CONDITIONING FACTORS FOR BIKE SHARING SUCCESSFUL EVOLUTION. THE CASE OF BICIMAD

Raky Julio
TRANSyT – Centro de Investigación del Transporte, Universidad Politécnica de Madrid
Andrés Monzon
Catedrático Departamento de Ingeniería Civil - Transportes, Universidad Politécnica de Madrid

ABSTRACT

Bike sharing systems (BSS) have gained great acceptance in many cities arround the world. Since the deployment of the first system, many cities promote the public bike not only as a sustainable mode of transportation, but also as a way to make visible the use of bicycles in urban environments. Four generations of BSS with great advances in between are recognized. BiciMAD in Madrid is one example of the last generation. A system deployed in mid-2014 with 1,560 bicycles and 123 stations.

During the early stage, TRANSyT-UPM conducted a series of studies to identify the intention of use, before the system deployment, and the user satisfaction and the relation between the use intention and real adoption, after the deployment. Since the last study in 2016, the system experienced some substantial changes and improvements in order to subsist.

Now that the system has reached its maturity, we conducted a survey in May of 2019, to study the evolution in the user satisfaction with the main factors that conditioned the success of BiciMAD. We asked subscribers, occasional users and non-users about their satisfaction with the elements of the system obtaining over 6,500 valid responses.

First, we compare the results obtained in previous surveys (2015 and 2016) with the latest, in order to identify changes in user profile and the conditioning factors for bike-sharing use.

Our results suggest that there are external and internal characteristics of the system that made it successful. For instance, the electric pedaling assistance is an attribute positively valuated that make user consider the streets slope unimportant. Also, the system had achieved some important goals, such as reduce the total trips in private car of the subscribers and not deterring users from walking.

1. INTRODUCTION

The phenomenon of urbanization, driven by the continuous rise in the population moving to cities, is prompting public authorities to pay more attention to the design, operation and management of urban transportation systems (Banister, 2005; Goldman & Gorham, 2006).

Therefore, transportation professionals and researchers are devoting efforts to promote sustainable travel alternatives, such as foster the use of public transport, and active modes such as walking and cycling, both affordable options to counter the negative effects of private car usage.

In this line, one popular strategy implemented among many cities since the early years of the 21st century is the installation of public bike-sharing systems (PBSS) (Fishman et al., 2013). Bike-sharing systems have enjoyed a widespread acceptance around the world. Since the deployment of the first system, many cities have promoted public bikes not only as a sustainable mode of transportation, but also as a way to give bicycles visibility as a practical mode of transport in urban environments. This popularization phenomenon is so called the "*renaissance of bike-sharing systems"* (Pucher et al., 2011 ;Shaheen et al., 2010), especially in Europe, East Asia and North America.
PBSS have gained popularity in cities at the time they did in scientific literature. The research on PBSS could be divided in three research lines: the history and evolution of bike-sharing systems and the suitability of their implementation, functioning and governance; PBSS integration in the transport network; and user satisfaction.

With this work, we aim to combine the study of the evolution of a bike sharing system, at the time we intend to identify the key elements that made BiciMAD a successful system and would enhance the user satisfaction. This is done by comparing the results of a series of surveys (2015, 2016 and 2019) on some special attributes of the user profile and the factors that influence the use of bicycles, as well as performing an Importance Performance Analysis (IPA) and applying the Three-Factor theory (3FT) to identify the key elements of the system.

2. LITERATURE REVIEW

Bike-sharing is a relatively new concept, since the implementation of the first system in the Netherlands in 1965. Since, the systems evolution could be divided in four generations. The first generation, "white bikes" consisted of unlocked bicycles randomly located throughout the city. The bicycles were painted in one bright color. They could be picked up and left anywhere in the city, and their use was free of charge. In most of the cases where this scheme was implemented, bikes were vandalized and the attempts were not successful. The second generation of BSS, the coin-deposit system, was introduced in the 1990s. In this generation, the system was properly organized by a transportation authority and some features were introduced in order to avoid the first generation problems.

These systems were characterized by the particular, strong construction and bright color of the bicycles. The designated docking stations where bicycles were borrowed and returned were also a special characteristic, and the fact that a payment was required for using the bikes (DeMaio, 2009).

These systems were mainly introduced in north European countries such as Denmark and the Netherlands (Bachand-Marleau et al., 2012). In addition to the second generation, the third incorporated transaction kiosks that allowed for identification of users that deter the misuse the bicycles. These introductions succeeded in reducing theft rates as users were subject to penalties if they failed to return the bicycles to the stations. The latest generation of BSS is the demand responsive (Shaheen et al., 2010). The main innovations include the solar powered stations, the use of mobile apps and smart carts, and the incentives for automatic redistribution of bicycles.

User satisfaction is one success determinant of a provided service. The greater the increase in satisfaction, the more likely it is that the user will continue to be a client of the service (Anderson & Sullivan, 1993; Boulding et al., 1993; Yi, 1991). With this consideration, there has been an increase in the analysis of the perceived quality of BSS and the keys to its success. Manzi & Saibene, (2017) investigate the reliability of PBSS customer satisfaction surveys and the potential of emerging technology to improve transportation systems.. Kim et al., (2017) evaluate policy strategies for optimal PBS implementation. Alvarez-Valdes et al., (2016) investigate the impact of bicycle distribution imbalances across stations on user perceptions of service quality, which is one of the attributes considered in this study as station occupancy/bicycle availability. According to Albiński et al., (2018), several factors affect the performance of a bike-sharing scheme, but the two that have the biggest impact on customer satisfaction are bike accessibility and pricing.. (Médard de Chardon et al., 2017) conduct a comprehensive analysis of 75 PBSS to identify the determinants of success in terms of number of uses per day, while (Eren & Uz, 2020) analyse external factors such as weather, land use, PT connection and the influence of safety on bike-sharing demand.

Finally, Morton's (2018) assessment identifies how the PBSS in London will maintain or attract new customers by improving service quality.

3. DATA AND METHODOLOGY

3.1 Case study

Madrid is the capital city of Spain. It has 3.27 million inhabitants (2019) and traditionally was not considered a “cycling city” (Muñoz et al., 2013). Some special characteristics, such as the lack of extensive cycling infrastructure, their inhabitants’ mobility behavior and the hilly topography (differences in elevation of up to 200 m) make it less attractive for cyclists than other European “cycling capitals”. However, there is a positive movement by cycling collectives and public authorities to foster cycling. The implementation of BiciMAD.

Madrid was the first to introduce a city-center-wide large bike-sharing fleet of pedal-assisted bicycles in Western countries (Munkácsy & Monzón, 2018). As well as the development of segregated cycling infrastructure – 282 km in 2018 (MITECO, 2020) –, the prioritization of roads in the city center for cyclists and pedestrians and active campaign strategies for raising awareness of the benefits of cycling are encouraging people to cycle.

BiciMAD, Madrid's public bike-sharing system, was implemented in 2014. BiciMAD was originally deployed in the inner and denser districts of Madrid with approximately 15,000 to 30,000 inhabitants per km2. At that time the system had 123 stations and 1,560 bicycles; the system has now grown to 258 stations, 2,964 bicycles and over 60,000 subscribers.

BiciMAD was a pioneer of demand-responsive systems (Munkácsy & Monzón, 2017). Its general configuration is:

- The first city-wide bike-sharing system with electric pedal-assisted bicycles only (pedelecs)
- The whole fleet is GPS tracked
- Minimum fee per use of €0.50, including the 30 first minutes
- User-based redistribution, rewarding users by applying a discount of €0.10 for taking a bike from a full station and €0.10 for returning it at an empty station.
- User interface fully supported by online mobile applications and solar-powered totems at the stations.
- Occasional user scheme, with a €4 per hour pay-by-use fee structure.

The general characteristics of BiciMAD subscribers (Ayuntamiento de Madrid, 2017) are:

- 35% woman, 65% men
- 40% between 30 and 40 years old, 25% between 20 and 30 years old
- 85% have a university degree, 13% general certificate of education or vocational studies, and 2% primary or secondary studies

3.2 Data collection

This research is based on data collected in a series of surveys. The first conducted in 2014, with 1859 responses, the second in 2015 with 430 responses, the third in 2016 with 336 and the fourth and last in 2019 with 5540 valid responses. The first one at an early stage, before the system deployment to evaluate the intention of use, the second, on year after, as part of a before-and-after panel survey and the third to explore the effects of pedelec-sharing on travel patterns, and the fourth to evaluate the system maturity and evolution.

The latest survey was specially tailored to evaluate the influence of specific service attributes performance and influence over overall satisfaction. The attributes were selected ad-hoc, considering the system particularities as recommended in the literature (De Oña & De Oña, 2015).

A hybrid methodology was applied to achieve a representative sample to the four surveys. The method combines the advantages of personal intercept interviews and online questionnaires to fulfil the basic requirements of a survey, namely good data quality, representativeness and minimal costs (Monzon et al., 2020).

3.3 Methodology

The first part of this study, is a comparative analysis of the results obtained with three of the four surveys. The results of the 2014 *ex-ante* survey are dismissed, as the questions posed were exclusive for this stage and do not allow further comparison. Therefore, we use only the results of the 2015, 2016 and 2019 surveys.

For the comparative analysis, we will address only the responses given by the subscribers, as they are more frequent users and compose the BiciMAD system orientation, rather than occasional leisure usage.

To study the relationship between the cycling experience of the respondents and the assessment of the factors that influence the use of bicycles the different aspects of use were distinguished.

- Frequency of use. We have distinguished 6 discrete scales of frequency of use of the bike. Respondents had to choose between whether they used the bike to commute daily, sometimes a week, once a week, sometimes a month, sometimes or never. These categories have been summarized for ease of interpretation in the results section.
- Reasons for use. The reasons for use have been analyzed from two close perspectives but not matching:
- By forced mobility or not: we understand by forced mobility that whose motive is a permanent and systematic daily activity such as work or study. The rest of reasons (leisure, sports, personal affairs, shopping, others) are not required mobility.

The subjective factors that influence the use of the bicycle have been selected after a extensive review of the literature (Fernández-Heredia and Monzón, 2010). The factors have been valued by respondents on a semantic Likert scale graduated in 6 levels to judge the degree of importance between nothing, very little, little, something, very important or fundamental.

4. RESULTS

4.1 Sociodemographic evolution

Regarding the socio-demographic characteristics of the users, it is possible to observe that the gender distribution remains equal since the system deployment, with men slightly overrepresented with an average of 64% versus 36% of woman.

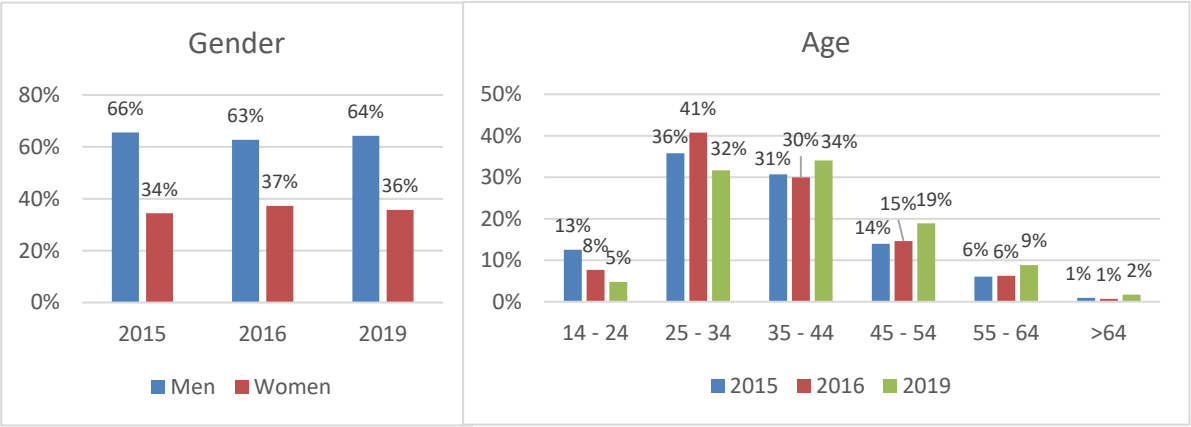

Figure 1. Gender and age evolution of BiciMAD subscribers

It is also possible to observe in figure 1, the aging of BiciMAD users, as all the intervals have increased in percentage on intervals over the 35 years and reduced on the lower intervals, from 14 to 34 years old.

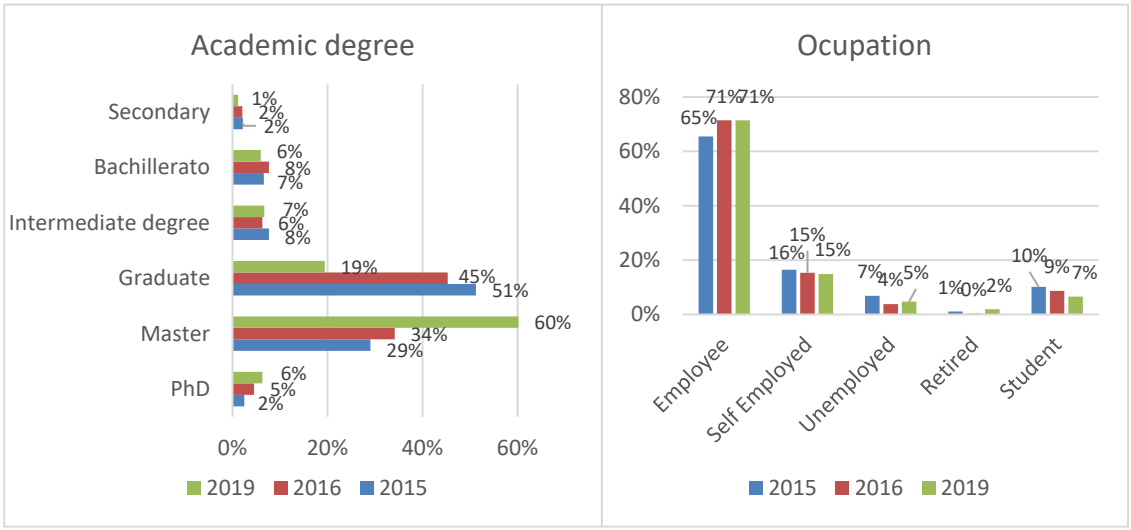

Figure 2. Academic degree and occupation evolution of BiciMAD subscribers

Regarding the academic degree, it is possible to observe that the average user of BiciMAD is becoming more educated. Especially if we concentrate in the difference between graduate, master and PhD. In 2015 and 2016 the majority of the sample was graduate, while in 2019 60% has a Master. This change could be explained with the introduction of the Bologna

Process, in which many careers demanded professionals to have a Master degree. The proportions of occupations remain steady. 85% of BiciMAD users have an income, either as employees or self-employed. It is noticeable that the percentage of students slightly decreased, while the retired slightly increased. Coherent with the aging of the user profile.

4.2 External factors evolution

We evaluate some external factors, general in the bicycle usage. This attributes are considered as a the more influential for the general cyclist.

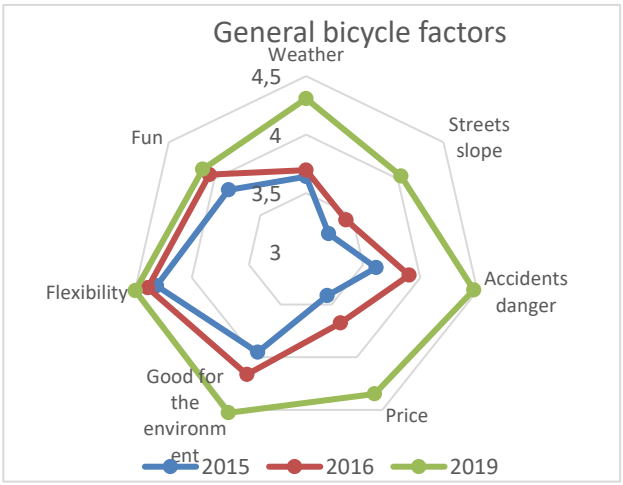

Figure 3. Evolution of factor importance

In general, subscribers of BiciMAD pose higher importance to all the attributes in 2019, compared with the results of previous years. Moreover, most of the factors have proportional increase along the years. That is to say, that factors such as the street slope remain as the less important. This might be conditioned due that BiciMAD is a fully electric BSS, then the effort needed for cycling using the service is less than a normal bicycle, therefore in Madrid, street slopes are not important.

The most important factors reported in the three surveys are “flexibility”, “good for the environment” and the “accident danger”. The first received the highest score for importance.

The absence of attachments for the use of BiciMAD, such as the storage, helmet and parking space make one of the most flexible modes for transportation in the city center of Madrid.

The good environmental perception of cycling is an important factor for subscribers, this factor could foster the use of bicycle and the promotion of the service in this sense could increase the use frequency.

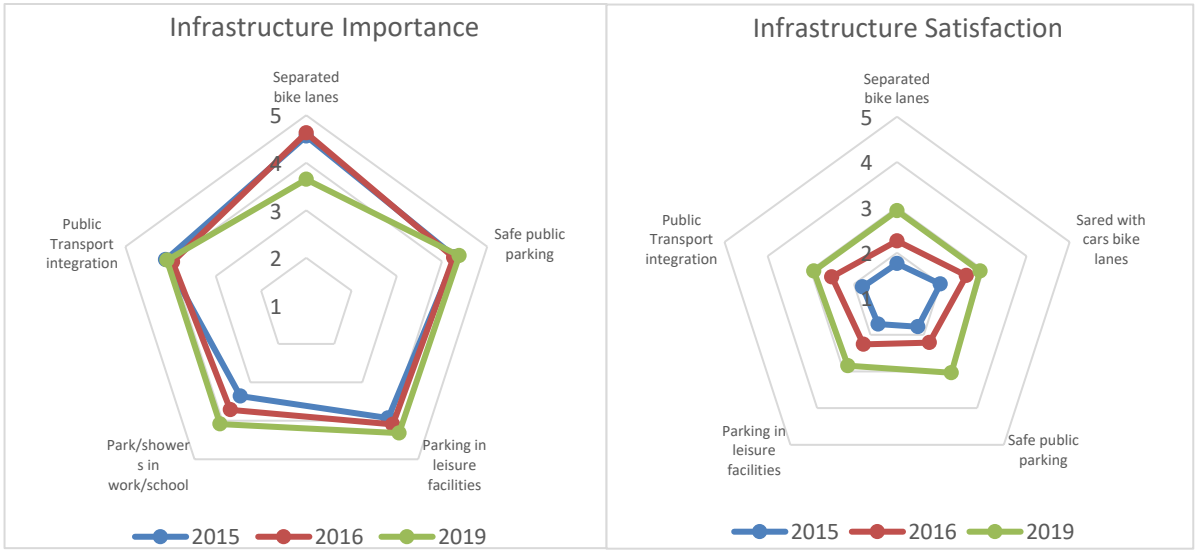

Figure 4. Evolution of infrastructure importance and satisfaction

In general, subscribers assign higher importance than satisfaction to Madrid cycling infrastructures. Regarding the importance, the "separated bike lanes" and the "safe public parking" are the infrastructures that receive more importance from subscribers. Moreover, BiciMAD do not require private parking places, users recognize that it is important for the general use of bicycle among all the years when surveys were conducted. Regarding the separated bike lanes, there is a clear change in the importance assigned to this infrastructure.

We consider that as cyclist are more familiar with sharing space with motorized vehicles, at the time there are more separated bike lanes than when the two first surveys were conducted. Therefore, this attribute is less important that at the beginning of the service introduction. It is possible to observe that the parking and showers at work and study places are gaining in importance, this is probably due to the popularization of cycling, then users demand better conditions on the facilities they regularly use.

There is a steady increase in satisfaction with all the infrastructures along the years. This might be due to a combination of familiarity with the bicycle usage, and the improvements in this regard.

4.2 Changes in use frequency and travel patterns

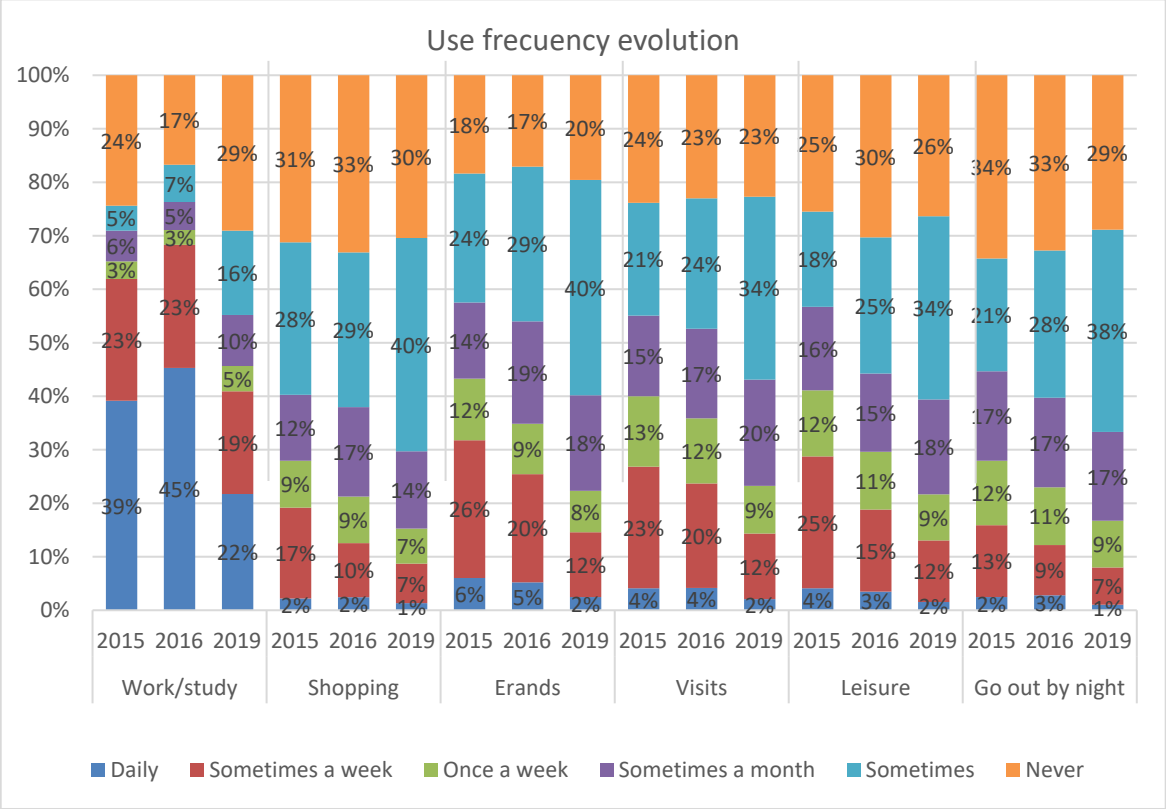

Figure 5. Evolution of use frequency

The frequency of use has reduced in general for all the purposes. It is notorious that the most intensive use categories have reduced significantly when, especially when it comes to the *daily* and *sometimes a week* frequency. If we focus on the work/study purposes, the percentage of daily use drops from 45% to 22%. The *sometimes a week* use for shopping reduces constantly all the years, from 17% in 2015 to 7% in 2019. Similar drops in use frequency could be observed for errands (26% in 2015 to 12% 2019), for visits (23% in 2015 to 12% in 2019), leisure (25% in 2015 to 12% in 2019) and go out by night (13% in 2015 to 7% in 2019).

The category that increases the most among the trip purposes is *sometimes*. It is worth of further studies to investigate the possible reasons for the drop in frequency of use, as well as to analyze the evolution of the number of subscribers

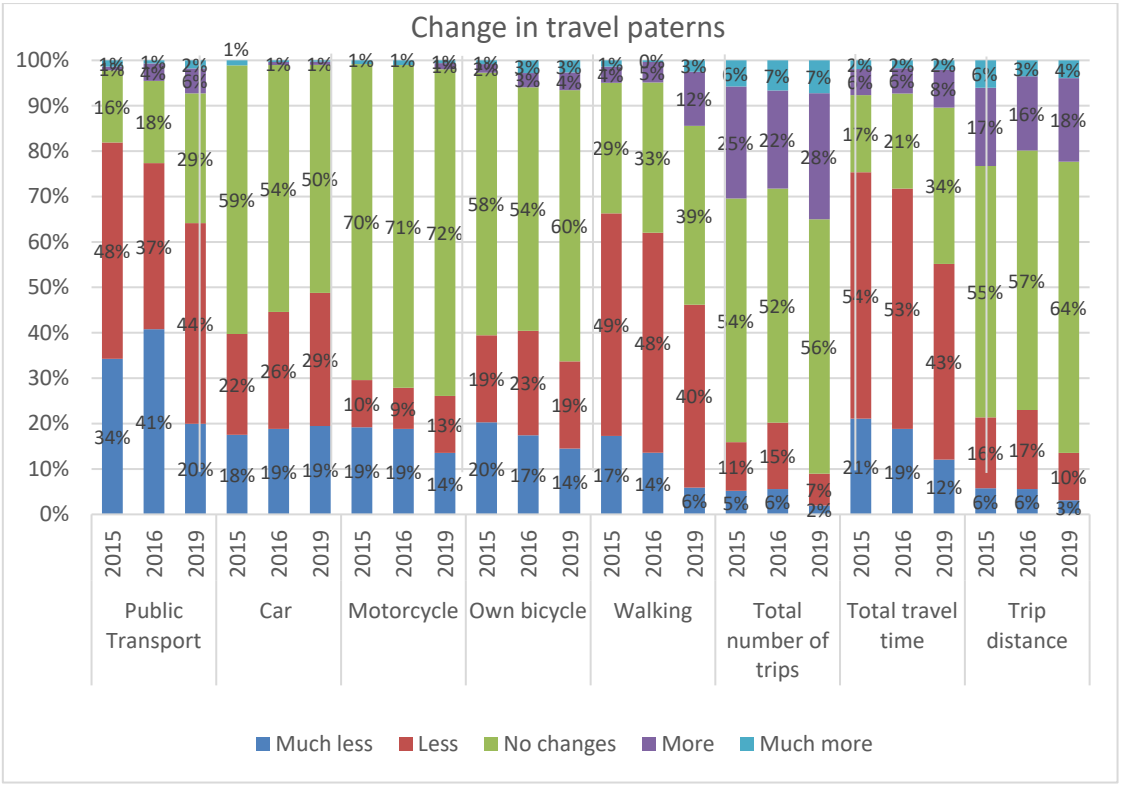

Figure 9. Evolution in travel patterns since the BiciMAD deployment

The respondents claim that they reduced their usage of public transport, this is possible to observe on a steady tendency since 2015 to 2019, if we focus on the values of much less and less putted together. This could be considered as a drawback of the BSS, as the purpose is not to take users out of the public transport, but from private vehicles, especially from the car.

In this regard, it is possible to observe that car usage also decreased from a 40% in 2015, up to a 48% in 2019, if we put together the values of *less* and *much less* together. A positive outcome of the implementation of the BSS.

There is a slightly increase in the use of the private bicycle, from around the 3% in 2015 to 7% in 2019. This positive effect is also compensated with the drop from 39% in 2015 to the 33% in 2019.

It is also positive that the walking passed from a 66% of reduction in 2015 to 46% in 2019. This is an indicator that the fee per use is effective when deterring the subscribers to take a bicycle that they could do walking. Indeed, it is possible to observe that from 2014 and 2015, the percentage of users that walk more since they subscribed to BiciMAD passed form around 5% to 15%.

Since 2015, less subscribers declare that the total travel time have reduced. A similar result with the trip distance, that almost remain steady since 2015.

4. CONCLUSIONS

As a result of the comparative analysis, it is possible to observe that there is significate change in some attributes and related with the user profile, perception of cycling factors and service use behavior and mobility patterns. This could be considered as conditioning factors for the evolution of BiciMAD system.

The profile of the user remains steady in most of the attributes, except the age and the academic degree, where is possible to observe the ageing of the subscribers, as well as possible effects of the Bologna Program, as there is a higher percentage of users with a master degree.

Pedelec bicycles are an influential factor of success. Due to this feature, the users assign little importance to the slopes of the streets in Madrid.
It is worthy to study the possible reasons for drop in use frequency, and if this is related with the number of daily use, and overall system performance in terms of Trips per Day per Bike (TDB) (Médard de Chardon et al., 2017). It is possible as well that user's perception of the use intensity would be due to the familiarity with the system, then their perception of use intensity is less than the reality. To conduct this verifications, it would be worthy to analyze the data of use intensity and number of subscribers in the system, as the administration claim that this values have stabilized in nearly 8 TDB and the number of subscribers is nearly 63,000.

The system has double effect over cycling, as it is possible to observe an increase in use of private bicycles, maybe because more users realize that it is possible to move by bicycle in Madrid, then are encouraged to start using it. At the same time, it reduces the usage on others, possibly because the convenience of BiciMAD, as there is no need of storage, maintenance, and other issues related to a bicycle ownership.
BiciMAD achieved the goal of not deter subscribers from walking, or at least reduce the number of users that stopped in 2015, that was much higher than in 2019.

Based on the results of this study, we identify a research gap, on the reasons conditioning the decrease in use frequency and its relationship with the above mentioned factors and the data from the service administration. This future research line could be conducted by performing and ordered logistic regression to understand the influence of each common variable among the three waves of surveys with the use frequency.

ACKNOWLEDGMENT

The authors thank the Ministry of Transport, Mobility and Urban Agenda (MITMA) for the agreement signed with the Universidad Politécnica de Madrid (UPM), in favor to support the Observatory of Metropolitan Mobility (OMM)

REFERENCES

ALBIŃSKI, S., FONTAINE, P., & MINNER, S. (2018). Performance analysis of a hybrid bike sharing system: A service-level-based approach under censored demand observations. Transportation Research Part E: Logistics and Transportation Review, 116, 59–69.

ANDERSON, E. W., & SULLIVAN, M. W. (1993). The Antecedents and Consequences of Customer Satisfaction for Firms. Marketing Science, 12(2), 125–143.

ALVAREZ-VALDES, R., BELENGUER, J. M., BENAVENT, E., BERMUDEZ, J. D., MUÑOZ, F., VERCHER, E., & VERDEJO, F. (2016). Optimizing the level of service quality of a bike-sharing system. Omega 62, 163–175.

BANISTER, D. (2005). Unsustainable transport: city transport in the new century. Routledge.

BOULDING, W., KALRA, A., STAELIN, R., & ZEITHAML, V. A. (1993). A Dynamic Process Model of Service Quality: From Expectations to Behavioral Intentions. Journal of Marketing Research, 30 (1), 7–27.

DEMAIO, P. (2009). Bike-sharing: History, Impacts, Models of Provision, and Future. Journal of Public Transportation, 12(4), 41–56.

DE OÑA, J., & DE OÑA, R. (2015). Quality of service in public transport based on customer satisfaction surveys: A review and assessment of methodological approaches. Transportation Science, 49(3), 605–622

EREN, E., & UZ, V. E. (2020). A review on bike-sharing: The factors affecting bike-sharing demand. Sustainable Cities and Society, 54.

FERNÁNDEZ-HEREDIA, A Y MONZÓN, A (2010). Cyclists' travel behavior, from theory

to reality. Ponencia para el 12th WCTR. 11-15/7/2010, Lisboa, Portugál.

FISHMAN, E., WASHINGTON, S., & HAWORTH, N. (2013). Bike Share: A Synthesis of the Literature. Transport Reviews, 33(2), 148–165.

GOLDMAN, T., & GORHAM, R. (2006). Sustainable urban transport: Four innovative directions. Technology in Society, 28(1–2), 261–273.

KIM, J., CHOI, K., KIM, S., & FUJII, S. (2017). How to promote sustainable public bike system from a psychological perspective? International Journal of Sustainable Transportation, 11(4), 272–281.

MANZI, G., & SAIBENE, G. (2017). Are they telling the truth? Revealing hidden traits of satisfaction with a public bike-sharing service. International Journal of Sustainable Transportation, 12(4), 253–270.

MÉDARD DE CHARDON, C., CARUSO, G., & THOMAS, I. (2017). Bicycle sharing system 'success' determinants. Transportation Research Part A: Policy and Practice, 100, 202–214.

MITECO. (2020). Informe OMM-2018 (Ministerio). http://www.observatoriomovilidad.es/es.html

MONZON, A., JULIO, R., & GARCIA-MARTINEZ, A. (2020). Hybrid methodology for improving response rates and data quality in mobility surveys. Travel Behaviour and Society, 20, 155–164.

MORTON, C. (2018). Appraising the market for bicycle sharing schemes: Perceived service quality, satisfaction, and behavioural intention in London. Case Studies on Transport Policy, 6(1), 102–111.

MUNKÁCSY, A., & MONZÓN, A. (2017A). Impacts of smart configuration in pedelec-sharing: Evidence from a panel survey in Madrid. Journal of Advanced Transportation, 2017

MUÑOZ, B., MONZON, A., & LOIS, D. (2013). Cycling Habits and Other Psychological Variables Affecting Commuting by Bicycle in Madrid, Spain. Transportation Research Record: Journal of the Transportation Research Board, 2382(1), 1–9.

PUCHER, J., BUEHLER, R., & SEINEN, M. (2011). Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. Transportation Research Part A: Policy and Practice, 45(6), 451–475.

SHAHEEN, S. A., GUZMAN, S., & ZHANG, H. (2010). Bikesharing in Europe, the Americas, and Asia. Transportation Research Record: Journal of the Transportation Research Board, 2143(1), 159–167

YI, Y. (1991). A critical review of consumer satisfaction. In V. A. Zeithaml (Ed.), Review of Marketing 1990 (pp. 68–123). Marketing Classics Press. https://books.google.es/books?hl=es&lr=&id=4TUXGG0Cf5cC&oi=fnd&pg=PA68&dq=A+critical+review+of+customer+satisfaction&ots=Vosq9OWKIt&sig=IqdLURTDmuyI0BHsoQLX4LEVcD0#v=onepage&q&f=false