's operational zone (e.g. shopping malls in the outskirts)			

N=676	Earliest adopters	Early majority	Late majority	Laggards
	-go to work/school by car more than the average -walk more than the average			travel by car a bit more than the average
<i>Driving license</i>	91%	87%	85%	78%
<i>Access to car</i>	63%	60%	52%	51%
<i>PT travel card</i>	46%	47%	50%	50%
<i>Opinion about bike infrastructure in the city</i>	-low ratings for bicycle infrastructure and public transport integration -the lowest marks for bike-parking facilities			
	the lowest ratings in general			

Table 17: Characteristics of adopter categories: bike-sharing and BiciMAD

N=676	Earliest adopters	Early majority	Late majority	Laggards
Knowledge of other bike-sharing systems	37 to 45% have ridden a shared bike before using BiciMAD (Earliest adopters being the most experienced in other cities)			
Trying out BiciMAD before becoming a subscriber	rare (8%)	one out of four tested BiciMAD before registration	more than one third of late adopters tried it out	
Motivation for the first ride on BiciMAD	-typically, it seemed faster than any other transport mode -high percentage of considering sustainability issues (bike-sharing being more eco-friendly than other modes)			(no survey)
	other people's recommendation and to see other people riding BiciMAD are not typical as a motivation for early adopters	high relevance of its price compared to other options	-less importance of time (being faster) and money (being cheaper than other modes) -relatively high percentage of curiosity and to do sports by BiciMAD	
How did/would you do the most frequent trip you now take by bike-sharing?	-motorized private vehicles are irrelevant in this term (only 2-4%) -a huge majority took/would take the trip by PT (63-76%)			
	replaces walking nearly half as many people as in later adopter categories		some of them do completely new trips as well (that they did not or would not without bike-sharing)	
	one out of five subscribers would do the frequent trips by foot			more people replaces PT and less walking
Bike-sharing trips by trip purpose	-users go to work/school on a daily (40%) or weekly basis (26%) by bike-sharing, Early majority being the group with the highest share -in comparison with private bicycle: less leisure/sports but more shopping, running errands, visiting people and evenings out with friends -no relevant differences by innovator categories			

N=676	Earliest adopters	Early majority	Late majority	Laggards
<i>Evaluation of BiciMAD</i>				
Bicycle	-groups are unanimously positive (but not very positive) about the design of the bicycles and its front bike rack -first adopters are more positive about ease of use, comfort and electric pedal assistance than later adopters -poor opinion about the maintenance of bicycles and breakdowns, especially the latest adopters			
Network	-users are critical about the extension of the operational zone -Laggards are more negative about the operational zone and the distance between stations than the average			
Stations	-in general, positive about the stations' design but rather negative about its operation (failures of the kiosk computer, malfunction of racks, etc.)			
Availability	-rather negative about station rebalancing issues (availability of bicycles to take or racks to return it) -early adopters are more negative than the Late majority and Laggards			
Fees and payment	-negative (but not very negative) about a fee per each use -Laggards accept more the yearly fee and a fee per use than others -slightly better opinion about fees that frequent users do not pay (fee for occasional use) -rather positive about discounts (for taking a bike from an overloaded station, reserving a rack at destination), especially the Late majority -no huge problems with the payment procedure and checking the balance of the bike-sharing account			
Mobile app	not very positive about it and no significant differences			
User support	rather positive (early adopters are more positive)			

5.3.2 Perceived attributes

For the analysis of attributes that may influence rate of adoption of bike-sharing as an innovation in the city, a specific group of questions were included in the 2nd and 3rd survey phases. Respondents had to express their agreement with 3 to 6 statements on a Likert-type scale⁷⁰, in line with the five above-mentioned attributes of IDT: relative advantage, compatibility, complexity/simplicity, trialability and observability.

An extensive research of Rondinella (2015) has found that “higher levels of cycling use for utilitarian purposes (i.e. higher levels of cycling familiarity) may lead to more positive levels of cycling consideration” (p. 183). This idea is the basis of the amendment of IDT by a potential additional attribute, namely cycling familiarity, to study its role in the decision about becoming a bike-sharing user. Thus, the present part of the study intends to contribute to: 1) the research about bike-sharing by the analysis of adopter profiles, 2) the mode familiarity research, by investigating the relation between one’s cycling familiarity and bike-sharing use, as well as 3) the research of diffusion of innovation in a specific field. As the surveys were defined originally for other purposes, the outcomes are not expected to be exhaustive in any of the three above mentioned topics. Nevertheless, results may let researchers extend the knowledge about bike-sharing users, their background in cycling and a new aspect that may influence the rate of adoption of a bike-sharing system as an innovation.

Three question items (statements) have been included in the survey for the analysis of cycling familiarity as an attribute:

- (1) *I have experience in riding a bike (e.g. my own bike) in the centre of Madrid.*
- (2) *I ride my bike with certain frequency for leisure or other purposes.*
- (3) *Before using BiciMAD I used to go to the city centre of Madrid by my own bicycle.*

As this is the very first insight into the adoption of bike-sharing as an innovation, the statements (including the above-mentioned 3 about cycling familiarity and other 24 related to the five attributes by IDT) were defined after a small scale pilot survey. After that, a more detailed analysis was used to confirm their validity for this research. Applying the methods of Atkinson (2007), an exploratory factor analysis – varimax rotation for the first simplification and oblique rotation for the determination of final factor loadings – was carried out to check whether the statements load together. The factor analysis resulted in 6 factors (with eigenvalues greater than 1) and variables with loadings greater or equal to .40 were retained on a factor.

⁷⁰ As mentioned above, different Likert-type scales of the 2nd and 3rd survey phase have been standardised to a common scale of 0 to 5.

Table 18: Factors and factor loadings for the development of a questionnaire about bike-sharing adoption attributes

Factor (eigenvalue; % of total variance)	Varimax rotation		Oblique rotation		Questionnaire item
	Attribute	Factor loading	Attribute	Factor loading	
1 (6.03; 22.35)	Relative advantage (4)	.57	Relative advantage (4)	.46	The pedal assistance make BiciMAD easier to use in Madrid than a normal bicycle
	Relative advantage (5)	.45			By BiciMAD I arrive to my destination faster than before
	Relative advantage (6)	.52	Relative advantage (6)	.41	BiciMAD is more modern and innovative than bike-sharing systems of other cities
	Simplicity (1)	.63	Simplicity (1)	.54	It is easy to me to take or return a bike in a BiciMAD docking station
	Simplicity (2)	.67	Simplicity (2)	.56	BiciMAD bikes are comfortable for me (to adjust saddle height, weight of a bike, etc.)
	Simplicity (3)	.73	Simplicity (3)	.62	By a BiciMAD I can go up the slopes of Madrid without any problem
	Simplicity (4)	.80	Simplicity (4)	.68	BiciMAD bikes are easy to handle
2 (2.52; 9.34)	Cycling familiarity (1)	.90	Cycling familiarity (1)	.90	I have experience in riding a bike (e.g. my own bike) in the centre of Madrid.
	Cycling familiarity (2)	.82	Cycling familiarity (2)	.82	I ride my bike with certain frequency for leisure or other purposes.
	Cycling familiarity (3)	.86	Cycling familiarity (3)	.86	Before using BiciMAD I used to go to the city centre of Madrid by my own bicycle.
3 (2.09; 7.73)	Relative advantage (1)	.77	Relative advantage (1)	.63	Using BiciMAD I feel more responsible in environmental and social terms
	Relative advantage (2)	.78	Relative advantage (2)	.62	BiciMAD is more ecological than other modes of transport
	Compatibility (1)	.46			BiciMAD, for me, is a form of travelling and doing exercises the same time
	Compatibility (3)	.67	Compatibility (3)	.51	Using BiciMAD fits my lifestyle
	Compatibility (4)	.73	Compatibility (4)	.59	Bike-sharing is one of the solutions to calm the traffic in the centre of Madrid
4 (1.73; 6.42)	Trialability (1)	.68	Trialability (1)	.65	It is good to try BiciMAD bikes to decide about being a frequent user
	Trialability (2)	.54	Trialability (2)	.54	To know or try a shared bike in another city helped to take the decision about using BiciMAD
	Trialability (3)	.80	Trialability (3)	.78	Trying a BiciMAD bike helped me to decide using (or not) the service
5 (1.29; 4.80)	Compatibility (6)	.57	Compatibility (6)	.46	I can easily find a BiciMAD bike (to take one) or dock (to return it)
	Simplicity (5)	.46			The touchscreen of a BiciMAD docking station is simple to use
	Simplicity (6)	.36*			It is easy to take control of my BiciMAD account
	Observability (1)	.66	Observability (1)	.56	To see others using BiciMAD helped me to decide about trying it and/or becoming a user
	Observability (2)	.50			Other people seemed interested in BiciMAD when they saw me using it
	Observability (3)	.61	Observability (3)	.47	Other users seem to like using BiciMAD
6 (1.17; 4.34)	Relative advantage (3)	.66	Relative advantage (3)	.49	BiciMAD is cheaper than other modes of transport
	Compatibility (2)	.49			BiciMAD network fits to my frequent and/or occasional routes
	Compatibility (5)	.48			The applied discounts (to book a dock at destination, to pick up a bike from a saturated docking station, etc.) rationalize the use of BiciMAD

*Simplicity (6) loads most highly on Factor 5, but its loading is slightly lower than .40.

A key finding of the analysis (Table 18) is that the three items of cycling familiarity load together as a unique factor in both varimax and oblique rotation, with an eigenvalue of 2.52 and accounting for 9.3% of the total variance (the cumulative percent of variance of the six factors is 55%). Another finding is that some other attributes (e.g. Relative advantage) load across factors and some others load together (Trialability, Simplicity) in the final solution, which may suggest courses of action like: 1) applying Rogers' theory and its attributes but carefully interpret them in bike-sharing, cycling or urban transport related surveys, i.e. in the present study and 2) define a new or modified set of perceived attributes, i.e. change Rogers' theory in the field of urban mobility research, adopting some additional attributes suggested by other authors (see above), as well.

Course 2) would lead to some new attributes like Factor 6 – Cost or Economic advantage, i.e. the degree to which an innovation is perceived as being affordable or cheaper than other ideas; Factor 3 – Personal and social convenience, i.e. the degree to which an innovation is perceived as compatible with lifestyle and social/environmental challenges; Factor 1 – Relative simplicity, i.e. the degree to which a technical innovation is perceived as easy to use in comparison with other existing (or past) ideas. Nevertheless, the present study follows course 1) because one questionnaire seems to be insufficient to re-establish Rogers' theory and the aim of the analysis is to study cycling familiarity as a perceived attribute and not to specify a new set of attributes. (Potential new factors may be analysed in a future study.)

Accordingly, characteristics of adopter categories concerning the six attributes (the five of IDT and cycling familiarity) are examined below to better understand the diffusion process of the bike-sharing system in the city. Other variables that affect the rate of adoption have not been studied in detail, but they might have both positive and negative influence on potential adopters' innovation-decision. On the one hand, using the bike-sharing service requires an individual-optional decision, i.e. it is expected that the bike-sharing will be adopted more rapidly than when the decision is made by an organisation or an authority. In spite of the lack of wide-scale awareness-raising campaigns, community media might have combined the advantages of mass media and interpersonal channels to increase the rate of adoption. On the other hand, due to a low cycling culture, an insufficient bicycle infrastructure and a possible disinterest of subscribers in the promotion of the service adoption might be slowed.

5.3.2.1 *Trialability*

Respondents were asked to evaluate statements on how the experiences about other bike-sharing systems and the option to try BiciMAD contribute to the decision on becoming a frequent user.

There is a growing number of bike-sharing schemes worldwide, including many tourist destinations, and Spain is the country with the most bike-sharing systems in the world (132 in operation in 2014). Among these, some commuter towns of the Community of Madrid have their own bike-sharing programme (e.g. Getafe, Tres Cantos) and, as it has already been mentioned, there was an experiment on a university campus of Madrid years before the introduction of BiciMAD. Thus, many people in Madrid may have some knowledge about

the concept of shared bikes with a good probability of even having tried one. Not surprisingly, those who have already tried (42%) another system, consider this fact much more relevant in their decision about becoming a frequent user of BiciMAD than those who have not. But, upon their self-evaluation, the experience in another city is not connected tightly to the adoption of this innovation in Madrid: Earliest adopters are only slightly dependent on their knowledge about other bike-sharing systems.

Trialability of BiciMAD was limited in its first months of operation. Due to the security concerns and a delay in IT development, occasional use was not possible from June to October 2014 and the only way to take a ride on a shared bike was to “borrow” the access card of a registered friend or relative. (A significant proportion of non-frequent users make use of a friend’s access card: more than 40% of surveyed occasional users do that regularly and also the same proportion of non-users who have already ridden a BiciMAD bike, tried it with another person’s card.) It is a general opinion that it is worth trying a shared bike before taking decision about registration. Concerning the effect of personal experiences on one’s decision, Earliest adopters were not able to try out BiciMAD; therefore exploratory uses had a crucial influence on almost the double proportion of later adopters. Furthermore, the small group of users who have tried BiciMAD but not another bike-sharing system are very dependent on the experiment.

In conclusion, BiciMAD is a special example of an innovation in terms of trialability since the technical difficulties of the introduction of BiciMAD have hindered the verification of Rogers’ conclusions. In other cases, early adopters rely more on trying out a new product or service and later adopters may be influenced by the experiences of others; in the case of BiciMAD, there was no chance of personal trial in the period of adoption by Earliest adopters.

5.3.2.2 *Relative advantage*

Advantage of an innovation, as per IDT, is relative to its nature. In case of a bike-sharing system, i.e. a new element of the public mobility services in a city, the study aims to explore how frequent users consider its advantages in comparison to other transport modes or the transport mode that has been substituted by bike-sharing. The addressed topics are costs, travel time, environmental and social issues, as well as ease of use.

The local government defined a unique fee system that makes BiciMAD competitive with motorised private transport but (as per the planners and decision-makers) it prevents people from stopping to walk and use public transport. A fee per each use is one of the most controversial measures about BiciMAD (rated negative in the three survey phases); however, latest adopters accept it better than other users. The latter also applies to the comparison of BiciMAD to other transport modes in terms of cheapness: later adopters evaluate it as more economical. Maybe late adopters took a more deliberate decision about using the service, taking into account actual costs and costs compared to other transport modes and not only the fact that it is one of the few bike-sharing systems worldwide which make users pay for each ride. And in total, in spite of a rather poor general opinion about the fee per each ride,

in terms of costs, a majority of frequent users are also aware of the relative advantage of taking a trip by bike-sharing and no other means of transport.

Eco-friendliness is a key concept of urban mobility nowadays and a relevant factor in the use of bicycles (in the three surveys, about 80% of the more than 2500 respondents consider it rather or very important in the decision about riding bicycle). Bike-sharing systems have elements that make it special in terms of environmental issues (e.g. land use problems of stations) and zero emission is still a challenge in the majority of these systems, including BiciMAD (repositioning of bicycles being carried out mainly by trucks). These “imperfections” may explain that, although a vast majority is convinced that BiciMAD is more eco-friendly than other urban transport modes (with no significant differences by adopter categories), much fewer respondents feel that riding shared bikes makes oneself more environmentally friendly or socially responsible.

Frequent users, especially Earliest adopters, are almost unanimous about the advantages of the fleet of pedelecs in the streets of Madrid city centre (compared to normal bicycles or heavy bikes of other systems). Not surprisingly, they consider that electric pedal assistance make BiciMAD easier to use on the sloping streets of the operational zone. Respondents also agree that bike-sharing has made their trips rather faster (much faster for the half of them), possibly due not only to the electric assistance, but also to the complementary and substitute character of bike-sharing (in relation to public transport and/or walking).

As an additional topic, respondents had to evaluate BiciMAD in comparison to other bike-sharing systems, based on their experiences, awareness or beliefs. In general, they agree about the relative modernity and innovativeness of BiciMAD. Later adopters have a quite clear opinion (rather positive); Earliest adopters seem to be less decisive about making a comparison with other systems. Those who have experience in other bike-sharing systems are the most convinced about BiciMAD’s advantages, i.e. that it might pave the way in an international perspective.

5.3.2.3 *Simplicity*

Instead of complexity, i.e. an attribute that is negatively related to the adoption of an innovation, the case study aims to study the ease of use of BiciMAD. Questions address three topics: user-friendliness of the software and hardware, simplicity of using a shared bike and the ease of riding it in the operational zone.

As it has already been mentioned, frequent users’ opinions are rather negative about the operation of bike-sharing stations and this applies also for simplicity of using the stations’ computer by touchscreen. Earliest adopters have very poor opinion about its user-friendliness, probably due to the failures of the computer in the first months of operation. In spite of a slightly better evaluation by the Early and Late majority, this is one of the most significant shortcomings of the bike-sharing system. In the specific case of checking one’s balance, users seem to be more satisfied but only few (especially among the earliest and latest adopters) state that they can easily access their account information.

Sloping streets are one of the key barriers of the promotion of cycling in the city centre of Madrid. That is the reason of the introduction of a fleet of pedelecs (a quite expensive and relatively complex service) and it is supposed that its success largely depends on the perception of the advantages of electric pedal assistance. A vast majority of those who started to use BiciMAD in the first groups of adopters agree that pedelecs are very easy to ride even on steep streets and later adopters also report on relative ease of riding BiciMAD bikes.

Offering a user-friendly service in terms of comfort is another top issue of bike-sharing promotion in a city like Madrid, where there are many objective and subjective barriers of cycling (like the lack of an extensive network of bicycle infrastructure or climate). BiciMAD bicycles are easy to use for all adopter categories and members of all categories agree that the bicycles are rather comfortable but most of them would make some changes in its design and setup options (e.g. adjusting to personal comfort), especially later adopters. Inconveniences seem to worsen or bothersome even more after a while, since an apparently more negative evaluation was done by the same early adopter categories in the third survey than a year before. Handling the bicycles and taking/returning them in the station rack cause no problem to frequent users, however, a more negative opinion may be observed by the time of adoption (late adopters are less positive).

5.3.2.4 Observability

Bike-sharing as an innovation in the urban mobility system may be observed easily by everyone, so its adoption depends on the effects of personal observation (and not the description by others or interpretation by experts). On the one hand, it may be supposed that this attribute may facilitate a faster adoption than in the case of more complex technologies or a software-based innovation. On the other hand, there are some difficulties in the observation of operational issues, e.g. the completely computer-based access procedure, a fact that may prevent elderly people from adoption.

Three viewpoints have been studied in the survey: 1) if users consider that other users seem to be pleased when riding BiciMAD; 2) if users were influenced in their decisions about the registration by observing other people riding BiciMAD; 3) if (according to users) other people become interested in BiciMAD by observing their rides. Obviously, Earliest adopters could not observe others using the bike-sharing system and, in time, later adopters depend more and more on the view they have of others. On the contrary, a higher proportion of early adopters feel that they are observed by others (who then become interested in using the service) and a lot more late adopters perceive not being observed at all (12% of Laggards, 3% of Earliest adopters). About the supposed satisfaction that other people feel when riding BiciMAD, most users (especially early adopters) are moderately critical and state that others may be rather but not very positive about it.

5.3.2.5 Compatibility

The scale of fitting to users' ideas and values has already been addressed indirectly (e.g. in some topics of Relative advantage). In this part of the study, questions about the compatibility of BiciMAD with travel behaviour, lifestyle, as well as ideas about urban

mobility were asked to understand the rate of adoption. Some topics of compatibility, e.g. how the rate of adoption is affected by the old idea, were not tackled by the survey due to the special characteristics of the innovation (e.g. a public service that is completely novel on city level).

Users who began to use BiciMAD as an Early majority are those who report in the highest proportion that the bike-sharing network fits into their frequent or occasional routes. One out of three users from this group state that the network of stations coincides perfectly with their daily destinations, i.e. it may be supposed, on the one hand, that their trips and itineraries have not been modified after the introduction and, on the other hand, they are able to take most of their usual trips by BiciMAD. (About 80% of Early majority live in the neighbourhoods where the bike-sharing system was introduced.) Other frequent users may use BiciMAD for less usual trips. One out of three or four states that the bike-sharing system fits only partially into his/her daily itinerary.

Increasing physical activity forms part of the greatest benefit of cycling and most subscribers apparently agree on taking advantage of it. On the basis of their responses, half of the first adopters seem to consider the ride on a shared bike more for travel than for sports purposes but at least two out of three of other users, especially the latest adopters, declare that for them doing exercise is an essential part of moving by BiciMAD. Most users, and first of all in the groups of Early majority and Laggards, report that using the bike-sharing system fits into their lifestyle. (According to another question of the survey, the way that cycling fits into one's lifestyle is more important for later adopters, as well.) It seems that opinions (and maybe lifestyles) are changing in a short time; according to the differences of the second and the third survey phase, there is a positive trend toward a way of life that is compatible with the use of bike-sharing in all groups.

Opinion about the compatibility of some specific services is rather negative. The real advantages of discounts (for users that contribute to the smart rebalancing of stations) and their effects on actual use is viewed favourably by later adopters, but the majority of the earliest users tend to disagree with a statement about the efficiency of reduced fares. Other issues of redistribution, availability of bicycles (to take) and racks (to return a bike) are evaluated even more negatively: less than 10% of any group and less than 5% of the Earliest adopters state firmly that one can easily access the service in this term, and vice versa.

Furthermore, there is no doubt about the global evaluation of BiciMAD: frequent users unanimously (with only slight differences among innovator groups) agree that the bike-sharing system is an efficient traffic calming measure, as well as a vehicle, to promote the use of bicycle in the city centre.

5.3.2.6 *Cycling familiarity*

Lack of private bicycle of nearly half of the respondents may explain the non-usage of any bicycle (for any purpose) by more than 50%; however, earlier adopters ride bicycles more than others. There may be several reasons why people do not own (e.g. lack of storing facilities at home, since most of the respondents live or work in the city centre) or use a

private bicycle (e.g. bicycle is/was not considered a means of transport or cycling is/was not an option as a leisure/sport activity).

The bike-sharing system in Madrid has been introduced in the city centre. Bicycle infrastructure in this area consists of some dedicated bike paths and lanes of a few kilometres without extensive network characteristics. According to local statistics, cycling infrastructure was increased by 45% in length in the three years prior to the introduction of bike-sharing (a total of 390 km in 2014). However, this extension is due almost completely to the introduction of many “ciclo-carril”, a shared lane on medium or high traffic multilane urban roads with 30 km/h speed limit only in the shared lane, designated by a white pictogram of a bicycle and the maximum speed. The cycling infrastructure includes ways in pedestrian areas and parks inside and close to the city centre (including some streets closed to motorized traffic on weekends), with an intensive recreational cycling demand on weekends and holidays. As mentioned above, modal share of cycling in Madrid was less than 1% before the introduction of bike-sharing.

In this context, the experience of riding a bike, and especially in the city centre, might be crucial when it comes to the decision about using bike-sharing services. Although non-adopters are underrepresented in the 3rd survey phase (15% of respondents), they report much less experience in riding a bicycle than adopters do (Figure 30). On the basis of cycling related characteristics (number of bicycles, travel modes, etc.), it might be supposed that cycling familiarity is positively related to the rate of adoption but a more detailed study on non-adopters would have been needed to statistically prove such an assumption.

% of respondents of the 3rd survey phase (n=332)

Figure 30: Reported cycling familiarity of BiciMAD adopters and non-adopters

Concerning BiciMAD subscribers, three out of five had some kind of experience in cycling in the central zone before using public bicycles. In the groups of Early and Late majority, there are more users who have never been to the city centre by private bicycle and therefore, the first time was the first ride by BiciMAD. A similar proportion of frequent users report riding on a bike in the city centre before starting to use shared bikes and a solid experience of cycling in the urban core.

Only one out of four frequent users believes that s(he) is an absolutely inexperienced bike rider in the centre of Madrid. Earliest adopters and Laggards are the most self-confident when it comes to going by bicycle to the city centre. Late majority is the group of most people who never ride a bike (and the least who own a bicycle, see above).

In sum, earlier adopters report both more frequency in riding a bike (for any reason) and more familiarity with cycling in the heart of Madrid. In this category, slightly more people have access to private bicycles than in any other and more than 80% of them live in the city centre, thus when it comes to riding a bicycle, most of them must do it in the catchment area of the bike-sharing system. Peculiarly Laggards seem to have nearly the same level of experience in the city centre. However, those who would take the same trip by bicycle (if bike-sharing would not be an option) are also mostly late adopters. Early majority is the group with the most bike-owners and most frequent cyclists; that is why there is the least proportion of people who report absolute inexperience, in spite of the level of their reported cycling familiarity in the city centre being below average.

Table 19: Characteristics of adopter categories: perceived attributes

N=676	Earliest adopters	Early majority	Late majority	Laggards
Trialability	-it is a general opinion that it is worth trying bike-sharing before taking the decision about registration -the small group of users who have tried BiciMAD but not another bike-sharing system are very dependent on the experiment			
Trying other bike-sharing Testing BiciMAD	-only slightly dependent on their knowledge about other bike-sharing systems	-exploratory uses have a crucial influence on almost the double proportion of later adopters -one out of four has not been influenced at all by trying out BiciMAD in the decision about subscription		
Relative advantage	-a majority of frequent users are aware of the relative advantage of taking a trip by bike-sharing, and no other means of transport (in terms of costs) -a vast majority is convinced that BiciMAD is more eco-friendly than other (motorized) urban transport modes, with no significant differences by adopter categories, but much fewer respondents feel that riding shared bikes makes oneself more environmentally friendly or socially responsible -respondents also agree that bike-sharing has made their trips faster (much faster for the half of them)			
Costs Travel time Environmental and social issues Ease of use	unanimously positive about the advantages of a fleet of pedelecs (compared to regular bicycles or traditional heavy bikes)		seem to be very decisive (rather positive) about BiciMAD's modernity and innovativeness in comparison with other systems	
Simplicity	-earlier adopters agree that pedelecs are very easy to ride even on steep streets, later adopters also report on relative ease of riding BiciMAD bikes -frequent users are unanimous about ease-of-use and comfort of BiciMAD bikes			
User-friendliness Riding BiciMAD Riding in the operational zone	very poor opinion about the computers at docking stations	relatively negative opinion about availability of account information		
			-less positive about design and setup options (e.g. adjusting bicycles to personal comfort) -less positive about handling the bicycles and taking/returning them in the station rack	
Observability	-a high proportion feel that they are observed by others (who then become interested in using the service) -especially (but not exclusively) early adopters are moderately critical about the supposed satisfaction that other people feel when riding BiciMAD -feel that others may be rather but not very positive about bike-sharing			-a lot more perceive not being observed at all -more dependent on the view they have of others
Perception of others Influence by earlier subscribers Influence on potential users				

N=676	Earliest adopters	Early majority	Late majority	Laggards
<i>Compatibility</i>	-unanimously (with only slight differences among innovator categories) agree that the bike-sharing system is an efficient traffic calming measure and a vehicle to promote the use of bicycle in the city			
Travel behaviour	-most frequent users apparently agree on taking advantage of the increasing physical benefit, i.e. one of the greatest benefits of cycling frequently			
Lifestyle	-seem to consider the ride on a shared bike more for travel than for sports purposes		-especially later adopters declare that for them doing exercise is an essential part of moving by BiciMAD	
Ideas about urban mobility	-tend to disagree with the efficiency of discounts on the use of bike-sharing		-discounts and their effects on actual use is viewed favourably	
	-availability of bicycles (to take) and racks (to return) are evaluated more negatively than by others	the highest proportion who report that bike-sharing network fits into their frequent or occasional routes	less users report that bike-sharing fits into their lifestyle	
<i>Cycling familiarity</i>	-three out of five had some kind of experience in cycling in the central zone before using BiciMAD			
Cycling in the city centre	-a similar proportion of subscribers report riding on a bike in the city centre before starting to use BiciMAD and a solid experience of cycling in the urban core			
Experience	-one out of four users believes that s(he) is an absolutely inexperienced cyclist in the centre			
Cycling for leisure or other purposes	report more frequency in riding a bike (for any reason) and more familiarity with cycling in the city centre	-more users who have never been to the city centre by private bicycle (the first time was the first ride by BiciMAD) -less self-confident when it comes to going by bicycle to the city centre		report more familiarity with riding on a bicycle in the city centre than the average
			more users who would take the same trip by bicycle if bike-sharing would not be an option	

5.3.3 User profiles in light of adoption attributes

Results indicate that characteristics of the diffusion of innovations in the case of bike-sharing (and maybe other new ideas in the urban mobility system) are different from many aspects of a typical diffusion process. In the case of perceived attributes (Table 19), for instance, the case study has not proved a statement of IDT about the perception of relative advantage, namely, that it is a reliable predictor of the adoption. Although this is true in some aspects, e.g. Earliest adopters are the most convinced about the advantages of riding pedelecs and not regular bicycles in the sloping streets of Madrid, they are not more dependent than later adopters on other related issues, such as eco-friendliness or costs. In theory, earlier adopters perceive trialability as more important than do later adopters. In the case of BiciMAD, Earliest adopters did not have a “legal” opportunity to try out public bicycles, thus, later adopters are much more dependent on exploratory uses. Concerning cycling familiarity, an attribute unprecedentedly analysed in this study, a key conclusion of the case study is that those who report an experience of riding a bicycle in the city centre mostly adopt among the first and last adopters. Individuals of these categories seem to have rather different profiles in other terms, for instance, in their travel behaviour and related characteristics (e.g. many more Earliest adopters have a driving license and access to a car, thus more of them go by car on a daily basis).

Findings of the case study show that Earliest adopters (month 1 to 3) are technology enthusiasts who are eager and can afford to start using the new public transport service without a thorough consideration, e.g. a test ride. Early majority (months 4 to 9) seem to make a more deliberate decision about becoming frequent users, taking into account experiences of exploratory uses, costs, and if the bike-sharing network fits perfectly into their daily itineraries. People with less familiarity with technology tend to adopt among later adopters. For them, doing exercise seems to be more important about bike-sharing. Late majority adopters (months 10 to 13) are very dependent on their observation of others using the service and the opinion of their peers, namely earlier adopters. Laggards (months 14 to 25) are like a combination of Earliest adopters (e.g. in terms of cycling familiarity) and Early majority (e.g. in terms of a prudent decision-making) but without any venturesomeness.

This is how each adopter profile can be described on the basis of the case study:

- Earliest adopters are typically men, employees, live in the first operational zone and they are slightly older than other users. This is the category with the highest percentage of employees. Although they seem to be more car dependent than others (the highest rate of having a driving license, access to car and use on a daily basis), but this is the category with an above average bike-ownership and share of walking. That is to say, these people seem to consciously make use of the advantages of diversity, i.e. in the case of transport, using self-owned and public transport modes in a city centre where they live (or work or move around), efficiently, individually and in combination. Earliest adopters care less about external factors of cycling like weather or topography. They seem to have been eager to have bike-sharing not only as an alternative of some of their trips (especially on foot and PT), but also as a new

element of their lifestyle. Their technology enthusiasm is reflected also by their critical approach: they are more positive about BiciMAD technology in general (e.g. ease-of-use, electric pedal assistance) than others, but extremely negative about poor bicycle infrastructure in the city or some weaknesses of BiciMAD technology (e.g. computers at kiosks).

- Early majority adopters (who have very similar personal and socioeconomic characteristics to Earliest adopters) tend to be more pragmatic, thus become frequent users after the early failures have been fixed and/or the option to try out bike-sharing has become available before subscription. They ride on a bicycle and consequently use bike-sharing for trips to work/school on the most frequent basis among all adopter categories. However, this is not true for all members in this category; with a high bike-ownership rate, many people seem to ride outside the city centre (e.g. for leisure). That is why there is the least proportion of people who report absolute inexperience, in spite of the level of their reported cycling familiarity in the city centre being below average. In their decision about travel mode, advantages of cycling (especially its flexibility and price compared to alternative transport modes) are more influential than for others. Their itineraries seem to be not affected by bike-sharing; most of them may use it for their usual daily trips because they seem to like cycling and “there is” a relatively cheap and high-tech bicycle service on their itineraries.
- Late majority adopters have less experience and interest in cycling than members of any other category. Those who ride a private bicycle with certain frequency tend to be leisure cyclists: the group is characterized by a below average bike-ownership rate, a high percentage of non-urban type bicycles and low levels of utility cycling. This seems to be true about their use of bike-sharing as well. They care less about its relative advantage in terms of time or price, they are more positive about discounts for user-based redistribution of bicycles (i.e. something that may make trips longer) and they use BiciMAD for sports and leisure more than the average. Although if cycling fits to one’s lifestyle is more important for them than for earlier adopters, many Late majority adopters report that bike-sharing is not in line with their way of life. Probably these users adopted the innovation as a result of pressure by the social system and needed to be persuaded (e.g. by exploratory uses).
- Laggards’ characteristics are closer to earlier adopters than to Late majority, but they are not as technology enthusiasts as Earliest adopters, not as dedicated cyclists like Early majority adopters, and much less risk-takers than members of any other category. Laggards seem to be fairweather cyclists and peculiarly they have nearly the same level of experience in cycling in the city centre as Earliest adopters. It is more common that people live in the extension area of BiciMAD or outside the operational zone, thus they are more critical about the network and availability of shared bikes (obviously people from outside the operational zone have access to less stations in a walkable distance). On the contrary, they tend to accept the unique fare system better than other users. This also applies to comparison of BiciMAD to other transport modes in terms of cheapness: latest adopters evaluate it as more economical. Maybe they took a more deliberate decision about using the service, taking into account actual costs and costs compared to other transport modes and not

only the fact that it is one of the few bike-sharing systems worldwide which make users pay for each ride.

In sum, besides a special application (and slight extension) of IDT, thanks to a new approach in the analysis of bike-sharing, a lot has been said about its users. This is something that has not yet been studied empirically and besides a contribution to research, it might have practical implications as well, e.g. in raising awareness about and advertising a new technology to potential users or schedule system extensions.

5.4 Findings about bike-sharing adopters

Diffusion of an innovation has been studied with the aim of broadening not only the literature about IDT by its novel application, but also the knowledge about bike-sharing users and, in a wider sense, travel behaviour. Thus, the present chapter is not intended to synthesize the “footnotes” to IDT generated over the past decades (e.g. Dearing and Meyer, 1994; Kolbe and Iverson, 1981; Moore and Benbasat, 1991; Sahin, 2006; Tornatzky and Klein, 1982), but rather to find its appropriate version after their review for the above mentioned aims and its application as a framework. For that, two elements of IDT have been adapted on the basis of a case study about a bike-sharing system. BiciMAD has been studied as a novel technology and a new public transport mode with a unique service configuration in the city of Madrid. Adopter categories have been divided into four types (instead of IDT’s five) in order to suit it to the diffusion speed of the analysed innovation. The two initial categories (Innovators and Early adopters) have been combined (called Earliest adopters) to include characteristics of both: a risk-taking attitude and an opinion-leadership in the social system. Although an exhaustive analysis of IDT’s generalization of the characteristics of adopter categories exceeds the boundaries of the present study, the categories serve as a framework for the exploration of attributes. On the contrary, the number of the attributes of the diffusion of innovations has been increased on the basis of former research about the role of mode familiarity in the decision about cycling. Accordingly, the role of cycling familiarity in the decision about using a bike-sharing service has been investigated in line with IDT.

Conclusions of the case study indicate that bike-sharing might be considered an innovation vector in urban mobility. On the one hand, it is a smart technology adopted very quickly by all adopter categories, according to their characteristics identified in line with IDT: first the venturesome and technology enthusiast Earliest adopters, then the rational and deliberate Early majority, the skeptical and peer-dependent Late majority, and finally the prudent Laggards. On the other hand, it is an efficient means (explicitly acknowledged by a huge majority of frequent users) to promote cycling in the city centre (García Martínez et al., 2016), used mainly for utility cycling by the two early adopter groups as well as also for sports and leisure purposes by later adopters. In terms of their background in cycling, adopter categories may be identified as follows: Earliest adopters as lifestyle cyclists, Early majority as dedicated cyclists, Late majority as leisure cyclists, and Laggards as fairweather cyclists.

Findings show that there are some peculiarities of the innovation adoption that have to be taken into account by both technology developers and service providers before the introduction of similar innovations in a city:

- Opinion leaders, who adopt among the first users, are extremely critical about technical issues. Initial breakdowns and errors of a new technology are usually inevitable, but a preventive communication strategy might ensure a better image of the project among the first adopters and those who rely on them.
- In this context, trialability (if the innovation may be experimented) is or would have been also crucial, similarly to other e-mobility innovations (Seign and Bogenberger, 2013), since it is a general opinion that it is worth trying a shared bike before taking decision about subscription. Due to privacy and IT issues, most Earliest adopters were not able to try out BiciMAD; therefore exploratory uses had a significant influence on almost double the proportion of later adopters. Furthermore, the small group of users who have tried BiciMAD but not another bike-sharing system previously are very dependent on the experiment.
- Electric pedal assistance is a key advantage of BiciMAD in comparison to cycling (regular bicycles) and other bike-sharing systems (traditional heavy bikes), particularly in a city centre with relatively difficult topography, like the one in Madrid. Particularly Earliest adopters (including technology enthusiasts) are very positive about the use of pedelecs. In this term, BiciMAD may pave the way for other cities that face the challenge of hilly streets as a possible barrier to the promotion of cycling or bike-sharing. Some outcomes of the present study, as a contribution to the increasing interest in e-bikes and pedelecs (Cherry and Cervero, 2007; Dill and Rose, 2012; Wolf and Seebauer, 2014) as well as e-bike-sharing (Ji et al., 2014) may help cities to find tailor-made solutions for a smooth diffusion.
- A fee per each ride (including the first 30 minutes, to avoid that people stop walking and using PT) has an explicitly poor evaluation in each adopter category; however, a majority of frequent users and especially later adopters are also aware of the relative advantage (in terms of costs) of taking a trip by bike-sharing, and by no other means of transport. It seems that this key mobility management measure about BiciMAD has been accepted by users, in spite of being one of the most controversial decisions about its configuration.

Obviously, more focus on non-adoption (MacVaugh and Schiavone, 2010) and non-adopter characteristics would help further understanding of these kinds of issues about adopter types and rate of adoption.

6 IMPACTS OF BICIMAD: EVIDENCE FROM A PANEL SURVEY

In this chapter

Despite the recently increasing research interest, this is one of the first studies employing a panel sample of users and non-users to understand the effects of bike-sharing implementation by before-and-after observations in Madrid (n=205). 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.

In parallel to the rapid rise of bike-sharing, there has been growing research interest in its study. As presented in Part I, some frequent issues related to service design, configuration and operation are station location, bicycle rebalancing, pricing, as well as, 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 (Fishman, 2016) 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 (2015) suggests the use of innovative research methods combining users' travel behaviour history as a result of bike-sharing, socioeconomic data and cycling patterns. This kind of research would allow a better understanding of user and non-user profiles and changes of travel behaviour.

In this chapter, after a brief but comprehensive literature review, a longitudinal research is presented. On the basis of the panel sample, this part of the dissertation aims to highlight the effects of the introduction of a smart pedelec-sharing scheme (that is BiciMAD) on using the service (by measuring the relationship of intention-to-use and actual use), factors that may motivate non-users to become clients, as well as impacts on mobility patterns.

6.1 Previous knowledge about intention-to-use and impacts

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 plays a significant role in the study of feasibility of new charges, especially congestion charge and road tolls (e.g. Grisolia et al., 2015; Jászberényi and Munkácsy, 2009; Yusuf et al., 2014), as well as new pricing schemes in public transport (Dell'Olio et al., 2011; Li et al., 2010; Liu et al., 2016). 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 (Farag and Lyons, 2012), improved quality and integration of public transport (Chowdhury and Ceder, 2016; De Oña et al., 2016; Fujii and Van, 2009; Kuo and Tang, 2013), automated driving (Payre et al., 2014), etc. Intention-to-use bike-sharing has also been investigated recently, including the identification of factors that may affect adoption (Bachand-Marleau et al., 2012; Fishman et al., 2014b; Fishman et al., 2015b), especially among young drivers (Efthymiou et al., 2013) and tourists (Kaplan et al., 2015), as well as the study of acceptability of ICTs and new pricing policy (Bak and Borkowski, 2015). 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 (DeMaio, 2009; Fishman, 2016; Fishman et al., 2013; Midgley, 2009, 2011; Shaheen et al., 2010), 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 researchers⁷¹ (not in order of importance).

Shaheen et al. (2013; 2014) and Martin and Shaheen (2014) 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, i.e. 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, as well as more complementary as a first or last mile connection in small to medium size and less denser cities.

Fishman et al. (2012b, 2014a, 2015a) 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 has 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. They suggest that consequently user-based or non-polluting redistribution of bicycles, as well as a mode shift from car, taxi (and even public transport) to bike-sharing shall be encouraged in all systems.

Ricci (2015) 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; as well as health, environmental and economic impacts. Among far-reaching

⁷¹ Susan A. Shaheen is an adjunct professor in civil and environmental engineering and a co-director of the Institute of Transportation Studies' Transportation Sustainability Research Center (TSRC) at the University of California (UC), Berkeley, USA. Elliot Fishman is the research director of the Institute for Sensible Transport in Melbourne, Australia. Miriam Ricci is a senior research fellow of the Centre for Transport and Society at the University of the West of England in Bristol, UK.

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. Alvarez-Valdes et al., 2016; Bordagaray et al., 2012; Castillo-Manzano et al., 2015; Faghih-Imani et al., 2017; García-Palomares et al., 2012; Kaltenbrunner et al., 2010; Molina-García et al., 2013; Romanillos et al., 2016; Romero et al., 2012) and there has been initiatives to disseminate information and data about bike-sharing systems (Anaya and Castro, 2017; Anaya et al., 2012; Ferrando et al., 2007), but there is still room for further investigation in the topics of the present study.

6.2 Longitudinal research frameworks

Here, research methods and the specific survey sample (panel) is described as an introduction to the before-and-after analysis of bike-sharing implementation in Madrid.

6.2.1 Methods to assess actual bike-sharing use

For the analysis of intention and actual use as well as the changes of travel behaviour and attitudes towards urban mobility and especially cycling, responses of the panel survey are considered. A total number of 205 individuals who responded in both the 1st and 2nd and/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).

As mentioned in Chapter 3, 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 examined 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 non-perfect 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:

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

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

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

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

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

6.2.2 Description of the survey panel

Some general data of the survey sample (n=205) may be seen in Table 20.

Table 20: Panel sample: personal, socioeconomic and transport related characteristics

		Total		Subscribers		Occasional users		Non-users	
% in survey		100		21.4		20.4		58.2	
Age in 2016		37.6		37.5		34.8		38.6	
(standard deviation)		(11.6)		(9.2)		(12.3)		(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

Panel sample (2014-2016), n=205

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:

- some people have finished school and entered the job market;
- a positive trend on the job market: lower unemployment rate and more people employed or self-employed;
- less single-person households (converted into households of two members, presumably young couples without children);
- lower average household income levels;
- less people with motorbike but more with car and driving license;
- 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).

6.3 Measuring the effects of bike-sharing

6.3.1 Association of intention-to-use and actual use

Three user categories of BiciMAD may be outlined: frequent users (subscribers), who after registration pay a yearly subscription fee and may use the service for a price per ride; occasional users, who pay a deposit and may use the service for a higher price per ride; and non-users, who have never tried out or used the system. 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 (non-user; occasional user; frequent user). An outcome of this approach in the analysis of the panel sample is represented in Figure 31.

Left: actual use in light of intention-to-use; right: intention-to-use in light of actual use, panel sample (2014–2016), n=205

Figure 31: Actual use before and intention-to-use after the implementation of BiciMAD

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) as well as to quantify the association (that is not expected to be strong). The test is based on a 3x3 contingency table, rows and columns representing the above mentioned categories. Results may be seen in Table 21.

Table 21: Results of the statistical test (Pearson's χ^2 and Cramer's V)

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, i.e. 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 22) and if they would start to use it under certain conditions. An obvious answer is a greater convenience of another mode of transport: 1) own bicycle, which has a high percentage (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 centre 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 risk of accidents on the road is reported as a barrier to start using bike-sharing by a much higher proportion of non-users 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.

Table 22: Reasons for non-use and non-frequent use of BiciMAD

	Non-users	Occasional users
I use my own bicycle	43.7	48.5
The network doesn't 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); etc.	10.1	6.1

“Why don't you use the service (or use it more frequently)?”, % of respondents, multiple answers, panel sample (2014–2016), n=205

This is in line with the intention to use in case of some changes, i.e. one out of two non-users 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, e.g. 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 32). They have become extremely negative about the price that they pay for their

casual rides. On the contrary, non-users are more 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.

Evaluation on a Likert-type scale, average score compared to the maximum, panel sample (2014–2016), n=205

Figure 32: Evaluation of prices and discounts before and after the implementation of BiciMAD

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 while 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.

6.3.2 Impacts on travel patterns

As a mobility management measure, bike-sharing is introduced in urban areas nowadays to promote sustainable mobility, i.e. to attract people who use motorized modes on relatively short distances, as well as 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 kilometres) 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 33).

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, congested, 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 centre and bike-sharing has been adopted rapidly (45,000 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%) who did or would not take some of their frequent trips without the service.

Figure 33: Replaced mode of transport on the most frequent trip by BiciMAD

Most of the panel respondents (two out of three) reported no changes in the number of daily trips; however, one out of four people travel more frequently than before starting to use bike-sharing (Figure 34). 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.

Figure 34: Perceived impacts of bike-sharing on trips in Madrid

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, i.e. people take more trips, 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 35). Other purposes (e.g. visiting friends or relatives, shopping) may have a destination relatively far from home and probably outside the city centre; 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, i.e. in 2015/2016, people still went on foot (32%), by PT (32%) or car (28%, e.g. to shopping malls in the outskirts) to do shopping, and replaced walking by cycling/bike-sharing only on some trips to small shops in the city centre that are not around the corner.

% of respondents, left: to work or school; right: to go out, panel sample (2014–2016), n=205

Figure 35: Modal distribution of trips to work/school and to go out before and after the implementation of BiciMAD

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 (see Table 20 in Chapter 6.2.2), 3) share of rides on motorbike

has increased in all user categories in spite of a decreasing access to these vehicles, i.e. 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 non-users 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 has an origin and/or destination in the city centre, i.e. 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 to 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 particularly 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).

6.4 Findings about bike-sharing (non-)users

Characteristics, attitudes and travel behaviour before and after implementation of a smart pedelec-sharing system has been analysed in this chapter 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 not only in 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), as well as 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 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, as well as 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.

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 (Bachand-Marleau et al., 2012; Fishman, 2016), a key issue of recent bike-sharing research (Chen et al., 2015; Chen and Sun, 2015; García-Palomares et al., 2012; Romero et al., 2012). 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 chapter. Findings shall be interpreted in their context, i.e. that Madrid has a dense city centre, with an extensive public transport service and walking of high modal share, with a low level of cycling infrastructure, etc. For instance, although non-users 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, e.g. Australian cities (Fishman et al., 2014b), where car convenience is traditionally predominant. Demographic and socioeconomic characteristics of a social system have also to 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, e.g. in Greece (Efthymiou et al., 2013).

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 (Pucher and Buehler, 2012). Results on the changes of individual travel behaviour 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 centre. 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, i.e.

further investigation may be conducted to study the interrelationship of the use of pedelecs (or e-bikes) and motorcycles (Fishman and Cherry, 2016).

User categories (subscribers, occasional users and non-users) are linked with different new travel patterns, obviously with more changes in the travel behaviour 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 behaviour, i.e. 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 (Ricci, 2015), 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 (Hampshire and Marla, 2012; Martin and Shaheen, 2014) 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 kilometres, most of the trips by bike-sharing replace the last two. This is in line with conclusions in many other cities (Fishman, 2016) 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 promote active travel, improve cycling culture as well as increase mobility (number and distance of trips) and decrease perceived travel time, which may be considered a key impact of bike-sharing.

PART III: FINDINGS

7 CONCLUSIONS

This dissertation has aimed to extend the knowledge about bike-sharing users by an original data collection and subsequent analysis. Aspects of marketing and innovation research have been integrated into transport research objectives, combining multidisciplinary considerations for a thorough examination of travel behaviour in relation to the implementation of bike-sharing, i.e. how and why do people use or not use the new service, and what is the effect of bike-sharing on their actions. A case of the latest generation of bike-sharing, BiciMAD, and its potential and actual users have served as a sample for analysis.

A recently developed survey technique (Hernández et al., 2016) has been employed to reach the targeted number of competent respondents and a panel sample has been studied for the first time to understand user aspirations before and actions after inauguration. As survey targets have been reached and research questions could be answered by responses in the questionnaire, this may be considered another justification (after some successful applications in the past years) that this method may be further applied in urban mobility related surveys. Although there have been some changes from one survey phase to another, this is not a significant limitation for the achievement of research objectives; on the contrary, this will allow further development of this surveying technique.

This final chapter presents the main findings and conclusions that are discussed together with other research outcomes. Recommendations about further improvements of BiciMAD and a smooth implementation of bike-sharing in other cities are provided as well. Limitations of this study are also outlined and, accordingly, future research directions are suggested.

7.1 Key findings and compliance with objectives

Due to the organisation of this dissertation, most chapters end with concluding remarks about results and findings. Here, by answering previously raised research questions, general findings are outlined, in order to understand bike-sharing users' perceptions and attitudes before and after implementation in two contexts: in the specific case of Madrid (as users of BiciMAD) and globally (as users of the latest generation of bike-sharing).

7.1.1 Discussion of research questions

On the basis of a literature review, research gaps have been identified and research questions have been formulated at the beginning of this dissertation. Answers to these questions are presented explicitly to summarize key findings.

RQ0: What factors have contributed to the recent popularity of bicycle use and a quick global spread of bike-sharing schemes, and what is the current practice of bike-sharing in light of its evolution?

This preliminary research question has served for setting the context about current urban mobility trends and, particularly, cycling and bike-sharing in an urban environment. A

review of recent phenomena has been carried out to highlight individual, social and policy factors of the global diffusion of cycling and bike-sharing, focusing on European cities. It has been a “good time” for urban cycling: social drivers (including urbanization processes and related transformation of city centres, safety concerns, increasing environmental awareness), policy implications (global strategies addressing sustainability issues like climate change, policies on national and local level to face urban and suburban mobility problems, etc.), as well as individual motivation (inspired by pro-cycling behaviour and recreational use of bicycles) seem to have had an interconnected positive effect on non-motorized active modes of transport. Accordingly, *attitudes towards cycling have changed essentially in the recent years, converting bicycle from a problem into a solution*. This is reflected on the European level by – among others – an increasing number of frequent cyclists (from 2011 to 2014, the rate of bicycle as the typical mode of transport increased from 7 to 8%, i.e. by approximately 14%, according to an EU-wide Eurobarometer survey) and acknowledgment of the EuroVelo long-distance bicycle route network as part of the TEN-T initiatives. Furthermore, after local and national policies to promote the sustainable mode of cycling, the first proposal for an EU cycling strategy has been presented to the European Commission by the European Cyclists’ Federation and it is expected to be included in the Commission’s work programme in 2018. This may be a basis of an intense further growth of cycling, especially in countries and cities with low current levels of bicycle use.

Despite its half-century-long history, bike-sharing has started to evolve rapidly only from the 2000s as a response to urban transport challenges of the 21st century (congestion, pollution, land use, etc.) and in line with new mobility concepts, such as sharing cities, Mobility as a Service, Smart Cities and global initiatives to overcome such problems. It features a best practice of public-private partnership in terms of financing and operation; state-of-the-art IT solutions and smart technology to allow a flexible service configuration; and full integration with other transport modes, especially public transport. Previous research indicates that bike-sharing may have different roles in urban mobility (Martin and Shaheen, 2014): it is a first/last mile connection, i.e. complementary to public transport in some (small and medium size and less denser) cities, or an individual – substitutive – mode in other (larger and denser) contexts. Findings have shown that bike-sharing is a proper solution for some barriers to individual cycling (by private bicycle), such as lack of space for storage, problems of secure on-street parking and multimodal trip chaining. It has also been shown that bike-sharing may be competitive to traditional bike rental services in monumental inner cities with a dense station network (without shortcomings like secure parking), but most systems are designed mainly for trips by local citizens.

Besides the *renaissance* of cycling from the late 1990s and an outbreak of bike-sharing from the late 2000s, electric cycles have started to spread quickly and globally as one of the fastest-growing segments of the transport market (Fishman and Cherry, 2016). E-bikes and pedelecs efficiently contribute to tackling barriers of regular cycling, such as topography and individual physical conditions like lack of fitness or old age (by providing cyclists with electric power assistance) and perceived and real safety in road traffic (by an increased speed and faster acceleration). As part of e-mobility solutions, e-bike-sharing and pedelec-sharing may efficiently help the promotion of sustainable transport in cities.

In addition to electric power assistance, latest systems feature full flexibility by smart dockless (virtual docking) technology and mobile app based user interface. These schemes allow the employment of light bicycles instead of traditional robust heavy bikes. First large scale experiences in China are getting adapted by Western cities in the moments of the finalization of this dissertation. Taking into account the speed of the recent bike-sharing evolution, a quick spread of this concept may be forecasted. Other emerging trends are new business models and competition of bike-sharing systems within the same city.

An example of the innovative systems — i.e. that provide a new technology or a new set of configuration in comparison to the state of the art — is BiciMAD in Madrid. It is one of the first large bike-sharing fleets in Western cities that consist exclusively of pedal-assisted bicycles. The characteristics of BiciMAD pedelecs (Booster Bikes) are different from the conventional heavy bikes of other traditional bike-sharing systems. Thanks 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 (attractive to more users). It offers improved accessibility and higher self-confidence of users in a city centre with unfavourable topography (in terms of cycling). A peculiar pricing policy (that makes each user pay for each ride) and incentives (that offer discounts to users who contribute to the rebalancing of docking stations) are applied to avoid that people stop walking or using public transport in Madrid city centre where these modes have high share, and to improve environmental efficiency of the system. Due to these specialties, BiciMAD seems to be an appropriate case for the study of user profiles and travel patterns of the latest generation of bike-sharing.

RQ1: What is the profile of potential users before the implementation of bike-sharing in light of their socioeconomic characteristics, background in cycling and attitudes towards smart configuration of the new urban mobility service?

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 has been carried out after the *ex-ante* survey (n=1694). It resulted in three clusters, i.e. the three potential (non-)user profiles of BiciMAD:

- *Fans* (43.4% of the sample): a group of people in their 20s and 30s, slightly more 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;
- *Vacillating and indifferent* (26.3%): 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;
- *Opponents and/or frequent cyclists* (30.3%): 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.

Data reduction techniques have also been employed to identify the underlying factors of bicycle use in Madrid. The factor analysis resulted in a selection of 3 variables (out of 13), namely:

- *Parking and intermodality*: variables linked to infrastructures, connections to public transport and accessibility to workplaces (schools) and public facilities by bicycle.
- *External factors*: variables that affect cycling conditions and habits, such as topography (a key barrier in the hilly street of Madrid city centre), climate (that makes cycling seasonal, from spring to autumn, with limitations in Madrid due to a hot summer), as well as risk of accidents of cyclists as unprotected road users.
- *Advantages of cycling*: variables that make cycling more convenient than other modes, such as its economical, eco-friendly and flexible character.

According to the clustering, infrastructure and connections to public transport (*Parking and intermodality*) are the most relevant factors for both “Fans” and “Opponents and/or frequent cyclists”. This is an obvious warning for the local government to provide safe cycling infrastructure with network characteristics, bike-and-ride facilities and secure parking on streets, as well as to launch campaigns for the improvement of bicycle accessibility of public centres, workplaces and schools. The potential user group of “Vacillating and indifferent” people tend to rely more on the *Advantages of cycling* when taking a decision about the use of a bicycle. In addition to raising of awareness and popularization of bike-sharing, they seemed to need good experiences of exploratory uses and positive feedbacks from friends and relatives to become clients of the service.

RQ2: What is the relation of the intention to use bike-sharing prior to its implementation and the final decision about becoming a user?

There was no well-defined specific target group for bike-sharing in Madrid, thus it may be supposed that the local government and the service provider considered all citizens (and other people working or moving around) in the catchment area likely to be a potential user. As bike-sharing is a completely new element of the urban transport system, who and why become a user is a peculiar question of the research on travel behaviour. Furthermore, understanding the relation of willingness and actual use is not only a question of urban mobility, but also a complex issue of marketing and innovation research.

After a number of studies about willingness to use new transport services and infrastructure, and particularly willingness to pay for charges in the transport system, to our knowledge, this is the first examination of a panel sample about the intention and actual use of urban bike-sharing. Responses of 205 individuals (who all responded before and after the implementation of BiciMAD) have been analysed to highlight factors that influenced their actual decision about becoming or not becoming users, using the service frequently or

casually and potentials of further development of BiciMAD. A description of the panel sample has shown that there have been some changes during the timeframe of the project, which may affect travel patterns, namely: positive trends on the labour market (more people employed than before the implementation of bike-sharing); some young respondents have entered the labour market (after finalising higher education); and there are less single-person households, but lower average income levels. In regard to mobility, there is varied alteration in public transport use and private bicycle ownership, and more people with a driving license and access to a car.

The statistical tests of Pearson's chi-square and Cramer's V have been calculated to measure the association of *intention-to-use* and *actual use*. Results ($\chi^2=24.76$, $V=0.24$) indicate that there is a moderate connection, i.e. intention to and final decision about the use of bike-sharing are associated with a medium magnitude. Accordance (proportion of people who acted after implementation as intended before) is 46%, with rates of 45, 26 and 64 percent for frequent, occasional and non-use, respectively.

Differences are twofold: a significant number of respondents decided not to start using the service after an expressed willingness (53%), but a not insignificant percentage of refusers started to use it after implementation (37%). Main reasons for non-use (with or without prior intention to use BiciMAD) are convenience of other modes, especially own bicycle; network deficiencies; prices; and a real or perceived risk of accidents in road traffic. Subscription fee and a fee per each use are strongly criticized by users, who – although they seem to accept charges – became more negative about them after implementation. It may be supposed that pricing keeps away many potential users. On the contrary, relative advantage of bike-sharing in speed, eco-friendliness, price and being an active mode of transport are key factors in a positive decision about becoming a user on an occasional or frequent basis. Availability (not geographical coverage but number of bicycles and docks at stations) is perceived as a potential barrier of further use only on a low extent.

Design (ease-of-use and comfort) of Booster Bikes pedelecs is accepted by both users and non-users in the panel sample. This is also true about electric pedal assistance in both the before and after survey responses: ex-ante evaluation of advanced pedalling technology was 3.5 (on a Likert-type scale of 0 to 5), but after implementation it has increased to the level of 3.98–4.17, with a bit higher rating by subscribers (4.00–4.29). *This is another evidence of the significance of personal tests in the case of such a new technology in urban mobility, i.e. familiarity with the system.*

RQ3: Are there differences between the adoption of bike-sharing as a new travel mode in the city and other types of innovation? If so, which are the characteristics of users in terms of innovation adoption?

Innovation Diffusion Theory – one of the most influencing models in the field of innovation research – has been employed as a framework to examine adoption of bike-sharing as a new element of the transport system in Madrid in light of its novel technology and unique service configuration. For that, some assumptions and decisions had to be made. On the one hand,

the first two years of operation of BiciMAD is considered a quasi-complete process of adoption and this period was not interrupted or finished during the subject period. On the other hand, due to circumstances of bike-sharing implementation (e.g. registration prior to inauguration) and speed of adoption in the initial period, the first two adopter categories of IDT (Innovators and Early adopters) had to be combined. This category is named Earliest adopters and supposedly includes attributes of both original categories like venturesomeness and opinion leader role in the social system. Thus, the adopters have been studied in the following categories: (1) Earliest adopters (who started to use BiciMAD from June to August 2014; (2) Early majority (September 2014 to February 2015); (3) Late majority (March to June 2015); and (4) Laggards (July 2015 to June 2016).

Previous research (Rondinella, 2015; Rondinella et al., 2012) has addressed the role of mode familiarity, i.e. experience of using bicycle through recreational and other trips in utility cycling. On this basis, a specific perceived attribute has been added to the five defined by IDT (Relative advantage, Compatibility, Simplicity, Trialability and Observability), namely Cycling familiarity. This is to identify the background of bike-sharing adopters in urban cycling, in order to better understand profile of users in each adopter category. *A key conclusion is that those who report an experience of riding a bicycle in the city centre are mostly among the first and last adopters.* Individuals of these categories seem to have rather different profiles in other terms, for instance, in their travel behaviour and related characteristics.

Furthermore, some outcomes indicate that *the diffusion of bike-sharing is different from typical innovation adoption processes.* For instance, Relative advantage is not a reliable predictor in all aspects (e.g. eco-friendliness or costs are not more important for first users than for later adopters) and Trialability is not perceived as more important by earlier adopters (they were not able to take exploratory rides due to a delay in the introduction of casual use). Taking into account these outcomes, it may be stated that *bike-sharing is a special innovation vector in urban mobility.*

Findings show that there are some clear differences among adopter categories:

- *Earliest adopters* (month 1 to 3) are technology enthusiasts who are eager and can afford to start using the new public transport service without a thorough consideration or a test ride. They are *lifestyle cyclists*, who care less about external factors of cycling like weather or topography. They seem to consider bike-sharing not only an alternative mode for some trips (especially on foot and by PT), but also a new element of their lifestyles.
- Individuals in the category of *Early majority* (months 4 to 9), with many *dedicated cyclists*, seem to make a more deliberate decision about becoming frequent users, taking into account experiences of exploratory uses, costs, and if the bike-sharing network fits perfectly into their daily itineraries.
- *Late majority* adopters (months 10 to 13) are very dependent on their observation of others using the service and the opinion of their peers, namely earlier adopters. They are mainly *leisure cyclists*, i.e. use their bicycles for leisure and sports purposes.

- *Laggards* (months 14 to 25), a group of *fairweather cyclists*, are like a combination of Earliest adopters (e.g. in terms of cycling familiarity) and Early majority (e.g. in terms of prudent decision-making) but without venturesomeness and opinion leadership.

People who are less familiar with technology tend to adopt among later adopters. For them, doing exercise (taking recreational trips or using bike-sharing on utility trips as part of their physical training) seems to be more essential for bike-sharing.

RQ4: What is the impact of pedelec-sharing on individual and urban travel patterns?

Understanding travel behaviour — particularly mode choice before and after implementation — is an extremely important issue about bike-sharing, since promoters launch bike-sharing programmes to tackle urban mobility problems in the first place. Thus, general improvement of cycling levels (including the use of private bicycles) is also expected when a bike-sharing scheme is introduced. Local governments look forward to positive impacts also in terms of modal split: they expect a modal shift from polluting sedentary vehicles to cycling. In Madrid, the “big picture” (full sample in 2016, n=409) indicates that this is not the case, i.e. *BiciMAD has replaced public transport (70%) and other active modes (walking 15%, bicycle 8%), and it has barely drawn from individual motorized modes (car 2%, motorbike 2%)*. However, this has to be interpreted in its context: share of individual motorized modes was moderate (13% in 2014) in the BiciMAD catchment area (that is inside the M-30 ring road), therefore bike-sharing could draw massively, especially from sustainable modes of high modal share: walking (54%) and public transport (30%).

Taking a look into details outlines some more — and more positive — effects of bike-sharing implementation. For this research question, responses of the panel sample (n=205) have been analysed in order to explore changes of travel patterns of the same respondents. Comparison of changes in two types of trips (to work/school; to go out) shows that modal share of cycling (use of private bicycle and bike-sharing) has increased in all user categories. There is a significant modal shift to cycling/bike-sharing on trips to work/school by occasional users and on trips to go out with friends by all users.

In the ex-ante survey in 2014, respondents were asked to express their opinions about the expected main purpose of bike-sharing use. They considered tourism and recreational trips as the most, and going out by night as one of the least frequent potential motives of BiciMAD use, even with regard to their future trips. The above findings about changes of travel patterns of trips to go out indicate that bike-sharing has been an efficient measure to promote modal shift towards this sustainable mode for these routes.

A crucial impact is that no one in the panel sample reports on more trips by car or motorbike than before the introduction of bike-sharing. Moreover, although a majority estimates that there are no changes in the number and total distance of their trips (Figure 36), many others state that they have taken more or many more trips (25%) and travel more or much longer distances (17%) after implementing the new service. This is extremely important in light of the fact that

— in addition to one out of two who travels the same time — 46% perceive that their total travel time has henceforth decreased. *This is a key impact of bike-sharing: increased mobility and decreased (perceived) travel time.*

Figure 36: Impacts of bike-sharing on mobility patterns in Madrid

With regard to user categories, they have different new travel patterns, with more changes in the travel patterns of actual bike-sharing users. Subscribers tend to ride bicycle/bike-sharing and motorbike instead of trips on foot. Occasional users — with a significantly lower unemployment rate in surveys after, rather than before implementation — do new trips and use public transport less than before, but go more both by bicycle/bike-sharing and individual motorized modes. Non-users have nearly the same travel patterns than before: slightly more rides on two-wheelers and less by public transport.

7.1.2 Recommendations

Research questions served as a framework for the analysis, and their aim was to underline some key issues about users before and after the introduction of pedelec-sharing. For the main objective of this dissertation, namely, assessing bike-sharing implementation in light of user profiles and adoption attributes, some general findings may be highlighted. This is to better understand urban mobility patterns in Madrid and to contextualize the outcomes as global implications of travel behaviour.

BiciMAD has been launched in the centre of the city of Madrid, i.e. a city of low cycling culture and an insignificant modal share of bicycle trips. However, it is part of a series of steps by the local government to promote cycling in a city with high demand for a good quality and extensive public transport service and a traditionally high share of walking. Although there are potential barriers to cycling — such as external conditions (e.g. topography) and social characteristics (e.g. ageing society) —, decision-makers opted for innovative solutions to tackle such difficulties. New technology of bicycles, stations and other system elements, as well as smart and flexible service configuration have been applied to solve problems caused by hilly streets, insufficient cycling infrastructure, risk of accidents in road traffic, environmental concerns and security issues. The unique scheme includes the

first large network of bicycles with electric pedal assistance in a Western city; vandal-proof batteries to avoid theft and built-in GPS to allow localization in case of incidents; a fully IT-based online system; kiosks with touchscreen at stations; physical integration and some fare integration with public transport; partly user-based rebalancing of docking stations; and a unique fee structure. A gradual extension might ensure full accessibility in the inner city (inside the M-30 ring road) within a few years after inauguration.

Results show that BiciMAD is an attractive new element of urban mobility in Madrid, since initial targets (number of subscribers) have been achieved beyond expectations. In this term, a unique demand responsive system with power-assisted bicycles – i.e. a costly alternative to usual bike-sharing schemes – is a success story and an efficient manner to improve cycling levels. Electric power assistance is a key advantage of BiciMAD and it may be supposed that this is also true in comparison to regular cycling (in Madrid) and other bike-sharing systems with traditional heavy bikes (globally). However, users' perceptions of service attributes indicate some further considerations. Public policy recommendations are presented first in local, followed by in global terms.

On the one hand, a shortcoming of the system is the network, namely, that it is slowly expanding towards other zones of the city (as per survey respondents). As pedal assistance makes cycling faster, pedelecs allow reaching higher distances in comparison to an average regular bicycle or traditional heavy bikes of other bike-sharing systems. In outer zones, BiciMAD could be a complementary service to public transport, where it has lower coverage (in time or space), e.g. during night hours. On the other hand, pricing is a controversial issue about bike-sharing in Madrid. Unlike most other schemes, BiciMAD makes all users – including subscribers for the usually free first 30 minutes – pay for each ride. The idea behind this measure is to avoid a massive modal shift from other sustainable modes (public transport and walking) with high modal share in Madrid, and to generate some income to avoid extreme losses of a relatively costly system. Users are almost all negative about it – since most of them know that other systems are “free of charge” –, with some differences according to user categories. For instance, there are some more accepting opinions in the potential user group of “Fans”; late adopters tend to be less negative than other subscribers; and non-users seem to be more positive after implementation. However, the low price of 0.5 EUR per ride is seemingly accepted, as there has been a strong demand since inauguration. Also, the relative advantage of using bike-sharing is acknowledged by frequent users, i.e. that it is cheaper than alternative travel options.

Taking into account these aspects, the competent authority and the service provider may likely *attract more potential users by a denser and more extensive network and a more efficient awareness-raising about the economical character of pedelec-sharing*. An intense marketing would have influenced early adoption, and 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 likely contribute to a more reliable estimation of future demand and a more realistic identification of potential user profiles.

The analysis of research questions about user profiles have revealed that there were clear differences among (non-)user categories before and after implementation. Outcomes about

the three clusters of potential users (Fans; Vacillating and indifferent; Opponents and/or frequent cyclists) and actual user groups (Subscribers; Occasional users; Non-users) show varied socioeconomic backgrounds, mobility patterns and attitudes towards cycling and bike-sharing. A deeper insight into the characteristics of one of these categories, namely frequent users, has identified peculiarities within one group: adoption has been quick and a classification according to the time of adoption has determined four categories with individuals of a unique profile (Earliest adopters, Early majority, Late majority, Laggards). This is a significant achievement, not only about the users of BiciMAD, but also other bike-sharing systems. In spite of some characteristics that may be dependent on local circumstances (for instance, growing mobility due to the return to work by a relevant number of respondents in the second and third survey phase, thanks to an economic recovery after the crisis), results of the first examination of a panel sample and the first analysis of adoption attributes may be interpreted in other contexts as well, to understand users and properly design bike-sharing schemes.

Other lessons learnt about BiciMAD users are also worth considering by planners and operators of other systems. First, cities without bike-sharing shall notice that *pedelec-sharing has had a positive impact: there are more trips and higher travelled distances, but a lower perceived travel time. Balance of effects on active travel modes also seem to be positive*, in line with findings in other contexts. Although bike-sharing has not been able to draw significantly from car use, there is a peculiar varied effect on the use of motorbikes (there are more utility trips by motorized two-wheelers after bike-sharing introduction, but there is also a reported lower access to motorbikes and less rides in total). Pedelec (and e-bike) seems to be substitutive to motorcycles in certain urban context, especially on trips that would take too long time on foot or public transport, or in case of a clear preference for an individual travel option. *Power-assisted bike-sharing – combining advantages of a public service and a private means of transport –, may be a solution to address some externalities of motorbikes, such as noise pollution or land use.*

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

7.2 Compliance with other research

In parallel to increasing activity in the promotion of cycling through soft and hard mobility measures in Madrid, there is growing interest in academic research to assess the transition towards a more cycling-friendly transport system in the city. In this section, outcomes of the dissertation are compared to previous and simultaneous findings to justify, contextualize

and further interpret research results. Two main topics are studied here, in line with the approach of other investigations: (1) factors that influence the use of bicycles in Madrid, (2) impacts of BiciMAD on travel behaviour.

There are recent publications on cycling and bike-sharing in Madrid with specific topics that are not directly related to the endeavour of the present work to understand demand implications of the introduction of a bike-sharing system. For instance, visualization of the flow of cyclists for the development of optimal bicycle networks has been presented by Romanillos and Zaltz Austwick (2016) as an outcome of the “Madrid Cycle Track”, an initiative to collect information on cycling patterns by casual and professional urban cyclists. This is one of the starting points of an extensive global review on the role of big data (big GPS data) in cycling and bike-sharing (Romanillos et al., 2016). A future bike-sharing system of Madrid is used as an example for the development of a method for station location by García-Palomares et al. (2012). Although not only GIS data is applied, but also potential demand is estimated to build up scenarios for network design, this is a methodological approach and not a demand forecasting analysis, i.e. cannot be directly compared to findings of the present dissertation.

7.2.1 Previous research on bicycle use in Madrid

A burning interest in understanding why people ride a bicycle (in the specific context of Spanish cities) has resulted in three PhD dissertations so far at TRANSyT-UPM. Fernández-Heredia⁷² and Muñoz⁷³ focused on latent variables in models explaining the use of bicycle and mode choice models, respectively. Rondinella⁷⁴ highlighted the role of mode familiarity in the decision about utility cycling. Their research has resulted in a variety of scientific publications in recent years (Fernández-Heredia et al., 2016; Fernández-Heredia et al., 2014; Muñoz et al., 2013; Muñoz et al., 2016; Rondinella et al., 2012).

In his doctoral thesis, Gianni Rondinella has reviewed factors that lead to behavioural change towards cycling; one may find relation between social ecological models and findings in Chapter 2 of the present dissertation about phenomena that has influenced recent global spread of cycling. Bridging several different fields of research are obviously common points of these two approaches. Concerning individual motivations, a sample of 2555 responses was analysed in his dissertation, from a survey in “Ciudad Universitaria” campus in 2008, to highlight differences of the perceptions of barriers and motivators of bicycle use in Madrid. Conclusions indicate that the perception is strongly associated with both frequency and purpose of bicycle trips. This outcome has inspired the study of the role of cycling familiarity in the decision about starting to use bike-sharing (Chapter 5).

⁷² Fernández-Heredia, Álvaro (2012): El potencial de las variables latentes en modelos explicativos del uso de la bicicleta. Supervisors: Andrés Monzón and Sergio Jara-Díaz

⁷³ Muñoz López, Begoña (2016): Integrating bicycle option in mode choice models through latent variables. Supervisors: Andrés Monzón and Ricardo A. Daziano

⁷⁴ Rondinella, Gianni (2015): Considering cycling for commuting: the role of mode familiarity. An exploration on the (circular) relation between cycling behaviours and attitudes toward cycling in Vitoria-Gasteiz, Spain. Supervisors: Andrés Monzón and Elena López

In regard to the intention to use bicycles in Madrid – by the analysis of 3048 responses from the same survey data in “Ciudad Universitaria” campus –, Fernández-Heredia et al. (2014) also found that there is significant difference between perceptions of people with cycling experience and non-cyclists in terms of bicycle related factors. Both frequency (occasional or habitual rides) and type of use (commuting, leisure sport) make a difference. Four latent variables are associated to the intention and frequency of use of a bicycle: convenience (that measures the practical nature of bicycle as a mode of transport, including flexibility and efficiency), pro-bike (set of characteristics and factors intrinsic to the bicycle which make it an attractive mode of transport: economical, fun, healthy, ecological), physical determinants (measures the impedance to use of the bicycle because it is not motorized: fitness, orography) and exogenous restrictions (importance of factors that restrict bicycle use and that are not under the users’ control: risk of accidents, vandalism and auxiliary facilities).

In line with other findings on the basis of qualitative and quantitative analysis in Spain (Lois et al., 2016; Lois et al., 2015), Muñoz et al. (2013) have identified two underlying factors among attitudinal variables, namely: direct benefits of cycling (such as reliability, comfort, safety, weather independence and relative speed) and long-term benefits (such as health benefits, quality of life, flexibility and environmental benefits). Three barriers have also been found, i.e. physical conditions (distance and topography), external facilities (safe parking at home and at destination, other facilities at destination), and individual capacities (physical fitness and cycling in traffic).

As a contribution to the same line of research, the present dissertation has also briefly highlighted factors that may influence the use of bicycles in Madrid. Conclusions indicate that there are three latent variables, namely parking and intermodality (safe parking, access to public centres, adaptation of workplaces and integration with public transport), external factors (topography, climate, risk of accidents) and advantages of cycling (flexibility, eco-friendliness, economical character and, to a lower extent, fun or if it fits one’s lifestyle).

It seems justified that different surveying techniques and samples⁷⁵, and especially a different approach, may lead to a varied set of findings. However, there are clear similarities (Table 23), thus some common factors may be outlined:

- *advantages*, comprising characteristics of cycling that make it more convenient than other individual or collective modes of transport (especially variables identified by the three studies, such as flexibility, environmental-friendliness and fun);
- *physical factors*, related to both individual and external conditions that may form a barrier to cycling (topography; furthermore, risk of accidents and fitness);
- *parking and access*, including safe storage and cycling-friendly adaptation of buildings.

⁷⁵ An online survey with 3048 complete responses by university students and staff in “Ciudad Universitaria” campus in mid-2008 (Fernández-Heredia et al., 2014); personal intercept interviews with 224 local citizens in the centre of Madrid in September 2011 (Muñoz et al., 2013); and a combination of personal intercept interviews and online questionnaire among potential users of the future bike-sharing system in mid-2014 (by this dissertation).

Table 23: Comparison of latent variables that influence the use of bicycles in Madrid

Researcher	Álvaro Fernández Heredia	Begoña Muñoz	András Munkácsy	
Survey period	April to July 2008	September 2011	May/June 2014	
Survey zone	“Ciudad Universitaria” university campus	City centre (on four streets)	City centre (BiciMAD catchment area)	
Survey method	Online questionnaire (e-mail invitations)	Face-to-face on-street interviews	Combination of personal intercepts with an online questionnaire	
Sample size	3048	224	1694	Common points
Factors and variables	<u>CONVENIENCE</u> efficiency flexibility	<u>DIRECT BENEFITS</u> reliability comfort safety weather independence relative speed	<u>ADVANTAGES OF CYCLING</u> flexibility eco-friendliness economical character fun/lifestyle	ADVANTAGES
	<u>PRO-BIKE</u> economical fun healthy ecological	<u>LONG-TERM BENEFITS</u> health benefits quality of life flexibility environmental benefits fun relaxation		
	<u>PHYSICAL DETERMINANTS</u> fitness orography	<u>PHYSICAL CONDITIONS</u> distance topography	<u>EXTERNAL FACTORS</u> topography climate risk of accidents	PHYSICAL FACTORS
	<u>EXOGENOUS RESTRICTIONS</u> danger vandalism auxiliary facilities	<u>INDIVIDUAL CAPACITIES</u> physical fitness cycling in traffic		
		<u>EXTERNAL FACILITIES</u> safe parking at home safe parking at destination other facilities at destination	<u>PARKING AND INTERMODALITY</u> safe parking access to public centres integration with public transport adaptation of workplaces road infrastructure speed limit to 30 km/h	PARKING AND ACCESS

Variables in more than one research are shown in italic.

These are not new or previously not identified factors; however, this finding verifies that these variables load together even in different approaches of a similar research context.

7.2.2 Other research on the implementation of BiciMAD

The implementation of BiciMAD has incited quick response from the research community to express a need for data collection on user patterns. This dissertation is part of a research line of TRANSyT-UPM (based on a series of surveys) that aims to explore the implications of the

implementation of a bike-sharing scheme in Madrid. Another independent initiative by researchers, the Bike-sharing Observatory of Spain blog intends to diffuse available data on bike-sharing systems in Spain, and to analyse and provide interested parties with further knowledge about these schemes.

In this section, the findings of this dissertation are discussed in line with (1) the results of the research by García Martínez et al. (2016) at TRANSyT-UPM about the impacts of BiciMAD on the use of a private bicycle, and (2) the analysis by Anaya and Castro (2017) about the effect of bike-sharing on urban mobility patterns in Madrid.

7.2.2.1 Impacts according to a survey by the Bike-sharing Observatory of Spain

An online questionnaire is the basis of bike-sharing impact assessment in Spain by Anaya and Castro (2017). From 2248 complete responses, there is a sample of 307 respondents from Madrid. The number of BiciMAD users among respondents is 234. The study has highlighted topics that are not included in this dissertation, especially due to a low number of responses in these specific categories: e.g. a more detailed examination of non-user characteristics and study of ex-users (both on the level of Spain). Here, only outcomes related to the objectives of the dissertation are discussed, in order to highlight compliances of results.

Interestingly, the report of the Bike-sharing Observatory has found that 88.9% of BiciMAD users have a private bicycle at home. Only 55.5% (n=380) of frequent or casual users had one or more bicycles at their disposal in the survey for this dissertation in 2015.

Modal change is a key issue of bike-sharing implementation, and it has been examined nearly by the same questions in the two questionnaires. As it may be seen in Figure 37, there are obvious common or nearly identical outcomes, namely that *two out of three bike-sharing users replace trips by public transport and there is a limited shift from individual motorised modes (6–9%)*. This is in line with other research on this topic as well (presented above).

Anaya and Castro: "Which transport mode did you use previously for your most frequent trip?", % of respondents, n=234
Dissertation: "By what other mode did or would you take your most frequent bike-sharing trip?", % of respondents, n=397

Figure 37: Comparison of observed modal shifts to bike-sharing in Madrid

A shift from nearly the same proportion of active modes is also revealed by the two surveys (22–24%); however, in contrast to the dissertation, Anaya and Castro (2017) have found that – focusing only on previous walking and cycling – bike-sharing substitutes mainly bicycle rides. Different sampling techniques and the possibility of a higher number of people with cycling experience in the survey by the Bike-sharing Observatory may explain such inconsistency. Furthermore, the third survey phase indicates a bit more similar distribution (15% on foot, 8% by bicycle) in 2016.

Although conditions of further use are analysed from a different perspective⁷⁶, and accordingly there are different answer options, there are common findings: especially that *there is a need for a more extensive bike-sharing network in Madrid*. This is mentioned among the top motivators of a potential more frequent use of bike-sharing in both studies.

7.2.2.2 Impacts on the use of private bicycle by the same survey data

The author contributed to a publication about the influence of bike-sharing on mobility patterns, specifically the use of bicycle in Madrid. García Martínez et al. (2016) focused on mode choice of respondents and applied clustering to explore user characteristics after the introduction of BiciMAD. Responses from the ex-ante and ex-post survey (2014 and 2015, respectively) by actual subscribers were analysed for such purposes. Figure 38 represents the mean of each trip motivation by cluster (on a scale of 0 to 5), indicating cooperation of the use of bicycles and bike-sharing for most trip purposes.

1: daily use, 2: few times per week, 3: once a week, 4: once a month; 5: never

Figure 38: Frequency of bicycle and bike-sharing use in Madrid by clusters

⁷⁶ Anaya and Castro: “Under which circumstances would you use bike-sharing more often?”, responses by any users, only one response per respondent; in the dissertation: “Why don’t you use the service more frequently?”, responses by occasional users, multiple answers.

Three groups have been found:

- *Cluster 1*: Regular cyclists, who use bicycle (mainly bike-sharing and sometimes private bicycle) for all types of trips;
- *Cluster 2*: Casual cyclists, who occasionally use a regular bicycle for utility trips and less frequently use BiciMAD for other trips;
- *Cluster 3*: New cyclists, who exclusively use bike-sharing for utility trips and private bicycles for other trips on a weekly or less frequent basis. They reported their intention to use bike-sharing in spite of no previous use of their own bicycle, i.e. this is a group of individuals who was attracted by the advantages of BiciMAD (e.g. a fleet of pedelecs) as a new mobility option.

A general conclusion is that, after one year of operation, bike-sharing has increased the use of private bicycles by subscribers. However, bike-sharing is predominant in utility cycling and, especially for Cluster 1, in trips at night. The article found that bike-sharing has a positive influence on utility cycling, namely that *the proportion of subscribers using bicycles or bike-sharing to work/school on a frequent (daily or weekly) basis was tripled from 2014 to 2015*. For other purposes, daily use was constant but weekly use increased significantly.

Figure 39 includes data from the 3rd survey phase⁷⁷, indicating that there was slight increase in frequent use from 2015 to 2016 as well: for utility trips both on a daily and a weekly basis, and for other trips mainly on a weekly basis.

Figure 39: Impacts of the implementation of bike-sharing on the use of bicycles in Madrid

⁷⁷ The data of the 3rd survey phase has not been presented in the article by García Martínez et al. (2016).

This is line with the outcomes of this dissertation about the impacts of bike-sharing (analysed for trips to work/school and to go out). And it also reflects why the implementation of a bike-sharing system have become the key measure to promote cycling in urban mobility in the 2010s and it justifies experiences demonstrating that such programmes have led to a significant increase in the use of bicycle (García-Palomares et al., 2012).

7.3 Limitations and further research

Findings of this dissertation have revealed how a bike-sharing system may influence individual travel behaviour and mobility patterns in a city and, concretely, what has been the effect of BiciMAD on urban mobility in Madrid before and after two years of operation. It has focused on user profiles and adoption attributes, thus there is a number of topics that has not been addressed or not described in detail. Partly this is due to methodological considerations, namely that this kind of random sampling cannot ensure full representativity and the applied survey technique enables only a limited number of questions to reach the targeted sample size. Further questions or more complicated issues would increase survey length and thus decrease response rates (Fan and Yan, 2010). Consequently, some topics related to general travel patterns (e.g. motivations of mode choice when not using bike-sharing) and to bike-sharing (e.g. trip characteristics in light of time-based prices and incentivized user-based redistribution) may be examined through other data collections. As implications of discounts on the use of stations with certain occupancy were addressed only by the ex-ante questionnaire and not by the other two survey phases (due to time limitations), this topic may be further studied, as well. More specific observations would also be needed for the extremely interesting research topic of *non-user and ex-user perceptions and behaviour*. A combination of questionnaires and other data collection methods (e.g. GPS tracking) would be necessary for the analysis of BiciMAD *pedelecs' performance in terms of speed, in comparison to regular bicycles and other means of transport, and to evaluate their impact on individual travel times*. This may be linked to previous research on mapping bicycle trips in Madrid (Romanillos and Zaltz Austwick, 2016).

There are some other topics that may be studied after new survey phases of the research project. For instance, further evidence is needed to confirm the assumptions about the diffusion of BiciMAD as an innovation, namely that bike-sharing adoption in Madrid may be considered quasi-complete after the first two years of operation. In addition to short-term effects, *medium and long-term influence of bike-sharing on individual travel behaviour and urban mobility* may be assessed by new observations as well.

As has been mentioned in the Introduction, the dataset built-up during the three survey phases (as part of a research project by TRANSyT-UPM about the use of BiciMAD) has been and is being exploited by various researchers. An outcome about the effects of bike-sharing on bicycle use has been briefly presented above (García Martínez et al., 2016). Furthermore, analysis of users with certain sociodemographic backgrounds, travel patterns and attitudes towards bike-sharing characteristics (before or after implementation) will certainly allow the appraisal of the behaviour changes of a certain group of users (e.g. students). Another line of

future research may be the comparative analysis of the performance and impact of BiciMAD and other bike-sharing schemes in similar cities, e.g. Bicyklen of Copenhagen, a pedelec-sharing with another unique pricing policy. A comparison of different types of cities (by size, topography, climate, etc.) and systems of different service configurations (pricing, rebalancing, etc.), technologies (pedelecs vs. heavy bikes, docking stations vs. dockless systems, etc.) and levels of public transport integration would be useful for better understanding of users and their travel behaviour. However, low availability and compatibility of data would make such effort difficult. Taking into account that cities are actively looking to learn from another (Marsden et al., 2009), the same would apply for direct transferability of the above results: *general outcomes (the “big picture”) about users may be of global interest but details must be interpreted in the context of Madrid in 2014 to 2016, and transferred to other cities with appropriate limitations or adaptive changes.*

Some burning issues about bike-sharing have deliberately not been examined in this dissertation, e.g. *operational implications of this large-scale pedelec-sharing scheme: financial assessment of a unique fee structure, economic efficiency and environmental evaluation of a partly user-based rebalancing of docking stations, costs of vandalism, etc.* As the business model was changed two years after inauguration, *an appraisal of the initial business plan and a comparison of the private and later public operation* would also be a valuable contribution to the bike-sharing literature.

A review by one of the most influential researchers of bike-sharing (Fishman, 2016) has identified two key directions of future research, namely (1) *GPS and dockless systems* and (2) *e-bike-sharing and pedelec-sharing*. Despite some new findings — including the contribution of this dissertation to (2) —, these are still under-researched topics due to the recent implementation and scarce evidence about such systems. More common problems listed by Anaya et al. (2012) also need deeper consideration by the research community, namely *overuse, underuse, failures, theft and vandalism, rebalancing, land use issues, legal aspects, economic and technological exclusion and economic unfeasibility.*

Standardised data collection and further research on cycling and bike-sharing seems to be essential for their promotion to tackle present and future challenges of urban mobility. Further investment in cycling and bike-sharing research would allow a more efficient use of limited resources, avoid failures, provide tools for decision-making and provide more accurate estimates about benefits (Handy et al., 2014). Accordingly, with regard to the topics of this dissertation, *a lot more has to be said about travel behaviour — i.e. when, how much, where and why people ride or not ride — to properly design bike-sharing systems and find mobility management strategies for effective promotion in cities worldwide.*

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ANNEXES

List of publications

The key papers that have been directly included and adapted into a chapter are underlined. (Information on publication as of 7 September 2017.)

Chapter 2:

Munkácsy, A (2014): Towards a new generation of bike-sharing. Ex-ante analysis of BiciMAD (Madrid public bike system). Research training work. Doctorate Programme on Civil Engineering Systems. Universidad Politécnica de Madrid. Reviewed (“Matrícula de Honor”).

Munkácsy, A (2009): Kerékpáros közlekedés és turizmus (Cycling and cycle tourism, *in Hungarian*). In: Jászberényi, M and Pálfalvi, J (ed.): Nemzetközi közlekedés és turizmus (International transport and tourism, *in Hungarian*). Aula, Budapest: 365–394. Book chapter.

Munkácsy, A (2010): Waterways as barriers for cyclists. Proceedings of the 6th European Inland Waterway Navigation (EIWN) Conference, 10–11 June 2010, Baja, Hungary. Műegyetemi Kiadó, Budapest. Full paper accepted, published in proceedings and presented.

Mezős, B and Munkácsy, A (2011): 12% – How to involve residents, living on hills of any cities, into bicycle transport. Velo-City Sevilla 2011 (session: Workshops), 23–25 March 2011, Sevilla, Spain. Abstract accepted and presented.

Chapter 3:

Monzón, A, Hernández, S, Munkácsy, A, García, A, Velázquez, G (2017): Improving mobility surveys’ quality and rate of responses at low cost by combining intercept and web questionnaire methods. 11th International Conference on Transport Survey Methods, 24–29 September 2017, Québec, Canada. Abstract accepted for presentation, full paper submitted.

Velázquez, G, Monzón, A and Munkácsy, A (2015): Smart mobility in Madrid: ex-ante survey for a public transport mobile app. International Conference on City Sciences (ICCS 2015): New Architectures, Infrastructures and Services for Future Cities. 4–5 June 2015, Tongji University, Shanghai, China. Full paper accepted, published in proceedings and presented.

Chapter 4:

Munkácsy, A and Monzón, A (2017): Potential User Profiles of Innovative Bike-Sharing Systems: The Case of BiciMAD (Madrid, Spain). *Asian Transport Studies* 4.3: 621–638.
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Munkácsy, A (2015): Perfiles de usuarios de la última generación del sistema de bicicleta pública. I Campus Científico del Foro de Ingeniería del Transporte, 23–24 April 2015, Cercedilla (Madrid), Spain. Abstract accepted and presented.

Munkácsy, A and Monzón, A (2016): User profiles of innovative bike-sharing systems. WCTRS World Conference on Transport Research, 10–15 July 2016, Shanghai, China. Paper peer-reviewed, published in proceedings and presented.

Chapter 5:

Munkácsy, A and Monzón, A (forthcoming): Diffusion of bike-sharing as an innovation vector in the city: the case of BiciMAD (Madrid). Paper submitted to Journal of Urban Technology, under review after the first round of revisions.

Munkácsy, A (2017): The role of cycling familiarity in the use of bike-sharing: an amendment to the Diffusion of Innovations Theory. Proceedings, Közlekedéstudományi Konferencia (Conference on Transport Sciences), 30–31 March 2017, Győr, Hungary, pp. 99–106. Full paper accepted, published in proceedings and presented.

Chapter 6:

Munkácsy, A and Monzón, A (2017): Impacts of Smart Configuration in Pedelec-Sharing: Evidence from a Panel Survey in Madrid. *Journal of Advanced Transportation*, vol. 2017, Article ID 4720627 (special issue: Travel Behavior and Transportation Systems Analysis of Electric Vehicles), 1–11. Journal Impact Factor: 1.813 (2016 Journal Citation Reports® Science Edition by Clarivate Analytics).

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See full article on page 185.

Munkácsy, A and Monzón, A (2017): Intention-to-use and actual use of bike-sharing: the case of BiciMAD (Madrid). 20th EURO Working Group on Transportation Meeting, EWGT 2017, 4–6 September 2017, Budapest (Hungary). Full paper peer-reviewed, accepted and presented.

Chapter 7:

Munkácsy, A and Monzón, A (2017): I want to ride my (bike-sharing) bicycle... Conclusions of a series of surveys among bike-sharing users in Madrid. European Transport Conference, 4–6 October 2017, Barcelona, Spain. Abstract accepted for presentation.

Munkácsy, A and Monzón, A (2017): Potential and actual profile of bike-sharing users: the case of BiciMAD (Madrid). Proceedings, Scientists for Cycling (S4C) Colloquium, 12 June 2017, Nijmegen, Netherlands, pp. 107–109. Extended abstract accepted, published in proceedings, lightning talk and poster presented.

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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 km². 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:

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

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

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

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 % of respondents	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).

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

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).

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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Questionnaires

Ex-ante questionnaire (2014)

TRANSyT, Centro de Investigación del Transporte de la Universidad Politécnica de Madrid, está realizando una encuesta para estudiar el uso de la bicicleta y la opinión de los ciudadanos sobre la implantación de un sistema público de préstamo de bicicletas en Madrid (**BiciMAD**).

¡Su opinión es muy importante para nosotros!

Participará en el **SORTEO DE UNA TABLET O UNA CAJA REGALO DE FIN DE SEMANA DE VALOR EQUIVALENTE** entre los participantes de la encuesta.

El plazo para realizar la encuesta es de dos semanas desde la fecha de entrega de la tarjeta.

Si tiene alguna duda póngase en contacto con nosotros en la siguiente dirección de correo electrónico:
bicimad@caminos.upm.es

¡Muchísimas gracias por su colaboración!

Por favor introduzca el NÚMERO DE ENCUESTA que aparece en la tarjeta que le fue entregada:

¿Cuál es el motivo de su estancia en la zona donde le entregaron la tarjeta?

- ☐ Vivo aquí
- ☐ Trabajo
- ☐ Estudio
- ☐ Visitas
- ☐ Compras
- ☐ Ocio
- ☐ Turismo
- ☐ Otro (especifique)

PRIMERA PARTE: USTED Y LA BICICLETA

¿Sabe montar en bicicleta?

- ☐ Sí
- ☐ No

Número de bicicletas

¿Cuántas bicicletas tiene?

- ☐ Ninguna
- ☐ 1
- ☐ 2
- ☐ 3 o más

Tipo de bicicleta

¿Qué tipo de bicicleta tiene Ud.? (puede marcar más de una)

- ☐ Plegable
- ☐ Urbana
- ☐ Montaña
- ☐ Bicicleta de carretera
- ☐ Bicicleta de cicloturismo
- ☐ Eléctrica
- ☐ Otra (especifique)

Frecuencia y motivos del uso de la bici

¿Cuándo fue la última vez que usó la bici?

- ☐ Hoy
- ☐ En los últimos 3 días
- ☐ En la última semana
- ☐ En el último mes
- ☐ En el último año
- ☐ Hace más tiempo

¿Con qué frecuencia monta la bici?

	A diario	Unas veces por semana	Una vez a la semana	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐
Compras o pequeños recados	☐	☐	☐	☐	☐
Visita a amigos o familiares	☐	☐	☐	☐	☐
Ocio y deporte	☐	☐	☐	☐	☐
Turismo	☐	☐	☐	☐	☐
Para salir de noche	☐	☐	☐	☐	☐

Factores que condicionan el uso de la bici

Valore la importancia de los factores en el uso de la bicicleta (para Ud.).

	0 (nada importante)	1	2	3	4	5 (muy importante)
Clima	☐	☐	☐	☐	☐	☐
Orografía	☐	☐	☐	☐	☐	☐
Peligro de accidentes	☐	☐	☐	☐	☐	☐
Precio: más barata que otros medios de transporte	☐	☐	☐	☐	☐	☐
Es buena para el medioambiente	☐	☐	☐	☐	☐	☐
Su flexibilidad y poder aparcar en cualquier parte	☐	☐	☐	☐	☐	☐
Es divertida y va con mi estilo de vida	☐	☐	☐	☐	☐	☐

Infraestructuras para la bici

Valore la importancia de las siguientes infraestructuras para el uso de la bicicleta (para Ud.).

	0 (nada importante)	1	2	3	4	5 (muy importante)
Carriles bici	☐	☐	☐	☐	☐	☐
Aparcamientos seguros en la vía pública	☐	☐	☐	☐	☐	☐
Acceso y aparcamiento en los centros comerciales, culturales y otros establecimientos públicos	☐	☐	☐	☐	☐	☐
Aparcamientos y duchas en el lugar de trabajo/estudio	☐	☐	☐	☐	☐	☐
Su integración con el transporte público	☐	☐	☐	☐	☐	☐
Límite de velocidad a 30 km/h (vehículos)	☐	☐	☐	☐	☐	☐

SEGUNDA PARTE: USTED Y LA BICICLETA PÚBLICA

El sistema de bicicletas públicas es un servicio cada vez más habitual en las ciudades europeas. Estos sistemas ponen a disposición de los usuarios unas bicicletas para realizar desplazamientos dentro de una área determinada (por ejemplo, el centro de la ciudad). El usuario toma una bicicleta en alguna estación y –al final de su trayecto– puede devolverla en otra.

¿Conoce algún sistema público de bicicletas?

- ☐ Sí
- ☐ No

Sistemas de bicicletas públicas

Marque los sistemas que conoce (de los que tiene noticia).

- ☐ Bicing (Barcelona)
- ☐ SEVICI (Sevilla)
- ☐ Bizi (Zaragoza)
- ☐ Nbici (Pamplona)
- ☐ BICIBUR (Burgos)
- ☐ D-BiZi (San Sebastián)
- ☐ Préstamo de Bicicletas (Vitoria)
- ☐ Vélib' (París)
- ☐ Vélo'v (Lyon)
- ☐ Barclays Cycle Hire (Londres)
- ☐ Otro (especifique)

El proyecto BiciMAD

El Ayuntamiento va a implantar próximamente un sistema público de bicicletas en los distritos centrales de Madrid (véase el mapa de abajo). El proyecto se llama BiciMAD y tendrá 123 estaciones y 1.560 bicicletas.

¿Tiene alguna noticia del proyecto BiciMAD?

- ☐ Sí
- ☐ No

¿Cómo se ha enterado del proyecto BiciMAD?

- ☐ Prensa online
- ☐ Página web del Ayuntamiento
- ☐ Página web de asociaciones ciclistas
- ☐ Revistas o periódicos
- ☐ Televisión
- ☐ Radio
- ☐ Por amigos, familiares o compañeros de trabajo
- ☐ Otro (especifique)

Tarifa para abonarse a BiciMAD

La cuota de inscripción anual para residentes en Madrid será de 25 euros. Para los titulares del Abono de Transportes del Consorcio será de 15 euros anuales.

¿Cómo valora las tarifas que tendrá el sistema?

	0 (inaceptable)	1	2	3	4	5 (óptima)
Inscripción para residentes en Madrid: 25 €/año	☐	☐	☐	☐	☐	☐
Inscripción para titulares Abono de Transportes: 15 €/año	☐	☐	☐	☐	☐	☐

Coste adicional por cada uso

Además del coste anual de la inscripción, el servicio de BiciMAD costará 50 céntimos la primera media hora. Las siguientes fracciones de 30 minutos costarán 60 céntimos. A partir de los 120 minutos, la hora adicional costará 4 €. (Las estaciones más lejanas del área de funcionamiento de BiciMAD están a menos de 30 minutos en bici.)

Para los usuarios no inscritos (por ejemplo, turistas), la primera hora costará 2 €, y las siguientes, 4 € cada una.

¿Cómo valora las tarifas que tendrá el sistema?

	0 (inaceptable)	1	2	3	4	5 (óptima)
Tarifa por la primera media hora para inscritos: 50 céntimos	☐	☐	☐	☐	☐	☐
Tarifa de las siguientes fracciones de 30 minutos (hasta 120 min.) para inscritos: 60 céntimos	☐	☐	☐	☐	☐	☐

TARIFAS PARA NO INSCRITOS (turistas, usuarios ocasionales, etc.)

	0 (inaceptable)	1	2	3	4	5 (óptima)
Tarifa por la primera media hora para no residentes: 2 euros	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 30 minutos: 4 euros	☐	☐	☐	☐	☐	☐

Inscribirse en BiciMAD

Con las condiciones anteriores, ¿piensa utilizar las bicicletas de BiciMAD?

- ☐ Sí, voy a inscribirme
- ☐ Sí, a veces (no voy a inscribirme)
- ☐ No

Frecuencia y motivos del uso

¿Con qué frecuencia utilizará BiciMAD?

	A diario	Unas veces por semana	Una vez a la semana	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐
Compras o pequeños recados	☐	☐	☐	☐	☐
Visita a amigos o familiares	☐	☐	☐	☐	☐
Ocio y deporte	☐	☐	☐	☐	☐
Turismo	☐	☐	☐	☐	☐
Para salir de noche	☐	☐	☐	☐	☐

Motivos del uso (usuario ocasional)

¿Para qué tipo de desplazamientos utilizará las bicicletas de BiciMAD? (puede marcar varios)

- ☐ Desplazamiento al trabajo/centro de estudios
- ☐ Compras o pequeños recados
- ☐ Visita a amigos o familiares
- ☐ Ocio y deporte
- ☐ Turismo
- ☐ Para salir de noche
- ☐ Ninguno

Otro (especifique)

Aplicaciones para teléfono móvil

Habrà una aplicación para móviles que permitirá saber dónde hay bicicletas disponibles y cuántas; si el usuario deja la bicicleta en estaciones con pocas bicis o toma una donde hay muchas tendrá una rebaja de 10 céntimos.

¿Cómo valora las características de BiciMAD?

	0 (nada importante)	1	2	3	4	5 (muy importante)
Aplicación para móvil para encontrar una bicicleta disponible o una plaza libre para dejarla al final del trayecto en bici	☐	☐	☐	☐	☐	☐
Rebaja por dejar la bici en una estación menos ocupada en la proximidad de su destino	☐	☐	☐	☐	☐	☐

Cercanía y disponibilidad

La distribución de estaciones por los distritos centrales de Madrid:

Imagínese que en la estación más próxima de BiciMAD no hay bicicletas disponibles o en el final de su trayecto la estación está llena. ¿Está dispuesto a caminar para poder utilizar las bicicletas de BiciMAD?

- ☐ Sí, hasta 6–8 minutos.
- ☐ Sí, pero no más de 3–5 minutos.
- ☐ No, quiero coger y dejar la bicicleta en la estación más próxima (menos de 3 minutos andando).

¿Con qué frecuencia utilizaría las bicidetas de BiciMAD, si...?

	A diario	Unas veces por semana	Una vez a la semana	Alguna vez	Nunca
...fuera gratuita la inscripción anual	☐	☐	☐	☐	☐
...fuera gratuita la primera media hora	☐	☐	☐	☐	☐
...estuviera disponible en otras zonas de la ciudad	☐	☐	☐	☐	☐
...hubiera más carriles bici en el centro	☐	☐	☐	☐	☐
...se redujera la velocidad máxima a 30 km/h (o menos) en el centro	☐	☐	☐	☐	☐

PRIMERA PARTE: USTED Y LA BICICLETA

¿Sabe montar la bicicleta?

☐ Sí ☐ No

Número de bicicletas

¿Cuántas bicicletas tiene Usted?

☐ Ninguna
☐ 1
☐ 2
☐ 3 ó más

Tipo de bicicleta

¿Qué tipo de bicicleta tiene Ud.? (puede marcar más de uno)

- ☐ Plegable
- ☐ Urbana
- ☐ Montaña
- ☐ Bicicleta de carretera
- ☐ Bicicleta de cicloturismo
- ☐ Eléctrica
- ☐ Otro (especifique)

Frecuencia y motivos del uso de la bici

¿Cuándo fue la última vez que montó la bici?

- ☐ Hoy
- ☐ En los últimos 3 días
- ☐ En la última semana
- ☐ En el último mes
- ☐ En el último año
- ☐ Hace más tiempo

¿Con qué frecuencia monta la bici?

	A diario	Unas veces por semana	Una vez a la semana	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐
Compras o pequeños recados	☐	☐	☐	☐	☐
Visita a amigos o familiares	☐	☐	☐	☐	☐
Ocio y deporte	☐	☐	☐	☐	☐
Turismo	☐	☐	☐	☐	☐
Para salir de noche	☐	☐	☐	☐	☐

Factores que condicionan el uso de la bici

Valore la importancia de los factores en el uso de la bicicleta (para Ud.).

	0 (nada importante)	1	2	3	4	5 (muy importante)
Clima	☐	☐	☐	☐	☐	☐
Orografía	☐	☐	☐	☐	☐	☐
Peligro de accidentes	☐	☐	☐	☐	☐	☐
Precio: más barata que otros modos	☐	☐	☐	☐	☐	☐
Es buena para el medioambiente	☐	☐	☐	☐	☐	☐
Su flexibilidad y poder aparcarse en cualquier parte	☐	☐	☐	☐	☐	☐
Es divertida y va con mi estilo de vida	☐	☐	☐	☐	☐	☐

Infraestructuras para la bici

Valore la importancia de las siguientes infraestructuras para el uso de la bicicleta (para Ud.).

	0 (nada importante)	1	2	3	4	5 (muy importante)
Carriles bici	☐	☐	☐	☐	☐	☐
Aparcamientos seguros en la vía pública	☐	☐	☐	☐	☐	☐
Acceso y aparcamiento en los centros comerciales, culturales y otros establecimientos públicos	☐	☐	☐	☐	☐	☐
Aparcamientos y duchas en el lugar de trabajo/estudio	☐	☐	☐	☐	☐	☐
Su integración con el transporte público	☐	☐	☐	☐	☐	☐
Límite de velocidad a 30 km/h (vehículos)	☐	☐	☐	☐	☐	☐

SEGUNDA PARTE: USTED Y LA BICICLETA PÚBLICA

El sistema de bicicletas públicas es un servicio cada vez más habitual en las ciudades europeas. Estos sistemas ponen a disposición de los usuarios unas bicicletas para realizar desplazamientos dentro de una área determinada (por ejemplo, el centro de la ciudad). El usuario toma una bicicleta en alguna estación y –al final de su trayecto– puede devolverla en otra

¿Conoce algún sistema de bicicletas públicas?

- ☐ Sí
- ☐ No

Sistemas de bicicletas públicas

Marque los sistemas que conoce (de los que tiene noticia).

- ☐ Bicing (Barcelona)
- ☐ SEVICI (Sevilla)
- ☐ Bizi (Zaragoza)
- ☐ Nbici (Pamplona)
- ☐ BICIBUR (Burgos)
- ☐ D-BiZi (San Sebastián)
- ☐ Préstamo de Bicicletas (Vitoria)
- ☐ Vélib' (París)
- ☐ Vélo'v (Lyon)
- ☐ Barclays Cycle Hire (Londres)
- ☐ Otro (especifique)

El Ayuntamiento tiene el proyecto de implantar próximamente un sistema de bicicletas públicas en los distritos centrales de Madrid (véase el mapa de abajo). Se llamará BiciMAD y tendrá 123 estaciones y 1.560 bicicletas.

¿Tiene noticia del proyecto BiciMAD?

☐ Sí

☐ No

¿Cómo se ha enterado del proyecto BiciMAD?

☐ Hotel

☐ Oficina de turismo

☐ Prensa online

☐ Página web del Ayuntamiento

☐ Página web de asociaciones ciclistas

☐ Revistas o periódicos

☐ Televisión

☐ Radio

☐ De amigos, familiares o compañeros de trabajo

☐ Otro (especifique)

Tarifas

Para turistas, la primera hora costará dos euros, y las siguientes, cuatro euros cada una.

¿Cómo valora las tarifas que tendrá el sistema?

	0 (inaceptable)	1	2	3	4	5 (óptima)
Tarifa por la primera hora para no inscritos: 2 euros	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 30 minutos para no inscritos: 4 euros	☐	☐	☐	☐	☐	☐

Inscribirse en BiciMAD

En las condiciones antedichas, ¿utilizaría las bicicletas de BiciMAD alguna vez cuando esté de nuevo en Madrid?

- ☐ Sí
- ☐ No

Cercanía y disponibilidad

Imagínese que en la estación más próxima no hay bicicletas disponibles o en el final de su trayecto (por ejemplo, al lado de un monumento) la estación está llena. ¿Está dispuesto a caminar para poder utilizar las bicicletas de BiciMAD?

- ☐ Sí, hasta 6–8 minutos.
- ☐ Sí, pero no más de 3–5 minutos.
- ☐ No, quiero coger y dejar la bicicleta en la estación más próxima (menos de 3 minutos andando).

Bicicletas eléctricas

BiciMAD es una sistema de última generación en el que todas las bicicletas serán eléctricas. Este tipo de bicicletas tendrán asistencia eléctrica al pedaleo, que ayuda a reducir el esfuerzo en las cuestas, en las salidas de los semáforos, etc.

¿Ha montado ya alguna bicicleta eléctrica?

- ☐ Sí
- ☐ No

¿Cómo valora que todas las bicicletas de BiciMAD serán eléctricas?

0 (nada importante)	1	2	3	4	5 (muy importante)
☐	☐	☐	☐	☐	☐

¿Qué uso cree que tendrán las bicicletas de BiciMAD?

¿Para qué tipo de viajes cree que serán más utilizadas las bicicletas de BiciMAD? (puede marcar varios)

- ☐ Viaje al trabajo
- ☐ Viaje al centro de estudios
- ☐ Compras o pequeños recados
- ☐ Visita a amigos o familiares
- ☐ Ocio y deporte
- ☐ Turismo
- ☐ Para salir de noche
- ☐ Otro (especifique)

Evaluación global de BiciMAD

¿Hasta qué punto está de acuerdo con que BiciMAD fomentará efectivamente el uso de la bicicleta en el centro de Madrid?

0 (nada efectivo)	1	2	3	4	5 (muy efectivo)
☐	☐	☐	☐	☐	☐

TERCERA PARTE: ALGUNOS DATOS SOBRE USTED

Género:

- ☐ Hombre
- ☐ Mujer

¿Cuántos años tiene?

	Años
Edad	<input type="text"/>

Nivel de estudios alcanzado:

- ☐ Enseñanza primaria
- ☐ Enseñanza secundaria
- ☐ Título universitario
- ☐ Otro (especifique)

¿Cuál es su situación laboral?

- ☐ Empleado
- ☐ Desempleado
- ☐ Jubilado
- ☐ Estudiante
- ☐ Ama/o de casa
- ☐ No responde
- ☐ Otro (especificar)

¿Usted tiene...?

- ☐ Carnet de conducir
- ☐ Dispone de coche propio
- ☐ Acceso a motocideta o ciclomotor
- ☐ Abono de Transportes
- ☐ Ninguna de las anteriores

El número de personas que conviven en su hogar (incl. Usted):

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Más

Nivel de ingresos neto por hogar al mes:

- ☐ Menos o igual de 1.300 €
- ☐ 1.300 – 2.500 €
- ☐ Más de 2.500 €

¿Cuál es su modo de transporte habitual?

	andar	transporte público	coche	moto	bicicleta	otro	no aplica o no responde
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐	☐
Compras o pequeños recados	☐	☐	☐	☐	☐	☐	☐
Visita a amigos o familiares	☐	☐	☐	☐	☐	☐	☐
Ocio y deporte	☐	☐	☐	☐	☐	☐	☐
Turismo	☐	☐	☐	☐	☐	☐	☐
Para salir de noche	☐	☐	☐	☐	☐	☐	☐

Comentarios

Aquí puede dejar sus comentarios sobre la movilidad ciclista en Madrid, BiciMAD o la propia encuesta.
(Campo opcional. Si no tiene comentarios, pulse el botón *Siguiente.*)

Ha finalizado la encuesta. ¡Muchas gracias por su colaboración!

Por favor visite la página web www.bicimad.transyt-projects.com el **30 de mayo de 2014** para saber si su número de encuesta es el **GANADOR**.

Si desea recibir información de los resultados directamente, por favor escriba su dirección de correo electrónico:

Si tiene alguna duda, póngase en contacto con nosotros en la siguiente dirección de correo: bicimad@caminos.upm.es

MUCHAS GRACIAS POR SU TIEMPO.

Questionnaire of the 2nd survey phase (2015)

BIENVENIDO

TRANSyT (Centro de Investigación del Transporte de la Universidad Politécnica de Madrid) está realizando una encuesta para estudiar la movilidad en Madrid y la opinión de los ciudadanos acerca del servicio público de bicicleta, BiciMAD.

¡Su opinión es muy importante para nosotros!

Participará en el **SORTEO DE UNA iPad O UNA CAJA REGALO DE FIN DE SEMANA DE VALOR EQUIVALENTE** entre las personas que rellenen la encuesta.

Al pulsar "*Siguiente*" accederá al cuestionario, que dura 10–12 minutos. El plazo para realizar la encuesta es de una semana desde la fecha de entrega de la tarjeta.

Si tiene alguna duda, puede ponerse en contacto con nosotros en la siguiente dirección de correo electrónico: bicimad@caminos.upm.es

La encuesta es anónima y de carácter voluntario, respetándose todas las normas en materia de protección de datos personales.

¡Muchas gracias por tu colaboración!

NÚMERO DE ACCESO

Por favor, introduzca el NÚMERO DE ACCESO* al cuestionario (código que aparece en la tarjeta que le fue entregada):

*EL CÓDIGO ES PERSONAL Y NO DEBE SER INTRODUCIDO POR MÁS DE UNA PERSONA (NO DA DERECHO A PREMIOS A MÁS DE UNA PERSONA).

*LE RECORDAMOS QUE TIENE QUE CONSERVAR LA TARJETA A LO LARGO DEL DESARROLLO DE LA ENCUESTA (SIN ELLA NO PODRÁ RECOGER EL PREMIO).

USTED Y LA BICICLETA

En la primera sección del cuestionario encontrará preguntas acerca de su relación con la bicicleta como modo de transporte urbano. Estas preguntas se refieren al uso de la bicicleta en general y no específicamente a los desplazamientos realizados con una bicicleta pública (BiciMAD).

A1. ¿Cuántas bicicletas tiene a su disposición en su hogar (para uso propio o compartido)?

- ☐ Ninguna
- ☐ 1
- ☐ 2
- ☐ 3 o más

USTED Y LA BICICLETA

A11. ¿Qué tipo de bicicleta es la que tiene a su disposición? (Puede marcar más de una.)

- ☐ Plegable
- ☐ Urbana
- ☐ Montaña
- ☐ Bicicleta de carretera
- ☐ Bicicleta de cicloturismo
- ☐ Eléctrica
- ☐ Otra (especifique)

A12. ¿Con qué frecuencia usa su bicicleta?

	A diario	Varias veces por semana	Una vez a la semana	Una vez o varias veces al mes	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐
Visitar amigos o familiares	☐	☐	☐	☐	☐	☐
Por ocio (por ejemplo, dar un paseo en bicicleta)	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A2. Valore la importancia de los factores en el uso de la bicicleta para usted (en general no específicamente en Madrid).

Emplee, por favor, una escala de 0 a 5, donde 0 significa nada importante y 5 muy importante.

	0 - nada importante	1	2	3	4	5 - muy importante
Clima	☐	☐	☐	☐	☐	☐
Orografía	☐	☐	☐	☐	☐	☐
Peligro de accidentes	☐	☐	☐	☐	☐	☐
Precio: más barata que otros medios de transporte	☐	☐	☐	☐	☐	☐
Es buena para el medioambiente	☐	☐	☐	☐	☐	☐
Su flexibilidad y poder aparcar en cualquier parte	☐	☐	☐	☐	☐	☐
Es divertida y va con mi estilo de vida	☐	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A3. Valore la importancia de las siguientes infraestructuras para el uso de la bicicleta para usted (en general, no específicamente en Madrid).

Emplee, por favor, una escala de 0 a 5, donde 0 significa nada importante y 5 muy importante.

	0 - nada importante	1	2	3	4	5 - muy importante
Carriles bici (separados del tráfico motorizado)	☐	☐	☐	☐	☐	☐
Aparcamientos seguros en la vía pública	☐	☐	☐	☐	☐	☐
Acceso y aparcamiento en los centros comerciales, culturales y otros establecimientos públicos	☐	☐	☐	☐	☐	☐
Aparcamientos y duchas en el lugar de trabajo/estudio	☐	☐	☐	☐	☐	☐
Su integración con el transporte público	☐	☐	☐	☐	☐	☐
Límite de velocidad a 30 km/h (vehículos)	☐	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A4. ¿Cuál es su modo de transporte habitual en los siguientes viajes?

En caso de varios modos de transporte, marque el que considera el modo más relevante.

	andar	transporte público	coche	moto	bicicleta	otro	no aplica o no responde
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐	☐
Visitar a amigos o familiares	☐	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A5. ¿Está satisfecho con la infraestructura y el servicio relacionado con la movilidad ciclista EN MADRID?

Emplee, por favor, una escala de 0 a 5, donde 0 significa que está totalmente insatisfecho y 5 que está muy satisfecho.

	0 - totalmente insatisfecho	1	2	3	4	5 - muy satisfecho
Carriles bici separados del tráfico motorizado y peatonal	☐	☐	☐	☐	☐	☐
Carriles compartidos con el tráfico motorizado (con límite de velocidad de 30 km/h)	☐	☐	☐	☐	☐	☐
Aparca-bicis (aparcamientos destinados a bicicletas normales, NO BiciMAD)	☐	☐	☐	☐	☐	☐
Facilidad de estacionar una bicicleta normal (NO BiciMAD) donde no hay aparcá-bici	☐	☐	☐	☐	☐	☐
Acceso con bicicleta al transporte público	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

En esta sección encontrará preguntas acerca de su opinión sobre BiciMAD, el servicio público de bicicleta eléctrica de Madrid.

B1. ¿Es Usted usuario de BiciMAD?

- ☐ Soy usuario CON abono propio de BiciMAD
- ☐ Soy usuario SIN abono propio de BiciMAD
- ☐ No soy usuario pero ya lo he probado
- ☐ No soy usuario y no lo he probado

USTED Y BICIMAD

B141. ¿Por qué no ha probado BiciMAD? (Puede marcar varias respuestas.)

- ☐ Uso mi propia bicicleta
- ☐ Las estaciones no coinciden con mis trayectos habituales/ocasionales
- ☐ La cuota anual me parece cara
- ☐ La tarifa por cada uso me parece cara
- ☐ No hay carril bici en mis trayectos habituales/ocasionales
- ☐ Los carriles bici segregados y/o no segregados que existen en mis trayectos son inadecuados para mí
- ☐ El tráfico motorizado es peligroso y/o demasiado rápido
- ☐ Me desplazo más rápido en otros modos de transporte
- ☐ La bicicleta de BiciMAD me parece difícil de manejar
- ☐ La bicicleta de BiciMAD me parece incómoda
- ☐ Otro (especifique)

B142. ¿Utilizaría las bicicletas de BiciMAD, si...?

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente en desacuerdo y 5 que está totalmente de acuerdo.

	0 - totalmente en desacuerdo	1	2	3	4	5 - totalmente de acuerdo
...la cuota anual fuera más barata	☐	☐	☐	☐	☐	☐
...la primera media hora de uso para inscritos fuera gratuita	☐	☐	☐	☐	☐	☐
...estuviera disponible en otras zonas de la ciudad	☐	☐	☐	☐	☐	☐
...hubiera más carriles bici en el centro	☐	☐	☐	☐	☐	☐
...los carriles bici segregados y no segregados le dieran más confianza, fueran más seguros, etc.	☐	☐	☐	☐	☐	☐
...la velocidad máxima de coches se redujera a 30 km/h en el centro	☐	☐	☐	☐	☐	☐
...las bicicletas de BiciMAD fueran más sencillas de usar	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B131. ¿Cuándo fue la primera vez que usó una bicicleta de BiciMAD?

	Año	Mes
Año y mes	<input type="text"/>	<input type="text"/>

B132. ¿Por qué? (Puede marcar varias respuestas.)

- ☐ Por recomendación de amigos o familiares
- ☐ Por la información en los medios
- ☐ Por ver que la gente la usaba
- ☐ Por mi experiencia de bicicleta pública en otras ciudades
- ☐ Porque me parecía más rápida que otros modos de transporte
- ☐ Porque me parecía más económica que otros modos de transporte
- ☐ Porque me parecía más ecológica que otros modos de transporte
- ☐ Para hacer deporte
- ☐ Por curiosidad
- ☐ Otro (especifique)

B133. ¿Con qué tipo de tarjeta probó el servicio?

- ☐ De 1 día
- ☐ De 3 días
- ☐ De 5 días
- ☐ Con el abono de un amigo o familiar

USTED Y BICIMAD

B134. ¿Por qué no ha utilizado BiciMAD más veces? (Puede marcar varios.)

- ☐ Generalmente uso mi propia bicicleta
- ☐ Las estaciones no coinciden con mis trayectos habituales
- ☐ Dificultades de encontrar una bicicleta libre (o un espacio para dejarla)
- ☐ La cuota anual me parece cara
- ☐ La tarifa por cada uso me parece caro
- ☐ No hay carril bici en mis trayectos habituales
- ☐ Los carriles bici segregados y/o no segregados que existen en mis trayectos son inadecuadas para mí
- ☐ El tráfico motorizado es peligroso y/o demasiado rápido
- ☐ Me desplazo más rápido en otros modos de transporte
- ☐ Las bicicletas son difíciles de manejar
- ☐ Las bicicletas son incómodas
- ☐ Otro (especifique)

B135. ¿Utilizaría más las bicicletas de BiciMAD, si...?

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente en desacuerdo y 5 que está totalmente de acuerdo.

	0 - totalmente en desacuerdo	1	2	3	4	5 - totalmente de acuerdo
...la cuota anual fuera más barata	☐	☐	☐	☐	☐	☐
...la primera media hora de uso para inscritos fuera gratuita	☐	☐	☐	☐	☐	☐
...estuviera disponible en otras zonas de la ciudad	☐	☐	☐	☐	☐	☐
...hubiera más carriles bici en el centro	☐	☐	☐	☐	☐	☐
...los carriles bici segregados y no segregados le dieran más confianza, fueran más seguros, etc.	☐	☐	☐	☐	☐	☐
...la velocidad máxima de coches se redujera a 30 km/h en el centro	☐	☐	☐	☐	☐	☐
...las bicicletas de BiciMAD fueran más sencillas de usar	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B121. ¿Antes de usar una bicicleta de BiciMAD, había probado otro sistema de bicicletas públicas?

- ☐ Sí
- ☐ No

B122. ¿Cuándo fue la primera vez que usó una bicicleta de BiciMAD?

	Año	Mes
Año y mes	<input type="text"/>	<input type="text"/>

B123. ¿Por qué usó por primera vez una bicicleta de BiciMAD? (Puede marcar varios.)

- ☐ Por recomendación de amigos o familiares
- ☐ Por la información en los medios
- ☐ Por ver que la gente la usaba
- ☐ Por mi experiencia de bicicleta pública en otras ciudades
- ☐ Porque me parecía más rápida que otros modos de transporte
- ☐ Porque me parecía más económica que otros modos de transporte
- ☐ Porque me parecía más ecológica que otros modos de transporte
- ☐ Para hacer deporte
- ☐ Por curiosidad
- ☐ Otro (especifique)

B124. ¿Con qué tipo de tarjeta utiliza el servicio como usuario ocasional? Puede marcar varios.

- ☐ De 1 día
- ☐ De 3 días
- ☐ De 5 días
- ☐ Con el abono de un amigo o familiar

USTED Y BICIMAD

B125. ¿Por qué no utiliza BiciMAD más veces? (Puede marcar varios.)

- ☐ Generalmente uso mi propia bicicleta
- ☐ Las estaciones no coinciden con mis trayectos habituales
- ☐ Dificultades de encontrar una bicicleta libre (o un espacio para dejarla) en mis trayectos habituales
- ☐ La cuota anual me parece cara
- ☐ La tarifa por cada uso me parece caro
- ☐ No hay carril bici en mis trayectos habituales
- ☐ Los carriles bici segregados y/o no segregados que existen en mis trayectos son inadecuados para mí
- ☐ El tráfico motorizado es peligroso y/o demasiado rápido
- ☐ Me desplazo más rápido en otros modos de transporte
- ☐ Las bicicletas son difíciles de manejar
- ☐ Las bicicletas son incómodas
- ☐ Otro (especifique)

B126. ¿Se plantea inscribirse como abonado anual algún día?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B111. ¿Desde cuándo está abonado al sistema BiciMAD?

	Año	Mes
Inicio	<input type="text"/>	<input type="text"/>

B112. ¿Antes de usar una bicicleta de BiciMAD, había probado algún otro sistema de bicicletas públicas?

- ☐ Sí
- ☐ No

B113. ¿Probó BiciMAD antes de inscribirse como abonado anual? (Por ej. como usuario ocasional, con la tarjeta de un amigo, etc.)

- ☐ Sí
- ☐ No

B114. ¿Se plantea renovar su abono para próximo(s) año(s)?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B115. ¿Por qué empezó a usar BiciMAD? (Puede marcar varios.)

- ☐ Por recomendación de amigos o familiares
- ☐ Por la información en los medios
- ☐ Por ver que la gente la usaba
- ☐ Por mi experiencia de bicicleta pública en otras ciudades
- ☐ Porque me parecía más rápida que otros modos de transporte
- ☐ Porque me parecía más económica que otros modos de transporte
- ☐ Porque me parecía más ecológica que otros modos de transporte
- ☐ Para hacer deporte
- ☐ Por curiosidad
- ☐ Otro (especifique)

USTED Y BICIMAD

B2. ¿Antes de la introducción del sistema BiciMAD en qué medio de transporte realizaba el viaje que actualmente hace en bicicleta pública (el viaje que realiza más veces con BiciMAD)?

- ☐ No hacía esta ruta
☐ Andando
☐ Transporte público
☐ Coche
☐ Moto
☐ Bicicleta
☐ Otro (especifique)

USTED Y BICIMAD

B3. ¿Con qué frecuencia y qué motivo usa en BiciMAD?

	A diario	Algunas veces por semana	Una vez a la semana	Una vez o algunas veces al mes	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐
Visitar a amigos o familiares	☐	☐	☐	☐	☐	☐
Por ocio (por ejemplo, dar un paseo en bicicleta)	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B4. ¿En comparación con su situación antes de usar BiciMAD, cuáles son sus hábitos de viaje actuales?

Responda, por favor, si actualmente viaja más o menos que antes de usar BiciMAD.

	Mucho menos que antes	Menos	No hay cambio	Más	Mucho más que antes
Viajes en transporte público	☐	☐	☐	☐	☐
Viajes en coche	☐	☐	☐	☐	☐
Viajes en moto	☐	☐	☐	☐	☐
Viajes en bicicleta (propia)	☐	☐	☐	☐	☐
Viajes andando	☐	☐	☐	☐	☐
Número total de viajes	☐	☐	☐	☐	☐
Duración total de sus desplazamientos	☐	☐	☐	☐	☐
Distancia total de sus viajes	☐	☐	☐	☐	☐

USTED Y BICIMAD

B5. ¿Cómo valora las características de BiciMAD?

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

A, Bicicletas

	0 - Totalmente insatisfecho	1	2	3	4	5 - Muy satisfecho
Diseño de la bicicleta	☐	☐	☐	☐	☐	☐
Facilidad de uso	☐	☐	☐	☐	☐	☐
Comodidad	☐	☐	☐	☐	☐	☐
Asistencia al pedaleo	☐	☐	☐	☐	☐	☐
Diseño y utilidad del transportín	☐	☐	☐	☐	☐	☐
Mantenimiento de las bicicletas	☐	☐	☐	☐	☐	☐

B, Estaciones

	0 - Totalmente insatisfecho	1	2	3	4	5 - Muy satisfecho
Extensión de la red actual de estaciones	☐	☐	☐	☐	☐	☐
Distancia entre estaciones	☐	☐	☐	☐	☐	☐
Diseño de las estaciones	☐	☐	☐	☐	☐	☐
Funcionamiento del tótem	☐	☐	☐	☐	☐	☐
Funcionamiento de los anclajes	☐	☐	☐	☐	☐	☐
Ocupación de estaciones y disponibilidad de bicicletas	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B5. ¿Cómo valora las características de BiciMAD?

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

C, Tarifas

	0 - Totalmente insatisfecho	1	2	3	4	5 - Muy satisfecho
Cuota anual (25€ para residentes, 15€ para titulares del Abono Transportes)	☐	☐	☐	☐	☐	☐
Tarifa por la primera media hora para inscritos (0,5€)	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 30 min. para inscritos (0,6€)	☐	☐	☐	☐	☐	☐
Tarifa de la primera hora para usuarios ocasionales (2€)	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 60 min. para usuarios ocasionales (4€)	☐	☐	☐	☐	☐	☐
Descuento por coger la bicicleta de una estación saturada (0,1€)	☐	☐	☐	☐	☐	☐
Descuento por reserva de anclaje en el destino (0,1€)	☐	☐	☐	☐	☐	☐

D, Pago y fuentes de información

	0 - Totalmente insatisfecho	1	2	3	4	5 - Muy satisfecho	No sé o no aplica
Proceso de pago	☐	☐	☐	☐	☐	☐	☐
Consulta del saldo	☐	☐	☐	☐	☐	☐	☐
Aplicación móvil	☐	☐	☐	☐	☐	☐	☐
Atención telefónica al usuario	☐	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B6. La siguiente sección contiene algunas afirmaciones acerca de BiciMAD. Por favor, indique su opinión.

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente en desacuerdo con la afirmación y 5 que está totalmente de acuerdo.

A,

	0 - Totalmente en desacuerdo	1	2	3	4	5 - Totalmente de acuerdo
Es bueno probar las bicicletas de BiciMAD para decidir si uno quiere ser usuario habitual	☐	☐	☐	☐	☐	☐
Conocer y/o probar una bicicleta pública en otra ciudad me ayudó a tomar la decisión de usar BiciMAD	☐	☐	☐	☐	☐	☐
Probar una bicicleta de BiciMAD me ayudó a tomar la decisión de usar (o no usar) el servicio	☐	☐	☐	☐	☐	☐
Tengo experiencia en ir en bicicleta (por ej. mi propia bici) por el centro de Madrid	☐	☐	☐	☐	☐	☐
Monto mi propia bicicleta con cierta frecuencia (por ocio u otro motivo)	☐	☐	☐	☐	☐	☐
Antes de usar BiciMAD ya había ido alguna vez al centro de Madrid en mi propia bicicleta	☐	☐	☐	☐	☐	☐

B,

	0 - Totalmente en desacuerdo	1	2	3	4	5 - Totalmente de acuerdo
Usando la bici pública me siento más responsable en lo medioambiental y social	☐	☐	☐	☐	☐	☐
BiciMAD es más ecológico que otros modos de transporte	☐	☐	☐	☐	☐	☐
BiciMAD es más económico que otros modos de transporte	☐	☐	☐	☐	☐	☐
La asistencia al pedaleo hace que BiciMAD sea más fácil de usar en Madrid que una bicicleta normal	☐	☐	☐	☐	☐	☐
Con BiciMAD llego a mi destino más rápido que antes	☐	☐	☐	☐	☐	☐
BiciMAD es más moderno e innovador que el sistema de bicicleta pública en otras ciudades	☐	☐	☐	☐	☐	☐

C,

	0 - Totalmente en desacuerdo	1	2	3	4	5 - Totalmente de acuerdo
BiciMAD, para mí, es una forma de moverme y practicar deporte a la vez	☐	☐	☐	☐	☐	☐
La red de BiciMAD corresponde a mis trayectos habituales y/u ocasionales	☐	☐	☐	☐	☐	☐
Usar BiciMAD va con mi estilo de vida	☐	☐	☐	☐	☐	☐
La bicicleta pública es una de las soluciones para calmar el tráfico en el centro de Madrid	☐	☐	☐	☐	☐	☐
Los descuentos aplicados (reservar anclaje, retirar una bicicleta de una estación saturada, etc.) racionalizan el uso del sistema BiciMAD	☐	☐	☐	☐	☐	☐
Encuentro fácilmente una bicicleta disponible o un anclaje para aparcarla	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B6. Por favor, indique su opinión.

Por favor, emplee una escala de 0 a 5, donde 0 significa que está totalmente en desacuerdo con la afirmación y 5 que está totalmente de acuerdo.

D,

	0 - Totalmente en desacuerdo	1	2	3	4	5 - Totalmente de acuerdo
Retirar y aparcar la bici en el anclaje de BiciMAD es sencillo para mí	☐	☐	☐	☐	☐	☐
Las bicicletas de BiciMAD son cómodas para mí (ajustar altura del sillín, peso de la bici, etc.)	☐	☐	☐	☐	☐	☐
En una bicicleta de BiciMAD puedo subir las cuestas de Madrid tranquilamente	☐	☐	☐	☐	☐	☐
Las bicicletas de BiciMAD son fáciles de manejar	☐	☐	☐	☐	☐	☐
Operar en la pantalla del tótem de las estaciones de BiciMAD es sencillo	☐	☐	☐	☐	☐	☐
Me resulta fácil llevar el control de mi saldo disponible en BiciMAD	☐	☐	☐	☐	☐	☐

E,

	0 - Totalmente en desacuerdo	1	2	3	4	5 - Totalmente de acuerdo
Ver a la gente usando bicicletas de BiciMAD me ayudó a tomar la decisión de ser usuario de las mismas y/o probar una	☐	☐	☐	☐	☐	☐
La gente se interesa al verme usar BiciMAD	☐	☐	☐	☐	☐	☐
Otros usuarios parecen estar contentos al usar BiciMAD	☐	☐	☐	☐	☐	☐
BiciMAD fomenta el uso de la bicicleta en el centro de Madrid	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B143. ¿Cómo valora las características de BiciMAD?

Por favor, emplee una escala de 0 a 5, donde 0 significa inaceptable y 5 significa óptima.

A, Tarifas

	0 - Inaceptable	1	2	3	4	5 - Óptima
Cuota anual (25€ para residentes, 15€ para titulares del Abono Transportes)	☐	☐	☐	☐	☐	☐
Tarifa por la primera media hora para inscritos (0,5€)	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 30 min. para inscritos (0,6€)	☐	☐	☐	☐	☐	☐
Tarifa de la primera hora para usuarios ocasionales (2€)	☐	☐	☐	☐	☐	☐
Siguientes fracciones de 60 min. para usuarios ocasionales (4€)	☐	☐	☐	☐	☐	☐
Descuento por coger la bicicleta de una estación saturada (0,1€)	☐	☐	☐	☐	☐	☐
Descuento por reserva de anclaje en el destino (0,1€)	☐	☐	☐	☐	☐	☐

B, Infraestructura

	0 - Inaceptable	1	2	3	4	5 - Óptima
Diseño de las bicicletas	☐	☐	☐	☐	☐	☐
Extensión actual de la red de estaciones BiciMAD	☐	☐	☐	☐	☐	☐
Diseño de las estaciones	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

B7. ¿Se ha enterado de que se está ampliando la red de BiciMAD en 2015?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B71. ¿Cómo?

- ☐ En el momento de ver las nuevas estaciones
- ☐ Por las redes sociales (Facebook, Twitter, etc.)
- ☐ Por la prensa online
- ☐ En la página web del Ayuntamiento
- ☐ Por la página web de una asociación ciclista
- ☐ Por una revista o periódico
- ☐ Por la televisión
- ☐ Por la radio
- ☐ Por amigos, familiares, compañeros de trabajo, etc.
- ☐ Otro (especifique)

DETALLES PERSONALES

A continuación encontrará algunas preguntas personales. Le recordamos que los datos se emplearán exclusivamente para un estudio científico de forma anónima, respetando las leyes en materia de protección de datos.

C1. Género:

- ☐ Hombre
- ☐ Mujer

C2. Edad:

Año

Año de nacimiento

C3. Nivel de estudios alcanzado:

- ☐ Sin estudios
- ☐ Enseñanza primaria
- ☐ Enseñanza secundaria
- ☐ Bachillerato
- ☐ Formación profesional
- ☐ Grado/Licenciatura/Diplomatura
- ☐ Máster
- ☐ Doctorado
- ☐ Otro (especifique)

DETALLES PERSONALES

C4. ¿Cuál es su situación laboral?

- ☐ Empleado
- ☐ Autónomo
- ☐ Desempleado
- ☐ Jubilado
- ☐ Estudiante
- ☐ Ama/o de casa
- ☐ Otro (especifique)

C5. ¿Usted tiene...?

- ☐ Carnet de conducir
- ☐ Acceso a coche
- ☐ Acceso a motocicleta o ciclomotor
- ☐ Abono de Transportes
- ☐ Ninguna de las anteriores

DETALLES PERSONALES

C6. Código postal de su domicilio o de su residencia habitual en Madrid:
(si no aplica: "00000")

C7. El número de personas que conviven en su hogar (incl. usted):

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Más

C8. Nivel de ingresos neto en su hogar al mes:

- ☐ Menos o igual de 1.300 €
- ☐ 1.300 – 2.500 €
- ☐ Más de 2.500 €

COMENTARIOS

Aquí puede dejar sus comentarios sobre la movilidad ciclista y el servicio público de bicicleta de Madrid.

(Campo opcional. Si no tiene comentarios, pulse el botón *Siguiente.*)

FIN DEL CUESTIONARIO

¡Muchas gracias por su colaboración!

Si desea participar en el sorteo y/o recibir información sobre los resultados de la encuesta directamente, por favor, escriba aquí su dirección de correo electrónico:

Confirmación del correo electrónico:

Número de teléfono (opcional, si quiere que se utilice este medio para avisarle del premio):

En la página web www.bicimad.transyt-projects.com el **30 de junio de 2015** se indicará si su número de encuesta es el **GANADOR**. Si nos da alguna de las informaciones anteriores se lo comunicaremos personalmente.

Si tiene alguna duda, póngase en contacto con nosotros en la siguiente dirección de correo: bicimad@caminos.upm.es

Para finalizar el cuestionario, pulse el botón "Listo".

MUCHAS GRACIAS POR SU TIEMPO.

Questionnaire of the 3rd survey phase (2016)

BIENVENIDO

TRANSyT (Centro de Investigación del Transporte de la Universidad Politécnica de Madrid) está realizando una encuesta para estudiar la movilidad en Madrid y la opinión de los ciudadanos acerca del servicio público de bicicletas, BiciMAD.

¡Su opinión es muy importante para nosotros!

Participará en el **SORTEO DE DOS VALES REGALO POR VALOR DE 50€ DE UNA TIENDA DE ARTÍCULOS CICLISTAS** entre las personas que rellenen la encuesta.

Al pulsar "*Siguiente*" accederá al cuestionario, que dura 10–12 minutos. El plazo para realizar la encuesta es de una semana desde la fecha en la que se le entregó la tarjeta.

Si tiene alguna duda, puede ponerse en contacto con nosotros en la siguiente dirección de correo electrónico: bicimad@caminos.upm.es

La encuesta es anónima y de carácter voluntario, respetándose todas las normas en materia de protección de datos personales.

¡Muchas gracias por su colaboración!

NÚMERO DE ACCESO

Por favor, introduzca el **NÚMERO DE ACCESO*** al cuestionario (código que aparece en la tarjeta que le fue entregada):

*EL CÓDIGO ES PERSONAL Y NO DEBE SER INTRODUCIDO POR MÁS DE UNA PERSONA (NO DA DERECHO A PREMIOS A MÁS DE UNA PERSONA).

*LE RECORDAMOS QUE TIENE QUE CONSERVAR LA TARJETA A LO LARGO DEL DESARROLLO DE LA ENCUESTA (SIN ELLA NO PODRÁ RECOGER EL PREMIO).

USTED Y LA BICICLETA

En la primera sección del cuestionario encontrará preguntas acerca de su relación con la bicicleta como modo de transporte urbano. Estas preguntas se refieren al **USO DE LA BICICLETA EN GENERAL** y no específicamente a los desplazamientos realizados con una bicicleta pública (BiciMAD).

A1. ¿Cuántas bicicletas tiene a su disposición en su hogar (para uso propio o compartido)?

- ☐ Ninguna
- ☐ 1
- ☐ 2
- ☐ 3 o más

USTED Y LA BICICLETA

A11. ¿Qué tipo de bicicleta es la que tiene a su disposición? (Puede marcar más de una.)

- ☐ Plegable
- ☐ Urbana
- ☐ Montaña
- ☐ Bicicleta de carretera
- ☐ Bicicleta de cicloturismo
- ☐ Eléctrica
- ☐ Otra (especifique)

A12. ¿Con qué frecuencia usa su bicicleta?

	A diario	Varias veces por semana	Una vez a la semana	Una vez o varias veces al mes	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐
Visitar amigos o familiares	☐	☐	☐	☐	☐	☐
Por ocio (por ejemplo, dar un paseo en bicicleta)	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A13. ¿Qué experiencia tiene montando en bicicleta?

- ☐ Muy poca
☐ Poca
☐ Media
☐ Bastante
☐ Mucha

A14. ¿Con qué regularidad hace ejercicio?

- ☐ Nunca
☐ Alguna vez
☐ Una o varias veces al mes
☐ Una vez a la semana
☐ Varias veces por semana
☐ A diario

USTED Y LA BICICLETA

A2. Valore la **IMPORTANCIA** de los factores en el **USO DE LA BICICLETA EN GENERAL** para usted (no específicamente en Madrid).

Emplee, por favor, una escala de 1 a 5, donde 1 significa nada importante y 5 muy importante.

	1 - Nada importante	2	3	4	5 - Muy importante
Clima	☐	☐	☐	☐	☐
Orografía	☐	☐	☐	☐	☐
Peligro de accidentes	☐	☐	☐	☐	☐
Precio: más barata que otros medios de transporte	☐	☐	☐	☐	☐
Es buena para el medioambiente	☐	☐	☐	☐	☐
Su flexibilidad y poder aparcar en cualquier parte	☐	☐	☐	☐	☐
Es divertida y va con mi estilo de vida	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A3. Valore la **IMPORTANCIA** de las siguientes infraestructuras para el **USO DE LA BICICLETA EN GENERAL** para usted (no específicamente en Madrid).

Emplee, por favor, una escala de 1 a 5, donde 1 significa nada importante y 5 muy importante.

	1 - Nada importante	2	3	4	5 - Muy importante
Carriles bici separados del tráfico motorizado y peatonal	☐	☐	☐	☐	☐
Carriles compartidos con el tráfico motorizado (con límite de velocidad de 30 km/h)	☐	☐	☐	☐	☐
Aparcamientos seguros en la vía pública	☐	☐	☐	☐	☐
Acceso y aparcamiento en los centros comerciales, culturales y otros establecimientos públicos	☐	☐	☐	☐	☐
Aparcamientos y duchas en el lugar de trabajo/estudio	☐	☐	☐	☐	☐
Acceso con bicicleta al transporte público	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A4. ¿Cuál es su nivel de SATISFACCIÓN (cómo lo valora) con la infraestructura y el servicio relacionado con la movilidad ciclista EN MADRID?

Emplee, por favor, una escala de 1 a 5, donde 1 significa que está totalmente insatisfecho y 5 que está totalmente satisfecho.

	1 - Totalmente insatisfecho	2	3	4	5 - Totalmente satisfecho
Carriles bici separados del tráfico motorizado y peatonal	☐	☐	☐	☐	☐
Carriles compartidos con el tráfico motorizado (con límite de velocidad de 30 km/h)	☐	☐	☐	☐	☐
Aparcamientos seguros en la vía pública (destinados a bicicletas normales, NO BiciMAD)	☐	☐	☐	☐	☐
Acceso y aparcamiento en los centros comerciales, culturales y otros establecimientos públicos (No BiciMAD)	☐	☐	☐	☐	☐
Aparcamientos y duchas en el lugar de trabajo/estudio	☐	☐	☐	☐	☐
Acceso con bicicleta al transporte público	☐	☐	☐	☐	☐

USTED Y LA BICICLETA

A5. ¿Cuál es su modo de transporte habitual en los siguientes viajes?

En caso de varios modos de transporte, marque el que considera el modo más relevante.

	andar	transporte público	coche	moto	bicicleta	otro	no aplica o no responde
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐	☐
Visitar amigos o familiares	☐	☐	☐	☐	☐	☐	☐
Por ocio (por ejemplo, dar un paseo en bicicleta)	☐	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐	☐

USTED Y BICIMAD

En esta sección encontrará preguntas acerca de su opinión sobre BiciMAD, el servicio público de bicicleta eléctrica de Madrid.

B1. ¿Es Usted usuario de BiciMAD?

- ☐ Soy usuario abonado de BiciMAD
- ☐ Soy usuario ocasional (no abonado) de BiciMAD
- ☐ No he probado BiciMAD nunca

USTED Y BICIMAD

B131. ¿Por qué no ha probado BiciMAD? (Puede marcar varias respuestas.)

- ☐ Uso mi propia bicicleta
- ☐ Las estaciones no coinciden con mis trayectos habituales/ocasionales
- ☐ La cuota anual me parece cara
- ☐ La tarifa por cada uso me parece cara
- ☐ No hay carril bici en mis trayectos habituales/ocasionales
- ☐ Los carriles bici segregados y/o no segregados que existen en mis trayectos son inadecuados para mí
- ☐ El tráfico motorizado es peligroso y/o demasiado rápido
- ☐ Me desplazo más rápido en otros modos de transporte
- ☐ La bicicleta de BiciMAD me parece difícil de manejar
- ☐ La bicicleta de BiciMAD me parece incómoda
- ☐ Otro (especifique)

B132. ¿Utilizaría las bicicletas de BiciMAD, si...?

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente en desacuerdo y 5 que está totalmente de acuerdo.

	1 - Totalmente en desacuerdo	2	3	4	5 - Totalmente de acuerdo
...la cuota anual fuera más barata	☐	☐	☐	☐	☐
...la primera media hora de uso para inscritos fuera gratuita	☐	☐	☐	☐	☐
...estuviera disponible en otras zonas de la ciudad	☐	☐	☐	☐	☐
...hubiera más carriles bici en el centro	☐	☐	☐	☐	☐
...los carriles bici segregados y no segregados le dieran más confianza, fueran más seguros, etc.	☐	☐	☐	☐	☐
...la velocidad máxima de coches se redujera a 30 km/h en el centro	☐	☐	☐	☐	☐
...las bicicletas de BiciMAD fueran más sencillas de usar	☐	☐	☐	☐	☐

USTED Y BICIMAD

B121. ¿Antes de usar una bicicleta de BiciMAD, había probado otro sistema de bicicletas públicas?

- ☐ Sí
- ☐ No

B122. ¿Cuándo fue la primera vez que usó una bicicleta de BiciMAD?

	Año	Mes
Año y mes	<input type="text"/>	<input type="text"/>

B123. ¿Por qué utiliza BiciMAD? (Puede marcar varios.)

- ☐ Porque me parece más rápida que otros modos de transporte
- ☐ Porque me parece más económica que otros modos de transporte
- ☐ Porque me parece más ecológica que otros modos de transporte
- ☐ Para hacer deporte
- ☐ Porque me lo paso bien yendo en bici
- ☐ Porque se puede aparcar fácilmente en el centro
- ☐ Otro (especifique)

B124. ¿Con qué tipo de tarjeta utiliza el servicio como usuario ocasional? Puede marcar varios.

- ☐ De 1 día
- ☐ De 3 días
- ☐ De 5 días
- ☐ Con el abono de un amigo o familiar

B125. ¿Estuvo abonado anteriormente a BiciMAD?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B126. ¿Por qué no utiliza BiciMAD más veces? (Puede marcar varios.)

- ☐ Generalmente uso mi propia bicicleta
- ☐ Las estaciones no coinciden con mis trayectos habituales
- ☐ Dificultades de encontrar una bicicleta libre (o un espacio para dejarla) en mis trayectos habituales
- ☐ La cuota anual me parece cara
- ☐ La tarifa por cada uso me parece caro
- ☐ No hay carril bici en mis trayectos habituales
- ☐ Los carriles bici segregados y/o no segregados que existen en mis trayectos son inadecuados para mí
- ☐ El tráfico motorizado es peligroso y/o demasiado rápido
- ☐ Me desplazo más rápido en otros modos de transporte
- ☐ Las bicicletas son difíciles de manejar
- ☐ Las bicicletas son incómodas
- ☐ Otro (especifique)

B127. ¿Se plantea inscribirse como abonado en el próximo año?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B111. ¿Desde cuándo está abonado al sistema BiciMAD?

	Año	Mes
Inicio	<div></div>	<div></div>

B112. ¿Antes de usar una bicicleta de BiciMAD, había probado algún otro sistema de bicicletas públicas?

- ☐ Sí
- ☐ No

B113. ¿Probó BiciMAD antes de inscribirse como abonado anual? (Por ej. como usuario ocasional, con la tarjeta de un amigo, etc.)

- ☐ Sí
- ☐ No

B114. ¿Se plantea renovar su abono para próximo(s) año(s)?

- ☐ Sí
- ☐ No

USTED Y BICIMAD

B115. ¿Por qué utiliza BiciMAD? (Puede marcar varios.)

- ☐ Porque me parece más rápida que otros modos de transporte
- ☐ Porque me parece más económica que otros modos de transporte
- ☐ Porque me parece más ecológica que otros modos de transporte
- ☐ Para hacer deporte
- ☐ Porque me lo paso bien yendo en bici
- ☐ Porque se puede aparcar fácilmente en el centro
- ☐ Otro (especifique)

USTED Y BICIMAD

B2. ¿Si no estuviese BiciMAD, en qué medio de transporte realizaría el viaje que actualmente hace en bicicleta pública (el viaje que realiza más veces con BiciMAD)?

- ☐ No haría esta ruta
- ☐ Andando
- ☐ Metro
- ☐ Autobús
- ☐ Coche
- ☐ Moto
- ☐ Bicicleta
- ☐ Otro (especifique)

USTED Y BICIMAD

B31. ¿Con qué frecuencia y qué motivo usa BiciMAD?

	A diario	Algunas veces por semana	Una vez a la semana	Una vez o algunas veces al mes	Alguna vez	Nunca
Desplazamiento al trabajo/centro de estudios	☐	☐	☐	☐	☐	☐
Ir de compras	☐	☐	☐	☐	☐	☐
Hacer pequeños recados	☐	☐	☐	☐	☐	☐
Visitar a amigos o familiares	☐	☐	☐	☐	☐	☐
Por ocio (por ejemplo, dar un paseo en bicicleta)	☐	☐	☐	☐	☐	☐
Salir de noche	☐	☐	☐	☐	☐	☐
Otros viajes	☐	☐	☐	☐	☐	☐

B32. ¿Cuál es la duración máxima del trayecto que está dispuesto a recorrer con BiciMAD según el motivo del viaje?

Duración máxima del trayecto	
Desplazamiento al trabajo/centro de estudios	<input type="text"/>
Ir de compras	<input type="text"/>
Hacer pequeños recados	<input type="text"/>
Visitar a amigos o familiares	<input type="text"/>
Por ocio (por ejemplo, dar un paseo en bicicleta)	<input type="text"/>
Salir de noche	<input type="text"/>
Otros viajes	<input type="text"/>

B33. ¿A cuántos minutos caminando de su domicilio se encuentra la estación de BiciMAD más cercana?

USTED Y BICIMAD

B4. ¿En comparación con su situación antes de usar BiciMAD, cuáles son sus hábitos de viaje actuales?

Responda, por favor, si actualmente viaja más o menos que antes de usar BiciMAD.

	Mucho menos que antes	Menos	No hay cambio	Más	Mucho más que antes
Viajes en transporte público	☐	☐	☐	☐	☐
Viajes en coche	☐	☐	☐	☐	☐
Viajes en moto	☐	☐	☐	☐	☐
Viajes en bicicleta (propia)	☐	☐	☐	☐	☐
Viajes andando	☐	☐	☐	☐	☐
Número total de viajes	☐	☐	☐	☐	☐
Duración total de sus desplazamientos	☐	☐	☐	☐	☐
Distancia total de sus viajes	☐	☐	☐	☐	☐

USTED Y BICIMAD

B51. ¿Hasta qué punto son **IMPORTANTES** para usted en el USO DE LA BICICLETA PÚBLICA EN GENERAL los siguientes atributos?

Emplee, por favor, una escala de 1 a 5, donde 1 significa nada importante y 5 muy importante.

	1 - Nada importante	2	3	4	5 - Muy importante
Diseño de la bicicleta	☐	☐	☐	☐	☐
Facilidad de uso	☐	☐	☐	☐	☐
Comodidad	☐	☐	☐	☐	☐
Asistencia al pedaleo	☐	☐	☐	☐	☐
Mantenimiento de las bicicletas	☐	☐	☐	☐	☐
Extensión de la red actual de estaciones	☐	☐	☐	☐	☐
Distancia entre estaciones	☐	☐	☐	☐	☐
Funcionamiento del tótem	☐	☐	☐	☐	☐
Funcionamiento de los anclajes	☐	☐	☐	☐	☐
Disponibilidad para aparcar la bicicleta	☐	☐	☐	☐	☐
Disponibilidad para coger una bicicleta	☐	☐	☐	☐	☐
Cuota anual	☐	☐	☐	☐	☐
Tarifa para inscritos	☐	☐	☐	☐	☐
Tarifa para usuarios ocasionales	☐	☐	☐	☐	☐
Descuentos	☐	☐	☐	☐	☐
Proceso de pago	☐	☐	☐	☐	☐
Consulta del saldo	☐	☐	☐	☐	☐
Aplicación móvil	☐	☐	☐	☐	☐
Atención telefónica al usuario	☐	☐	☐	☐	☐

USTED Y BICIMAD

B52. ¿Cuál es su nivel de **SATISFACCIÓN** (cómo lo valora) con cada una de las siguientes características de BiciMAD?

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

	1 - Totalmente insatisfecho	2	3	4	5 - Totalmente satisfecho
Diseño de la bicicleta	☐	☐	☐	☐	☐
Facilidad de uso	☐	☐	☐	☐	☐
Comodidad	☐	☐	☐	☐	☐
Asistencia al pedaleo	☐	☐	☐	☐	☐
Mantenimiento de las bicicletas	☐	☐	☐	☐	☐
Extensión de la red actual de estaciones	☐	☐	☐	☐	☐
Distancia entre estaciones	☐	☐	☐	☐	☐
Funcionamiento del tótem	☐	☐	☐	☐	☐
Funcionamiento de los anclajes	☐	☐	☐	☐	☐
Disponibilidad para aparcar la bicicleta	☐	☐	☐	☐	☐
Disponibilidad de bicicletas	☐	☐	☐	☐	☐
Cuota anual (25€ para residentes, 15€ para titulares del Abono Transportes)	☐	☐	☐	☐	☐
Tarifa para inscritos (0,5€ la primera media hora, 0,6€ las siguientes fracciones de 30 min.)	☐	☐	☐	☐	☐
Tarifa para usuarios ocasionales (2€ la primera hora, 4€ las siguientes fracciones de 60 min.)	☐	☐	☐	☐	☐
Descuentos (0,1€ por coger la bicicleta de una estación saturada y 0,1€ por reserva de anclaje o dejar la bicicleta en una estación con baja ocupación)	☐	☐	☐	☐	☐
Proceso de pago	☐	☐	☐	☐	☐
Consulta del saldo	☐	☐	☐	☐	☐
Aplicación móvil	☐	☐	☐	☐	☐
Atención telefónica al usuario	☐	☐	☐	☐	☐

B53. ¿Cuál es su nivel de **SATISFACCIÓN GENERAL** (cómo lo valora) con el servicio de bicicleta pública que presta BiciMAD?

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

	1 - Totalmente insatisfecho	2	3	4	5 - Totalmente satisfecho
Satisfacción general con BiciMAD	☐	☐	☐	☐	☐

USTED Y BICIMAD

B6. La siguiente sección contiene algunas afirmaciones acerca de BiciMAD. Por favor, indique su opinión.

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente en desacuerdo con la afirmación y 5 que está totalmente de acuerdo.

	1 - Totalmente en desacuerdo	2	3	4	5 - Totalmente de acuerdo
Probar una bicicleta de BiciMAD me ayudó a tomar la decisión de usar (o no usar) el servicio	☐	☐	☐	☐	☐
Tengo experiencia en ir en bicicleta (por ej. mi propia bici) por el centro de Madrid	☐	☐	☐	☐	☐
Antes de usar BiciMAD ya había ido alguna vez al centro de Madrid en mi propia bicicleta	☐	☐	☐	☐	☐
Usando la bici pública me siento más responsable en lo medioambiental y social	☐	☐	☐	☐	☐
BiciMAD es más ecológico que otros modos de transporte	☐	☐	☐	☐	☐
BiciMAD es más económico que otros modos de transporte	☐	☐	☐	☐	☐
Con BiciMAD llego a mi destino más rápido que antes	☐	☐	☐	☐	☐
BiciMAD, para mí, es una forma de moverme y practicar deporte a la vez	☐	☐	☐	☐	☐
La red de BiciMAD corresponde a mis trayectos habituales y/u ocasionales	☐	☐	☐	☐	☐
Usar BiciMAD va con mi estilo de vida	☐	☐	☐	☐	☐
La bicicleta pública es una de las soluciones para calmar el tráfico en el centro de Madrid	☐	☐	☐	☐	☐
Los descuentos aplicados (reservar anclaje, retirar una bicicleta de una estación saturada, etc.) racionalizan el uso del sistema BiciMAD	☐	☐	☐	☐	☐
Encuentro fácilmente una bicicleta disponible o un anclaje para aparcarla	☐	☐	☐	☐	☐
Retirar y aparcar la bici en el anclaje de BiciMAD es sencillo para mí	☐	☐	☐	☐	☐
Las bicicletas de BiciMAD son cómodas para mí (ajustar altura del sillín, peso de la bici, etc.)	☐	☐	☐	☐	☐
En una bicicleta de BiciMAD puedo subir las cuestas de Madrid tranquilamente	☐	☐	☐	☐	☐
Las bicicletas de BiciMAD son fáciles de manejar	☐	☐	☐	☐	☐
Operar en la pantalla del tótem de las estaciones de BiciMAD es sencillo	☐	☐	☐	☐	☐

	1 - Totalmente en desacuerdo	2	3	4	5 - Totalmente de acuerdo
Me resulta fácil llevar el control de mi saldo disponible en BiciMAD	☐	☐	☐	☐	☐
La gente se interesa al verme usar BiciMAD	☐	☐	☐	☐	☐
Otros usuarios parecen estar contentos al usar BiciMAD	☐	☐	☐	☐	☐
BiciMAD fomenta el uso de la bicicleta en el centro de Madrid	☐	☐	☐	☐	☐
Recomiendo BiciMAD a aquellos que quieran moverse por Madrid	☐	☐	☐	☐	☐

USTED Y BICIMAD

B133. ¿Hasta qué punto son IMPORTANTES para usted en el USO DE LA BICICLETA PÚBLICA EN GENERAL los siguientes atributos?

Emplee, por favor, una escala de 1 a 5, donde 1 significa nada importante y 5 muy importante.

	1 - Nada importante	2	3	4	5 - Muy importante
Diseño de la bicicleta	☐	☐	☐	☐	☐
Facilidad de uso	☐	☐	☐	☐	☐
Comodidad	☐	☐	☐	☐	☐
Asistencia al pedaleo	☐	☐	☐	☐	☐
Mantenimiento de las bicicletas	☐	☐	☐	☐	☐
Extensión de la red actual de estaciones	☐	☐	☐	☐	☐
Distancia entre estaciones	☐	☐	☐	☐	☐
Funcionamiento del tótem	☐	☐	☐	☐	☐
Funcionamiento de los anclajes	☐	☐	☐	☐	☐
Disponibilidad para aparcar la bicicleta	☐	☐	☐	☐	☐
Disponibilidad para coger una bicicleta	☐	☐	☐	☐	☐
Cuota anual	☐	☐	☐	☐	☐
Tarifa para inscritos	☐	☐	☐	☐	☐
Tarifa para usuarios ocasionales	☐	☐	☐	☐	☐
Descuentos	☐	☐	☐	☐	☐
Proceso de pago	☐	☐	☐	☐	☐
Consulta del saldo	☐	☐	☐	☐	☐
Aplicación móvil	☐	☐	☐	☐	☐
Atención telefónica al usuario	☐	☐	☐	☐	☐

USTED Y BICIMAD

B134. ¿Cuál es su nivel de **SATISFACCIÓN** (cómo lo valora) con cada una de las siguientes características de BiciMAD?

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

	1 - Totalmente insatisfecho	2	3	4	5 - Totalmente satisfecho
Extensión de la red actual de estaciones	☐	☐	☐	☐	☐
Distancia entre estaciones	☐	☐	☐	☐	☐
Cuota anual (25€ para residentes, 15€ para titulares del Abono Transportes)	☐	☐	☐	☐	☐
Tarifa para inscritos (0,5€ la primera media hora, 0,6€ las siguientes fracciones de 30 min.)	☐	☐	☐	☐	☐
Tarifa para usuarios ocasionales (2€ la primera hora, 4€ las siguientes fracciones de 60 min.)	☐	☐	☐	☐	☐
Descuentos (0,1€ por coger la bicicleta de una estación saturada y 0,1€ por reserva de anclaje o dejar la bicicleta en una estación con baja ocupación)	☐	☐	☐	☐	☐

B135. ¿Cuál es su nivel de **SATISFACCIÓN GENERAL** (cómo lo valora) con el servicio de bicicleta pública que presta BiciMAD?

Por favor, emplee una escala de 1 a 5, donde 1 significa que está totalmente insatisfecho con la característica y 5 que está muy satisfecho.

	1 - Totalmente insatisfecho	2	3	4	5 - Totalmente satisfecho
Satisfacción general con BiciMAD	☐	☐	☐	☐	☐

DETALLES PERSONALES

A continuación encontrará algunas preguntas personales. Le recordamos que los datos se emplearán exclusivamente para un estudio científico de forma anónima, respetando las leyes en materia de protección de datos.

C1. Género:

- ☐ Hombre
- ☐ Mujer

C2. Edad:

Año

Año de nacimiento

C3. Nivel de estudios alcanzado:

- ☐ Sin estudios
- ☐ Enseñanza primaria
- ☐ Enseñanza secundaria
- ☐ Bachillerato
- ☐ Formación profesional
- ☐ Grado/Licenciatura/Diplomatura
- ☐ Máster
- ☐ Doctorado
- ☐ Otro (especifique)

DETALLES PERSONALES

C4. ¿Cuál es su situación laboral?

- ☐ Empleado
- ☐ Autónomo
- ☐ Desempleado
- ☐ Jubilado
- ☐ Estudiante
- ☐ Ama/o de casa
- ☐ Otro (especifique)

C5. ¿Usted tiene...?

- ☐ Carnet de conducir
- ☐ Acceso a coche
- ☐ Acceso a motocicleta o ciclomotor
- ☐ Abono de Transportes
- ☐ Ninguna de las anteriores

DETALLES PERSONALES

C6. Código postal de su domicilio o de su residencia habitual en Madrid:
(si no aplica: "00000")

C7. El número de personas que conviven en su hogar (incl. usted):

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Más

C8. Nivel de ingresos neto en su hogar al mes:

- ☐ Menos o igual de 1.300 €
- ☐ 1.300 – 2.500 €
- ☐ Más de 2.500 €

COMENTARIOS

Aquí puede dejar sus comentarios sobre la movilidad ciclista y el servicio público de bicicleta de Madrid.

(Campo opcional. Si no tiene comentarios, pulse el botón *Siguiente.*)

FIN DEL CUESTIONARIO

¡Muchas gracias por su colaboración!

Si desea participar en el sorteo y/o recibir información sobre los resultados de la encuesta directamente, por favor, escriba aquí su dirección de correo electrónico:

Confirmación del correo electrónico:

Número de teléfono (opcional, si quiere que se utilice este medio para avisarle del premio):

En la página web www.bicimad.transyt-projects.com la semana del 4 de julio de 2016 se indicará si su número de encuesta es el **GANADOR**. Si nos da alguna de las informaciones anteriores se lo comunicaremos personalmente.

Si tiene alguna duda, póngase en contacto con nosotros en la siguiente dirección de correo: bicimad@caminos.upm.es

Para finalizar el cuestionario, pulse el botón "Listo".

MUCHAS GRACIAS POR SU TIEMPO.