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ABSTRACT

Bike-Sharing: Network Efficiency and Demand Profiles*

This paper analyzes a bike-sharing service from both network efficiency and demand profiles perspectives. Specifically, it focuses on the BIZI service in the city of Zaragoza (Spain), which was launched in May 2008 with the aim of increasing the use of the bicycle in the city. Since then, the number of users has increased smoothly, and the service currently constitutes an integrated transport mode as an alternative to the use of cars and public transport in the city. The paper analyzes the evolution of the use of the BIZI service, using network analysis to show that efficiency increased rapidly over time until reaching an optimum value after two years. Furthermore, using regression models the paper characterizes the groups that most use this service, and relates service demand to factors such as weather conditions, number of bike lanes, and service extensions. This analysis will allow us to characterize the demand for this service, which can be of great importance when developing integrated transport payment systems.

JEL Classification: R40, C45

Keywords: BIZI service, efficiency, weather conditions, socio-demographic characteristics, bike lanes, bike stations

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1. Introduction

Millions of people travel every day in cities and regions around the world, from home to work, from home to school, or on other journeys. The Resolution of the European Parliament, of December 2, 2015, on Urban Mobility (2014/2242, INI) highlights that the mobility of the European population is mostly based on the use of private vehicles (50% use private vehicles daily, while only 16% use public transport and 12% use bicycles). The same Resolution also acknowledges that daily mobility generates around 25% of CO_2 emissions in Europe. Thus, local and national governments are asked to adopt the necessary measures to promote alternative and sustainable modes of mobility, where the use of public transport or physical modes of transport have been shown to be important in CO_2 and Greenhouse Gas (GHG) reduction (Chapman, 2007; Gossling and Choi, 2015; Holian and Kahn, 2015). In this context, the implementation of bike-sharing systems may represent a mobility alternative to cars that may help to reduce CO_2 and GHG emissions, and local government/city halls in many cities worldwide have implemented bike-sharing systems.

One of these cases is the bike-sharing service of the city of Zaragoza (Spain), called "BIZI". The BIZI service is a public bicycle rental service which the Zaragoza City Council makes available to users. It is an economical, comfortable, and sustainable means of transport, and was launched in May 2008 with the aim of increasing the use of the bicycle in the city. Since then, there have been significant changes in the city. Extensions have been made in the number of bicycle stations available, going from 30 stations in 2008 to 130 in May 2011. In addition, the Zaragoza city council has dedicated resources to the development of bike lanes throughout the city, with the aim of allowing safe circulation throughout the city. Additionally, all one-way streets have a maximum speed limit of 30 km/h, which facilitates coexistence between cyclists and motor vehicles. All these actions have been aimed at improving and increasing the use of bicycles in the city, and a greater and better use of the BIZI service.

Within this framework, we analyze daily data for the BIZI service from May 2008 to August 2019, which provides information on more than 24 million uses by citizens. Having data on the service over time allows us to characterize the system in terms of organization, using network analysis (Boccaletti, 2006). Furthermore, we analyze the efficiency of the system over time, considering the normalized difference between dockings and undockings (picking up and leaving the bicycles at the station), and we find that efficiency (adjustment between demand and supply of the service) increased rapidly over time until reaching an optimum value after two years. This two-year period may serve as a reference value for other cities trying to implement similar bike-sharing systems.

The level of detail of the data allows us to relate the day of use of the BIZI service to the number of stations and the distance (in kilometers) of bike lanes available in the city. Thus, we analyze whether the expansion of the number of BIZI stations, and the increase in kilometers of bike lanes, are related to a greater number of users of the service, and to a decrease in the time necessary to make the actual journeys. We find that the expansion of the system through new stations is related to an increase in the number of uses and users and a decrease in the average travel time of each use. Furthermore, the expansion of bike lanes is also related to a decrease in the duration of trips. This analysis may be of interest, as it shows that good planning and a greater availability of stations and bike lanes can boost the bicycle system in the city, to the detriment of other modes of transport, such as the car.

Finally, we link the day of use with the weather conditions on that day. Zaragoza has a semi-desert continental Mediterranean climate, typical of the Ebro depression area, which gives weather conditions in Zaragoza enough variation over the year to represent a natural experiment into how weather conditions affect the demand of the bike-sharing system.[1] We find that higher average temperature, volume of rain, average wind speed, the stronger gusts of wind, and the greater number of hours of sunshine are all negatively related to the number of uses of the service, while higher minimum and maximum temperatures during the day all related to greater use. Regarding the duration of trips, a lower average temperature and stronger gusts of wind are related to a shorter duration of trips, while higher minimum and maximum temperatures, volume of rain and average wind speed are all related to a greater duration of trips.

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[1] Zaragoza is characterized by great contrasts between the seasons, since in winter it is very cold with strong frosts, and in Summer it is quite hot, often exceeding 35 degrees, and sometimes as high as 40. Being a semi-desert climate, it does not receive the influence of the sea and rains are scarce throughout the year, concentrating especially during spring and autumn (May is usually the wettest month, statistically speaking). In addition, the presence of the “cierzo”, a northwesterly wind that blows with differing intensity, is characteristic of the city. In winter, ‘el cierzo’ provides a sensation of cold (the so-called ‘wind chill’) much greater than that indicated by a thermometer, while in summer it produces the opposite effect, cooling from the suffocating heat.

We contribute to the literature on the application of network analysis to transport systems (Luo et al., 2019; Falchetta, Noussan and Hammad, 2021; Liu et al., 2021). Our analysis allows us to characterize the network of the system, and analyze its efficiency, showing how much time the service needs to reach optimal efficiency. Second, we contribute to the literature on how planning and infrastructure is related to the use of bike-sharing systems. Prior research has analyzed strategic planning, and infrastructures are related to cycling in particular (Rietveld and Daniel, 2004; Doran, El-Geneidy and Manaugh, 2021), and to sustainable transport in general (Knowles, 2021). We acknowledge the importance of planning and availability of bike lanes and docking stations as a way to boost use. Third, we contribute to the literature on the relationship between weather conditions and the use of bicycles, with a focus on the use of bike-sharing services. Existing studies have shown that the climatic conditions of the area are related to the individual use of bicycles (Shannon et al., 2006; Guo, Wilson and Rahbee, 2007; Cools, Moons and Wets, 2010; Flynn et al. 2012; Böcker, Prillwitz and Dijst, 2013; Lee and Pojani, 2019) and factors such as rain, wind, and heat are related to less use of this medium (and other active means) of transport.

The rest of the document is organized as follows. In Section 2, we describe the data and present some analysis on the number of uses and the duration of the journeys. In Section 3, we present the network analysis to characterize the BIZI system, and the efficiency analysis. In Section 4, we show our analysis of the factors affecting the use and duration of bike trips, and Section 5 outlines our main conclusions.

2. Data and empirical evidence

The data for the BIZI service in the city of Zaragoza (Spain) were obtained through the #OpenUrbanLab, the Zaragoza Open Source R&D laboratory, which has been conceived as a physical and digital space for urban innovation and allows the downloading and use of a range of data (https://openurbanlab.com/). The Open Urban Laboratory is a workspace in the Etopia Art and Technology Center where innovative projects to improve the city are experienced, learned, facilitated, and prototyped. This Laboratory is concerned with adopting an agile and open source approach, with a very simple work methodology through 4 stages: 1) identification of problems to solve, and agents committed to doing so, 2) development of innovative ideas, 3) prototyping and financing solutions, and 4) scaling from prototypes to projects. Smart city projects are addressed, using innovation both at the level of processes and of technologies, in fields as diverse as mobility, public space, commerce, energy, education, citizen participation, culture, and the environment.

The BIZI Zaragoza data used here covers the period from the start-up in May 2008 to August 2019. The data have been used for different analyzes, including an analysis of travel origins and destinations, and examinations of routing proposals (https://openurbanlab.com/2020/07/14/visualizacion-zaragoza-bici/). We have analysed 24,346,082 observations, covering all the uses of the BIZI Zaragoza service for each day of the period considered. We have information about the day of use, the origin and destination stations, the duration of the journey, and the time of day. Additionally, information is available on the users' year of birth (grouped into 5-year cohorts) and gender.

Figure 1 presents the number of total uses of the service for each day of the period considered. We can observe the temporal evolution of the number of daily uses of the BIZI Zaragoza service. We include an adjustment function of a locally adjusted regression, to reduce the variability of the number of uses (Cleveland, 1979). At the beginning of the period there was a large increase in the daily use of the service, going from around 1,300-1,500 uses per day in 2008 and early 2009 to around 15,000 daily uses by late 2011 and early 2012. A significant surge in the number of daily uses in the middle of 2009 probably corresponds to the expansion of the number of stations, from 30 to 70 stations.[2] The number was expanded again in October 2009 and May 2011, which could explain the accumulated increase in the number of uses in that period.

However, since the peak years of 2011 and 2012, the number of daily uses has been falling gradually, to the point that, at the end of the period (2019), daily uses fell to around 6,000-6,500. This decline could reflect a change in the city in terms of mobility, representing an advance in terms of sustainable mobility - the inauguration of the tram on April 19, 2011, and its second phase in March 2013. In fact, the adjustment function shows that the maximum number of daily uses of the tram was reached in 2013 and the daily uses of the BIZI service have followed a decreasing trend since then.

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[2] Table A1 in the Appendix presents the dates of the extensions, as well as the number of stations available in each phase. There are three distinct phases: implementation, in which the first 30 stations were established; expansion, which ended in April 2009 with the commissioning of 40 more stations; – and extension, in May of 2011, which added 60 more stations.

Figure 2 shows the evolution of the average time of journeys of the BIZI Zaragoza service.[3] We include in the figure a locally fitted regression to reduce the variability of the duration variable. Here we observe a decreasing trend in the duration of the journeys. Thus, while in 2009 the average duration was around 12 minutes, at the end of the period, the average duration of the journey was around 10 minutes. The adjustment function clearly reflects this decreasing trend in journey times. The expansion in the number of BIZI Zaragoza stations is obviously a factor, since the distance between available stations - and therefore the time needed to go from point A to point B is reduced. The development of bike lanes in the city (see Figure 3 for a description of the Km of bike lanes available in the city) can also be a key factor, since these lanes prioritize cyclists and improve efficiency in terms of bicycle traffic, reducing travel times.[4]

We next analyze the personal characteristics of the users of the BIZI Zaragoza service. Here, we recognize that the information available is scant, since data is only available on gender (male or female) and age (measured in cohorts of 5 years). Table 1 presents the distribution of gender and age, on average, over the years and for each year. The birth cohorts have been pooled for those born between 1900 and 1950, between 1950 and 1990, and 1990 onward. We observe that the users of the service are mostly (62.25%) men. There is no clear trend in terms of the use by men or women, so we cannot say that use of the service has increased among either gender during this period. Regarding the age of users, they mostly belong to the group born between 1950 and 1990. However, here a trend is observed in which the use of this service has decreased among users born before 1990, and has increased among those born after 1990, indicating that younger individuals use this service more and more. The average duration of journeys, is 11.48 minutes, although a steady decrease is observed in this

[3] It is necessary to point out that an annual fee is paid for the use of the BIZI service (the current annual fee is €36.93), which gives the right to use bicycles for journeys of a maximum of 30 minutes. From there, an increase of 52 cents per half-hour of use is charged, up to 2 hours, after which time there is a penalty of €3.16 euros per hour, up to a maximum of €200 if 24 hours elapse. It appears that users of the BIZI Zaragoza service have adjusted well to the 30-minute limit.

[4] It should be noted that the strong increase has occurred throughout the study period, since the number of kilometers available has been expanded by more than 100%, compared to the beginning of the analysis period, despite having several years in which the increases were practically nil. The bike lane data is presented annually, without specifying the specific day on which it could begin to be used, so that the extension is understood to have taken place on January 1 of each year.

average from 14.75 minutes in 2008 to 10.40 minutes in 2019 (consistent with the findings seen in Figure 2).

We now analyze the connectivity of the BIZI service, that is the functioning of the network, via an analysis of the underlying graph of the system (Boccaletti, 2006). To this end, we consider a weighted, directed network G in which nodes represent the stations and links represent the connection between each node. The weight of each link is directly proportional to the number of trips from the origin to the destination, measured during the considered period (see Figure 4). To avoid bias in the use of stations, we consider the trips from the last extension in the number of stations available, i.e., May 2011, which corresponds to the expansion to 130 stations; this subset preserves 81.33% of the registers. Given the high total number of trips (more than 19 million), we obtain a fully connected network.

In order to gain insight into the behavior of the system, we have performed a community analysis. The spectral analysis of the directed network reveals five communities that match those generated by the modularity algorithm (Blondel, 2008). In Figure 4, each community is displayed in a different color. As can be seen, a community does not necessarily need the presence of hubs. Some communities have one or more hubs, while others (red, green) are decentralized and do not have a hub. Thus, the connectivity is heterogeneous, as shown by the degree distribution. Figure 5 shows the degree distribution of the network, where blue columns correspond to the weighted degree (*i.e.*, the number of trips that either started or finished at the corresponding station), and the red line represents the (weighted) in- minus out-degree (*i.e.*, the number of trips finished in the station minus those that started from it), which constitutes a measure of the station's bicycle surplus. The lower the absolute surplus, the more efficient the station. High absolute bicycle surpluses imply i) a lower availability for the users, and ii) a higher cost associated with the redistribution of the bicycles by the concession company. Note that there is no significant correlation between the degree and the absolute value of the surplus (Pearson's correlation coefficient ρ=0.24), which indicates that the most-used stations have better performance than those with less demand. Table 2 presents the descriptive statistics of the weighted degree distributions, which turns out to be heterogeneous: a relative median of 0.29 times the maximum value indicates the existence of a few highly connected nodes (hubs) and a majority of secondary nodes.

Finally, in order to study the evolution of the system, we have performed a temporal analysis of the network, splitting the network N into slices *N(t)* of constant time lapse. Each slice *N(t)* consists of the same nodes as the original network N, the stations, while the weight of each link of *N(t)* is proportional to the number of trips from the origin to the destination, measured during the considered period. The final goal is to unveil possible self-organization processes that would involve a positive increment of efficiency. Let us define the inefficiency of the system in period t as the average normalized absolute value of the in- minus the out-degree (*i.e.*, the normalized difference between dockings and undockings) averaged over all the operative stations, during the course of a week. Inefficiency can take values from 0 to 1. We define the efficiency of the system as the complement to efficiency:

$$Efficiency(t) = 1 - \frac{\sum_i |(k_i^{\text{in}} - k_i^{out})| / max(k_i^{\text{in}} - k_i^{out})}{numberofoperativestations} \quad (1)$$

Figure 6 displays the evolution of the efficiency for different period lengths, namely days and weeks. As shown, although efficiency fluctuates in all time scales, it exhibits a clear trend to increase rapidly over time until reaching an optimum value after two years, with this result being robust against the time scale choice. In the first month, the daily efficiency fluctuates around a mean value of 0.986 (σ=0.012); from the second year, the mean efficiency is 0.998 (σ=0.0018). Although the mean value increment is not so impressive, the significant decrease of the standard deviation over time indicates a clear reduction in the occasional imbalance between demand and use of the stations. That means that the system self-organizes towards an efficiency close to one. A plausible explanation is that some users adapt their trip schedules to the availability of bicycles at the stations throughout the day.

3. Factors associated with the number of uses and trip duration of the BIZI service

In this Section, we relate the use of the BIZI Zaragoza service to the following factors: extensions of the number of stations, kilometers of bike lanes in the city, and the weather conditions of the city of Zaragoza. We have obtained the daily climatological variables of the city of Zaragoza from the Spanish Meteorological Agency (AEMET). These climatological variables are the maximum, minimum, and average temperature, the hours of sunshine, the maximum wind speed, and its average value, all in daily values for the city of Zaragoza. (We have daily information on these variables, and for reasons of space we do not show their values although they are available on request.)

We want to analyze the factors related to both the number of uses and the duration of the journey, so we must take into account that the nature of both variables is different, and the methodologies (econometric model used) will differ. Regarding the number of uses, we want a count data variable. For this, the model to be estimated is a "poisson" type model, which is used to estimate regression models when the variable is a non-negative counting variable (Cameron and Trivedi, 2013). Said regression is a type of generalized linear model in which the response variable has a Poisson distribution, and the logarithm of its expected value can be modeled by a linear combination of unknown parameters; that is, the logarithm is the canonical link function. Poisson regression assumes that the dependent variable (e.g., y) has a poisson distribution, and the expectation (and variance) of y given x is: $\lambda = E(y|x) = e^{x'\beta}$. Therefore, $log\big(E(y|x)\big) = x'\beta$. These models are estimated with the following explanatory variables: male (1 if male, 0 if female), cohort 1900-1950 (1 if born between 1900 and 1949, 0 otherwise), cohort 1950-1900 (1 if born between 1950 and 1989, 0 otherwise), number of stations, number of kilometers of bike lanes in the city, and weather variables that collect the maximum, minimum, and average temperature, the hours of sunshine, the maximum speed of the wind, and its average value.

The application of the Poisson regression model can give rise to the phenomenon known as over-scattering. In this sense, a peculiarity of the Poisson distribution is that its mean is equal to its variance. However, in certain data sets, a variance higher than expected is observed, and in this case the Poisson model would not be adequate. To try to solve this problem, a negative binomial model can be used. According to this model, applicable to a non-negative counting dependent variable, it is assumed that the counting variable is generated by a process similar to Poisson, except that the variation is allowed to be greater than that of a true Poisson.

Regarding the duration of the journey, the variable is a continuous variable that can take any value, and therefore we apply an Ordinary Least Squares (OLS) model. This model is specified as follows:

$$T_i = \mu + \beta X + \varepsilon_i \qquad (2)$$

where T_i represents the journey time for the "i-th" observation. X is a vector of variables and includes the same explanatory variables that are included in the Poisson and Negative Binomial models. ε_i is the regression error term, and the standard errors are robust.

When we begin with the number of uses of the BIZI Zaragoza service, columns 1 and 2 of table 2 show the results of estimating the Poisson and Negative Binomial models, respectively. First, and comparing the results, we observe that the results are robust to the use of alternative models, as shown by the sign and significance of most of the coefficients in both columns. The only exception is for the variable of bike lane kilometers, where the sign of the coefficient changes, depending on the model. Since the Poisson model assumes that the mean and variance of the variable are equal, which can lead to the problem of over-dispersion, and that the Negative Binomial model has fewer restrictions on its assumptions, we will focus our attention on the results obtained with the Negative Binomial model.

Regarding the relationship of the explanatory variables with the number of uses, we observe the following relationships: being a man (vs being a woman), the number of BIZI Zaragoza stations, the number of kilometers of bike lanes, and the maximum and minimum temperature of the day, are all related to a greater number of uses. Users born between 1900 and 1990 (compared to those born after 1990), the average temperature of the day, the average rainfall of the day, the average speed and gusts of wind, and the number of hours of sunshine are all negatively related to the use of the service.

Column 3 presents the results for the estimated OLS model. Being a man, the kilometers of bike lanes, the average temperature of the day, and the existence of gusts of wind is negatively related to duration. Users born before 1990, the average rainfall of the day, the maximum and minimum temperature of the day, the average wind speed and the number of hours of sunshine are all related to longer journey times. The results for the number of stations may be counterintuitive, since we find that a greater number of BIZI stations is related to longer travel times, although, logically, more stations and should result in shorter travel times. We interpret this result as that those who previously did not use this service because there were no stations near them, began using the service as new stations appeared - especially to go from the center to the periphery of the city or vice-versa (https://openurbanlab.com/2020/07/14/visualizacion-zaragoza-bici/), which may be compatible with the increase in travel time.

4. CONCLUSIONS

The BIZI Zaragoza Service is a public bicycle rental service in which the Zaragoza City Council makes available to users an economical, comfortable, and sustainable means of transport. The Service was launched in May 2008, with the aim of increasing the use of the bicycle in the city. Given the daily use of this service, knowing the needs and demands of the users is essential for the proper functioning and promotion of the service. We first analyze the evolution of the use of the BIZI service, using network analysis, and we show that efficiency increased rapidly over time until reaching an optimum value after two years. We find that being a man, the availability of BIZI stations, kilometers of bike lanes, and higher temperatures are all related to greater use of the service. In addition, younger individuals use the service more, and the Service is used less on rainy and windy days and with fewer hours of sunshine (i.e., winter). Being a man, the kilometers of bike lanes, the average temperature of the day, and the existence of gusts of wind are all negatively related to the duration of trips. Longer journey times are related to older users, the average rainfall of the day, the maximum and minimum temperatures of the day, the average wind speed and the number hours of sunshine.

Our results are consistent with prior studies analyzing the relationship between climatic conditions and bicycle use. In addition, knowing how the factors controllable by the city council are related to the use of this service is important from the point of view of sustainable mobility, since a greater number of BIZI stations and kilometers of bike lanes are related to a greater use of this service, and therefore with a greater importance of sustainable mobility in the city of Zaragoza. Finally, knowing the socio-demographic characteristics of users can serve to guide the development and implementation of MaaS (Mobility as a Service) platforms, where a set of mobility services is offered (bicycle, car-pooling, bus, tram) at an economic price.

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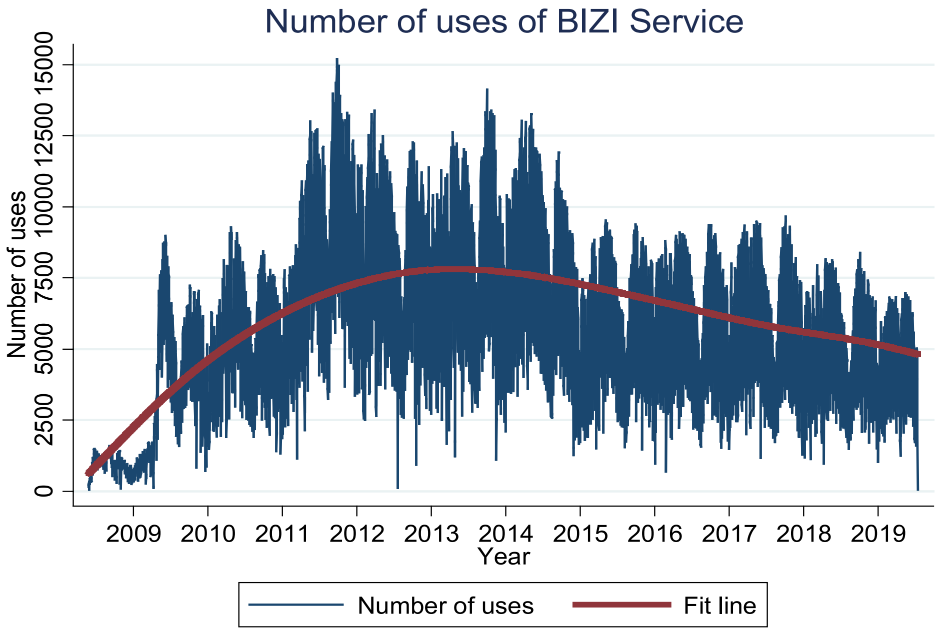
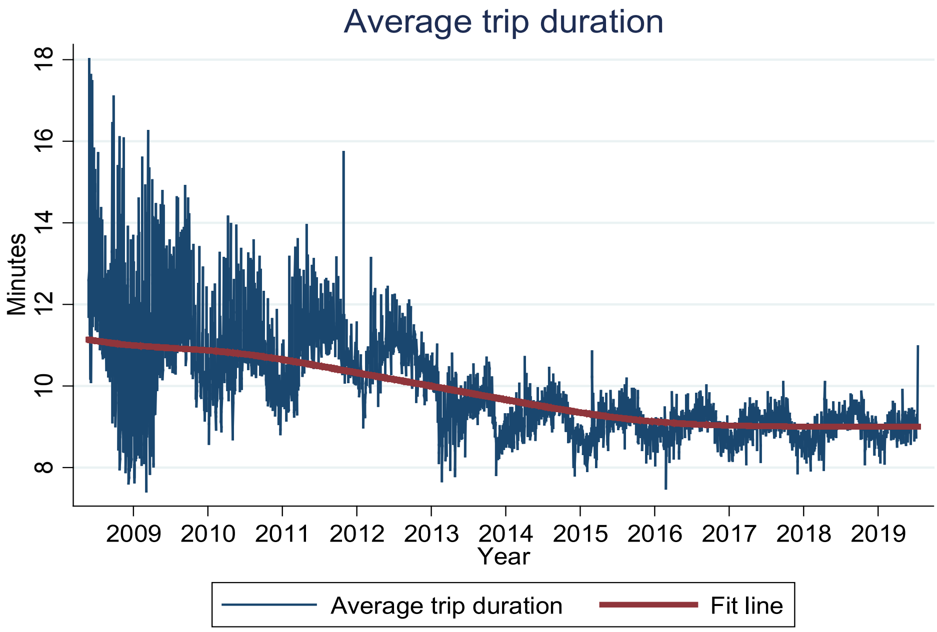
Figure 1. Evolution in the number of uses



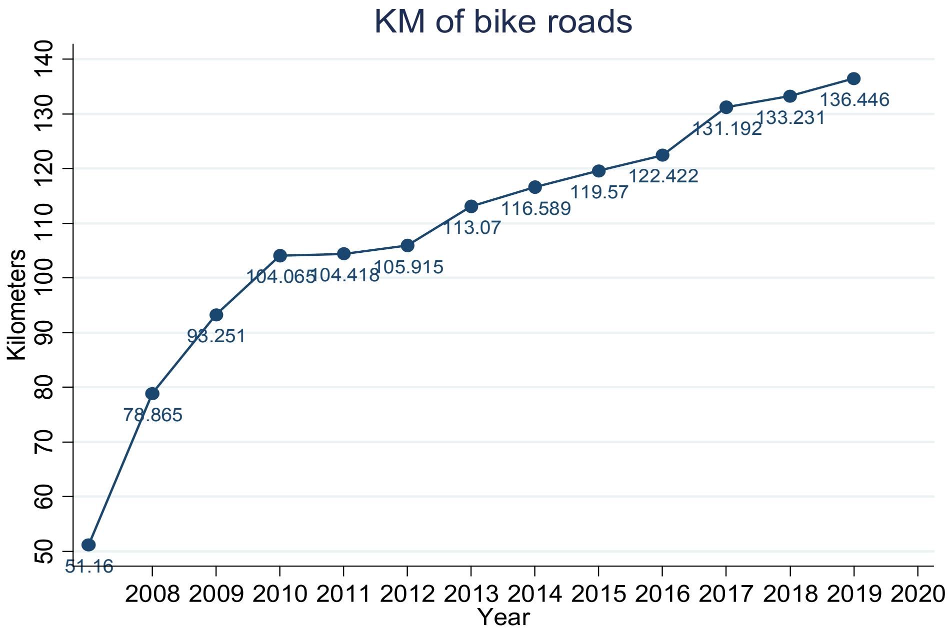
Notes: The number of uses refer to the May-2008/August-2019 period, and are available in the Open Urban Laboratory. The number of uses refers to the number of total daily uses. We use a connected line graph.

Figure 2. Evolution of the duration of BIZI trips



Notes: The analysis data refer to the May-2008/August-2019 period, and are available in the Open Urban Laboratory. The duration is based on the difference between the pick-up time and the drop-off time of the bike at the station. We use a graph of connected lines.

Figure 3. KM of bike lanes in Zaragoza

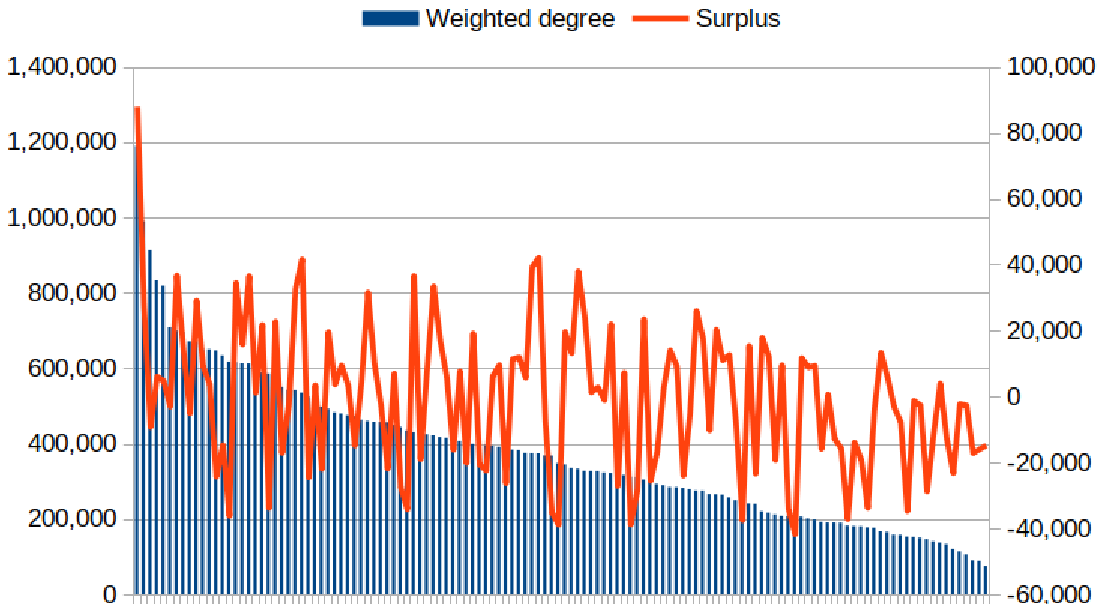


Source: self-made with information available at Zaragoza City Hall.

Figure 4. Representation of the network

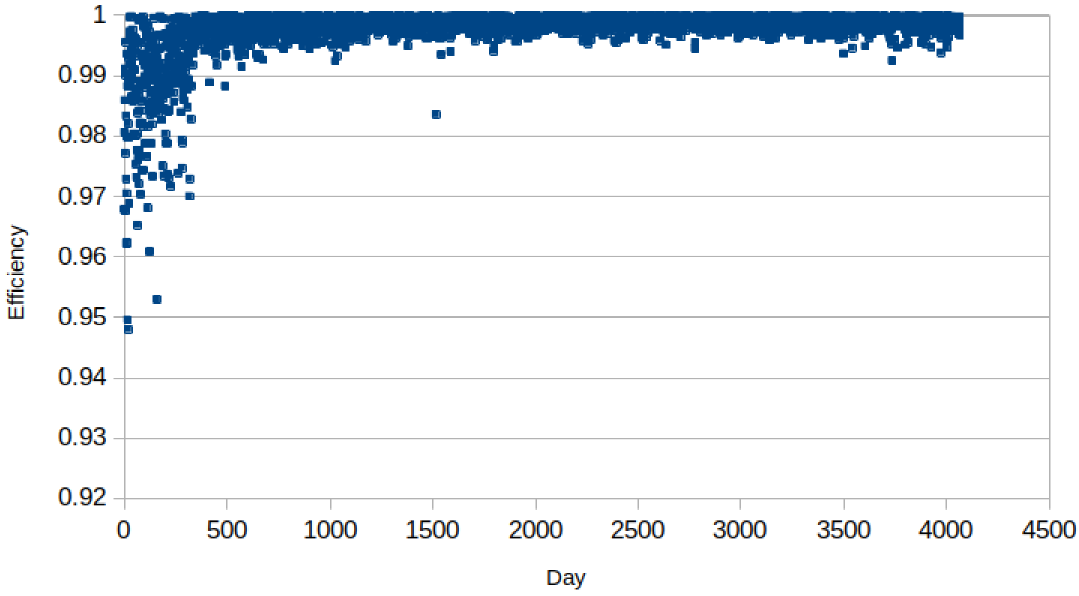
Notes: Each node corresponds to a station and each link to a connection. The *thickness* of each link is proportional to the number of trips connecting both stations; the diameter of each node is proportional to its weighted degree, i.e., to the number of trips that began or ended from that station. Node color corresponds to the community *to which* they belong (Blondel, 2008). To highlight the community structure, the position of nodes is determined by a force atlas (Bastian, 2009). In this representation, for the sake of clarity, only links with a weight of at least 0.1 as the heaviest has been plotted.

Figure 5. Degree distribution



Notes: Stations are sorted according to their use, i.e., the total weighted degree of the nodes. Blue columns (left scale) correspond to the total weighted degree of the node, i.e., undockings and dockings. Red line (red scale) represents the difference between the weighted in- and out-degree, i.e., the number of dockings minus the number of undockings.

Figure 6. Evolution of the efficiency of the system



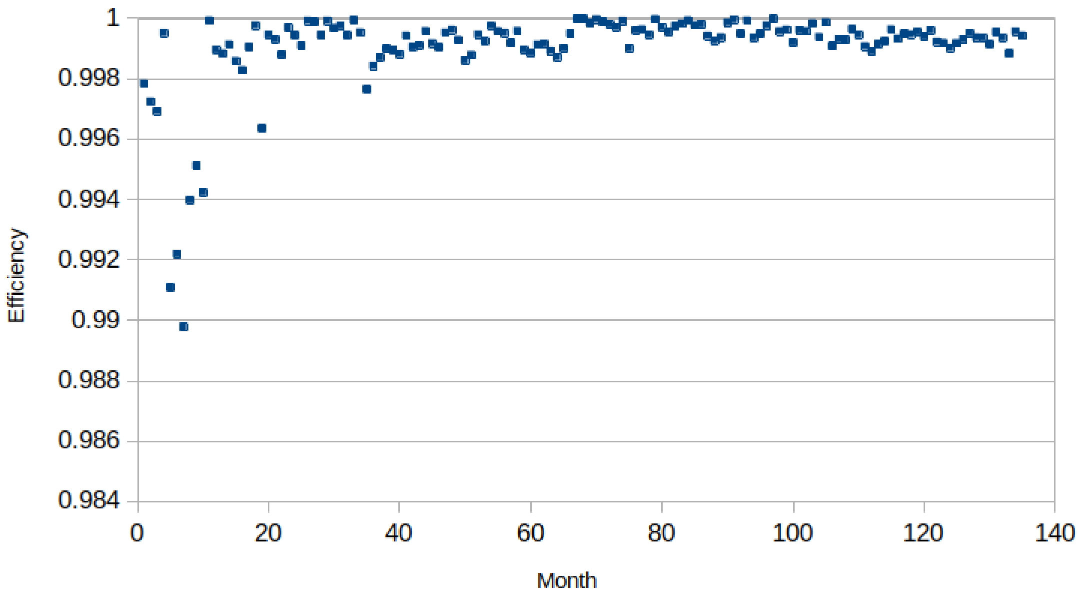


Table 1. Gender, age, and duration, by year

	Men (vs Women)	Cohort 1900-1950	Cohort 1950-1990	Cohort 1990-2010	Trip duration
Average	62.25%	7.29%	79.05%	13.67%	11.48
2008	61.77%	10.08%	88.28%	1.64%	14.75
2009	60.70%	9.58%	88.01%	2.41%	13.41
2010	61.53%	9.04%	87.32%	3.64%	12.63
2011	60.69%	8.23%	84.58%	7.19%	12.75
2012	62.16%	8.11%	82.31%	9.58%	12.44
2013	62.51%	7.54%	79.66%	12.79%	11.01
2014	62.90%	7.00%	76.96%	16.04%	10.80
2015	64.71%	6.78%	75.77%	17.44%	10.55
2016	63.22%	6.06%	74.26%	19.68%	10.54
2017	62.85%	5.79%	72.77%	21.44%	10.48
2018	61.37%	5.34%	71.00%	23.66%	10.50
2019	61.34%	5.25%	71.30%	23.45%	10.40
Observaciones	24,398,631		24,398,631		24,398,631

Notes: The analysis data refer to the May-2008/August-2019 period, and are available at the Open Urban Laboratory. The duration is based on the difference between the pick-up time and the drop-off time at the station.

Table 2. Statistics of the weighted degree distributions

	Weighted out-degree	Weighted in-degree	Weighted degree
Mean	188,625	188,625	377,250
Standard Error	8,384	9,069	17,358
Median	171,666	178,283	346,473
First Quartile	113,528	108,519	213,337
Third Quartile	236,463	239,289	475,025
Variance	9,138,927,330	10,693,165,555	39,170,704,956
Standard Deviation	95,598	103,408	197,916
Kurtosis	1.321	2.292	1.822
Skewness	1.021	1.136	1.087
Range	505,950	608,651	1,114,601
Minimum	44,994	30,381	75,375
Maximum	550,944	639,032	1,189,976
Sum	24,521,275	24,521,275	49,042,550
Count (stations)	130	130	130

Notes: The columns correspond to the weighted out-degree (number of undockings at the station), in-degree (dockings), and degree (total number of uses of the station), respectively.

Table 3. Factors associated with the use of BIZI Service

Variables	Number of uses		Duration
	Poisson	Binomial Negative	OLS
Men (vs. women)	0.002***	0.002***	-0.070***
	(0.000)	(0.000)	(0.000)
Cohort 1900-1950	-0.004***	-0.004***	0.227***
	(0.000)	(0.000)	(0.001)
Cohort 1950-1990	-0.004***	-0.003***	0.080***
	(0.000)	(0.000)	(0.000)
Number of stations	0.014***	0.014***	0.000***
	(0.000)	(0.000)	(0.000)
Km de bike lanes	-0.000***	0.014***	-0.004***
	(0.000)	(0.000)	(0.000)
Average temperature in day	-0.011***	-0.008***	-0.015***
	(0.000)	(0.001)	(0.003)
Average rain in day	-0.000***	-0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Minimum temperature in day	0.011***	0.009***	0.007***
	(0.000)	(0.000)	(0.002)
Maximum temperature in day	0.004***	0.002***	0.009***
	(0.000)	(0.000)	(0.002)
Average wind speed	-0.001***	-0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Maximum wind speed	-0.001***	-0.001***	-0.000***
	(0.000)	(0.000)	(0.000)
Number of hours of sun	-0.001***	-0.001***	0.002***
	(0.000)	(0.000)	(0.000)
Year	0.149***	0.102***	-0.008***
	(0.000)	(0.000)	(0.000)
Constant	-293.350***	-201.378***	19.525***
	(0.063)	(0.153)	(0.416)
Number of observations	24,346,082	24,346,082	24,346,082
Pseudo-R squared	0.965	0.210	-
R Squared	-	-	0.029

Notes: Robust standard errors in parentheses. The analysis data refer to the May-2008 / August-2019 period, and are available at the Open Urban Laboratory. The duration is based on the difference between the pick-up time and the drop-off time at the station. * Significant at the 10% level ** Significant at the 5% level *** Significant at the 1% level.

APPENDIX

Table A1. Number of BIZI stations

Extensions	Date	New Stations	Total
Start	2008	-	30
First extension	April-2009	40	70
Scond extension	October-2009	30	100
Third extension	May-2011	30	130

Source: self-made with information available at Zaragoza City Hall