Bocconi

IEFE
Centre for Research on Energy and Environmental Economics and Policy

Working Paper Series - ISSN 1973-0381

Optimizing the position of bike sharing stations. The Milan case.

Edoardo Croci and Davide Rossi

Working Paper n. 68

June 2014

IEFE - The Center for Research on Energy and Environmental Economics and Policy at Bocconi University
via Guglielmo Röntgen 1, I-20136 Milan
tel. +39.02.5836.3820 – fax +39.02.5836.3890
www.iefe.unibocconi.it – iefe@unibocconi.it

Electronic copy available at: https://ssrn.com/abstract=2461179

Electronic copy available at: https://ssrn.com/abstract=2461179

Optimizing the position of bike sharing stations. The Milan case.*

Edoardo Croci and Davide Rossi
IEFE – Bocconi University, Milan

Abstract

Bike Sharing systems are rapidly spreading around in European cities. Bike sharing is a new type of public transportation based on the use of public bikes to cover relatively short distances in urban areas. It is used both in conjunction with traditional public transport to complete the "last mile", or in alternative for its flexibility. Usage fees are usually very low, compared to other means of transport, as costs of service are often covered by advertising. In this work we will focus on the case of Milan where the bike sharing system, called "BikeMi", was introduced in 2008 and has already reached over 200 stations and 3.000 bikes with 1.8 million travels in 2013. The aim of the paper is to assess which attractors influence the use of bike sharing stations. The paper also examines the different effect of proximity and visibility of bike sharing stations from attractors. An econometric analysis is performed, based on the data set of use of the system and on GIS information on the position of bike sharing stations and attractors. The main results suggest that the presence of metro and train stations, universities, museums, cinema and restricted traffic areas in correspondence of bike sharing stations significantly increase use. On the other hand the presence of tram and bus stops and theatres does not and has an opposite influence. With respect to visibility, there is a positive effect for tram, bus and metro stops, theatres and cinemas. On the other hand, universities and museums show a negative correlation. The results appear robust to the inclusion of time and other possible confounding variables, such as weather conditions. The analysis supports the relevance of the role of urban planning for the best positioning of bike sharing stations and the need to carefully consider the features of surrounding environment to optimise the distribution of bike sharing stations in a territory.

Keywords: bike sharing, sustainable mobility, urban mobility

JEL Classification: D04, Q58, R42

*We would like to thank Valentina Bosetti for her useful inputs to develop this work.

Electronic copy available at: https://ssrn.com/abstract=2461179

1. Introduction

Public transportation service is a key feature of the quality of urban life and a determinant of attractiveness and competitiveness of a territory. Major metropolis in the world are endowed with extensive surface and (at least in developed Countries) underground public transport networks. The idea of using bicycles as means of public transportation is quite recent and has developed through various generations of bike sharing systems. Innovation in ICTs is the cause of the boom of bike sharing in recent years.
The history of Bike Sharing started in Amsterdam in 1965 with the White Bikes, the first generation of bike sharing. They were ordinary bikes provided for public use with no charge. Due to the absence of any deposit and tracking, the system collapsed in few days. The second generation was officially introduced in 1995 in Copenhagen with the City bikes (Bycyklen) program. The improvements were substantial, bikes were more robust and made for intense usage and they were provided with plates on the wheels for advertisement. Most importantly, bikes were collected and returned to specific locations through a coin deposit. Even if this program worked better, the users were still anonymous. This maintained the level of thefts high. In the third, and actual, generation a crucial improvement has been made to eliminate the anonymity of the users as magnetic stripe cards have been introduced. The first new generation program was launched in 1996, at Porsmouth University in England. In 2005 in Lyon the first large program was implemented, the Velo'v. It involved 1500 bikes and it easily reached 15000 member users. The growth of the phenomenon continued and two years later, in 2007, Paris opened a larger program, the Vélib, with about 7000 bikes and 750 stations, which expanded to 23.600 bikes in a few years. Since 2010 bike sharing systems spread all over the world, as new programs were launched in North and South America and in Asia.

Bike sharing is a service with which bicycles are made available for usage for very short periods of time normally sufficient for single trips. Stations are disposed in city areas with racks, in which bicycles are locked. Users can pick up a bicycle from any station, ride and leave it in any station, either the same from which he started his trip or another one. The first 30 minutes (or another limited amount of time) are usually free of charge. Such a system is designed to foster the use of bicycles in substitution or in conjunction with other public or private means of transport, also avoiding the use of private bicycles. Indeed, bike sharing programs solve some of the primary concerns of bicycle ownership, such as loss from theft or vandalism, lack of parking or storage, and maintenance requirements. Bike sharing can be used either as a substitute of the ordinary public transportation or as a complement, in order to cover the so-called "last mile". This expression describes the use of the bicycle for riding the distance between the user's departure or destination point and the closest public transportation station or parking lot.
Analysis on the success factors of bike sharing is limited. Choices on models, usage rules, features of bikes, number of stations, number of bikes per station, distribution of stations on a territory in terms of distance and positioning are

Electronic copy available at: https://ssrn.com/abstract=2461179

made through ex ante analysis in the absence of consolidated models. Ex post evaluations are scarce. Indeed, we found only two works (Master projects), Maurer (2011) and Daddio (2012).
In this work we will focus on the specific case of Milan where the bike sharing system is named "BikeMi". The service started operating on 8th December 2008 and it reached 190 stations and 3412 bikes at the end of 2013.
The objective of this work is to use available data on BikeMi in order to estimate the influence of major geographical attractors on the use of the bike sharing system.
In particular, we look at the presence of public transportation stops (e.g. tram, bus, metro and train), universities, museums, cinemas and theatres in a radius of 100m from the existing stations. We also consider whether the station of interest is visible from those attractors or not. To test the strength of our results we add some weather and time controls. What we expect to observe is that the presence of and the visibility from any of these attractors will both influence positively the use of a given station.
Understanding which are the key geographical factors that influence the use of bike sharing systems is important in order to optimize the distribution of bikes and stations and to maximize system performance.
The work is organised as follows. In chapter 2 we analyse available literature, in chapter 3 we describe the evolution of bike sharing systems, in chapter 4 we describe mobility in Milan, in chapter 5 the features of BikeMi. In chapter 6 we describe our model, perform an econometric analysis and comment results.

2. Research background

Thanks to the success and rapid diffusion of bike sharing programs all around the world the amount of literature on bicycle use in cities is increasing. Various researches focuse on bicycle user behaviours, assessing which factors are critical for bicycle use (Rietveld and Daniel (2004), Akar and Clifton (2008), Pucher and Buehler (2008), Winters et al. (2010 and 2011), Heinen et al. (2010), Handy et al. (2010), Winters et al. (2011)). The main relevant considered factors are:

1) individual factors, such as age, household income or race;
2) physical environmental elements, for instance traffic conditions or the presence of a bicycle friendly neighbourhood;
3) travel costs, in terms of safety, travel time and effort or transportation modes costs.

Initially research tried to understand which were the pushing factors of private bicycle uses. Rietveld and Daniel (2004) started questioning whether municipal policies could be a determinant of bicycle use. Pucher and Buehler (2008) continued on this field making a review of policies applied in the Netherlands, Denmark and Germany. Heinen et al. (2010) defined in a literature review the most common factors affecting bicycle use. They suggested a large range of factors, such as built environment (urban form, infrastructures, facilities, etc.) and natural environment (hilliness, weather, seasons, etc.), socio-economic and psychological factors (attitudes, social norms and habits), cost, travel

Electronic copy available at: https://ssrn.com/abstract=2461179

time, effort and safety factors. Winters et al. (2011) made a similar analysis indicating the top ten motivators and deterrents of bicycling. Hand, Xing and Buehler (2010) extended the pushing factors to explain not only the use, but the ownership of bicycles,.

These studies show that the environment has an influence on transportation modes and bicycle use. This topic is studied more deeply in other works, starting with Targa and Clifton (2005), who present an empirical analysis of the effects of several land-use and urban form attributes on the frequency of walking. Subsequently, Akar and Clifton (2009) and Winters et al. (2010) estimated the effect of these urban features on the frequency of cycling. All studies consider as relevant variables: hilliness, road traffic, road crosses, land use, population density and bicycle infrastructures.

A more specific literature on bike sharing also developed. DeMaio (2004 and 2009) and Midgley (2009) describe the evolution of bike sharing systems, highlighting the advantages and the lacks of this new transit mode. A particulraly relevant research topic is the optimal distribution of bikes or stations. We find both qualitative and quantitative works (Bryant (2013), Chen (2013), Daddio (2012), Garcia-Palomares et al. (2012), Lin and Ta-Hui (2011), Rybarczyk and Wu (2010)). Most of quantitative ones focus on the problem of bicycles redistribution or on the use of Geographical Information System (GIS) data to evaluate the positioning of bike sharing stations. What can be learnt from the history of bike sharing programs is that in any bike sharing program, one of the key to success is the location and distribution of bike stations.

We refer here to systems characterized by the presence of stations where bikes have to be got and returned. A different model of bike sharing needs no station. An example of this is “Call a Bike”, present in Germany, where users can find and leave bicycles in any place and open the lock on the bike with the code provided when they book the bicycle.

The existing background is rich of feasibility studies for cities planning to introduce their own bike sharing system, like the ones of Milan (2007), Vancouver (2008), New York (2009), Ottawa (2009) and Copenhagen (2011). These reports look at the distribution of variables such as population and public transportation densities and indicate which areas are more suitable. Other reports, like the ones for Seattle (2010), Philadelphia (2010), Boise (2012), San Francisco (2013), Richmond (2013) and the works by Rybarczyk and Wu (2010) and Garcia-Palomares, Gutiérrez and Latorre (2012) on the cities of Milwaukee and Madrid used a more technical approach applying GIS optimization analysis, like set or maximal covering problems, to create a suitability map identifying the best locations to place bike-sharing stations.

Maurer (2011) and Daddio (2012) add an econometric analysis to the GIS analysis and estimate the effect of social variables of the population (density, age, racial mixture, household income), built environment characteristics (hotel rooms, attractors, retails, university areas, parks) and transportation features (bus stops, metrorail, bike infrastructure and distance from system centre). They study the cases of Sacramento and Washington. They find positive and significant effect for income level of neighbourhood population, number of retails in the surrounding area, presence of metrorail and distance

Electronic copy available at: https://ssrn.com/abstract=2461179

to rail stops. They estimate negative and significant effect for prevalence of non-white people, distance to centre of the bike sharing system and distance to parks.
Previous studies considered and modelled how to position bike sharing stations with respect to the presence of attractors. Nevertheless no study estimates accurately the effect that the presence of these factors exerts on the level of daily uses of a given bike sharing station. Maurer (2011) and Daddio (2012) considere average monthly uses of stations, but this can generate distortions. First of all different factors can have different effects over the year. Secondly, the use in working days and weekends can have different explanations. For these reasons we prefer to estimate the influence of attractors on the disaggregated daily data for every station.

This work tries to fill the gap between economic - behavioural studies and geographical distribution assessments by quantifying the influence that proximity to attractors can exercise on bike sharing usages. The aim of our analysis is to support decisions in designing a successful bike sharing system.

3. Evolution of bike sharing systems

Bike sharing was introduced in the Netherlands in the 1960s and is now diffused to more than 49 countries. For instance, 132 programs are counted in Spain, 104 in Italy and 79 in China, which are respectively the countries with the highest number of programs. In Figures from 1 to 3 (Source: http://bikes.oobrien.com/global.php) it is possible to have a clearer view of the level of diffusion that bike sharing systems reached. Each point represents a bike sharing program, the dimension of the point is proportional to the dimension of the program itself and red points indicate programs with higher intensity of uses, computed as average percentage of bicycles used.

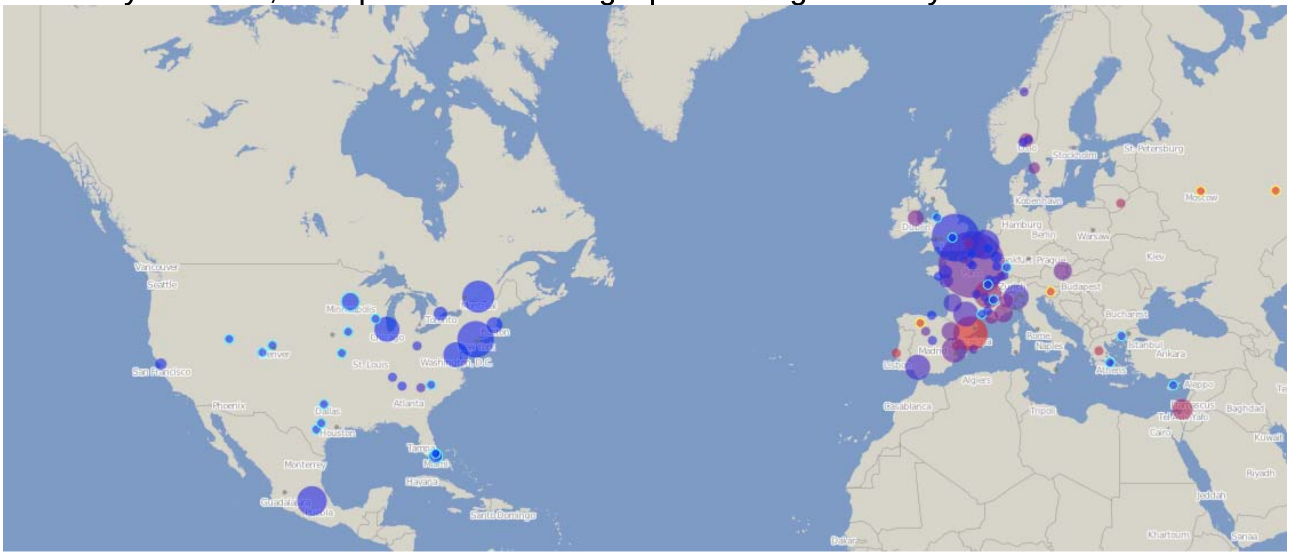


Figure 1: Map of Bike sharing programs in North America and Europe

Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 2: Map of Bike sharing programs in South America

Electronic copy available at: https://ssrn.com/abstract=2461179

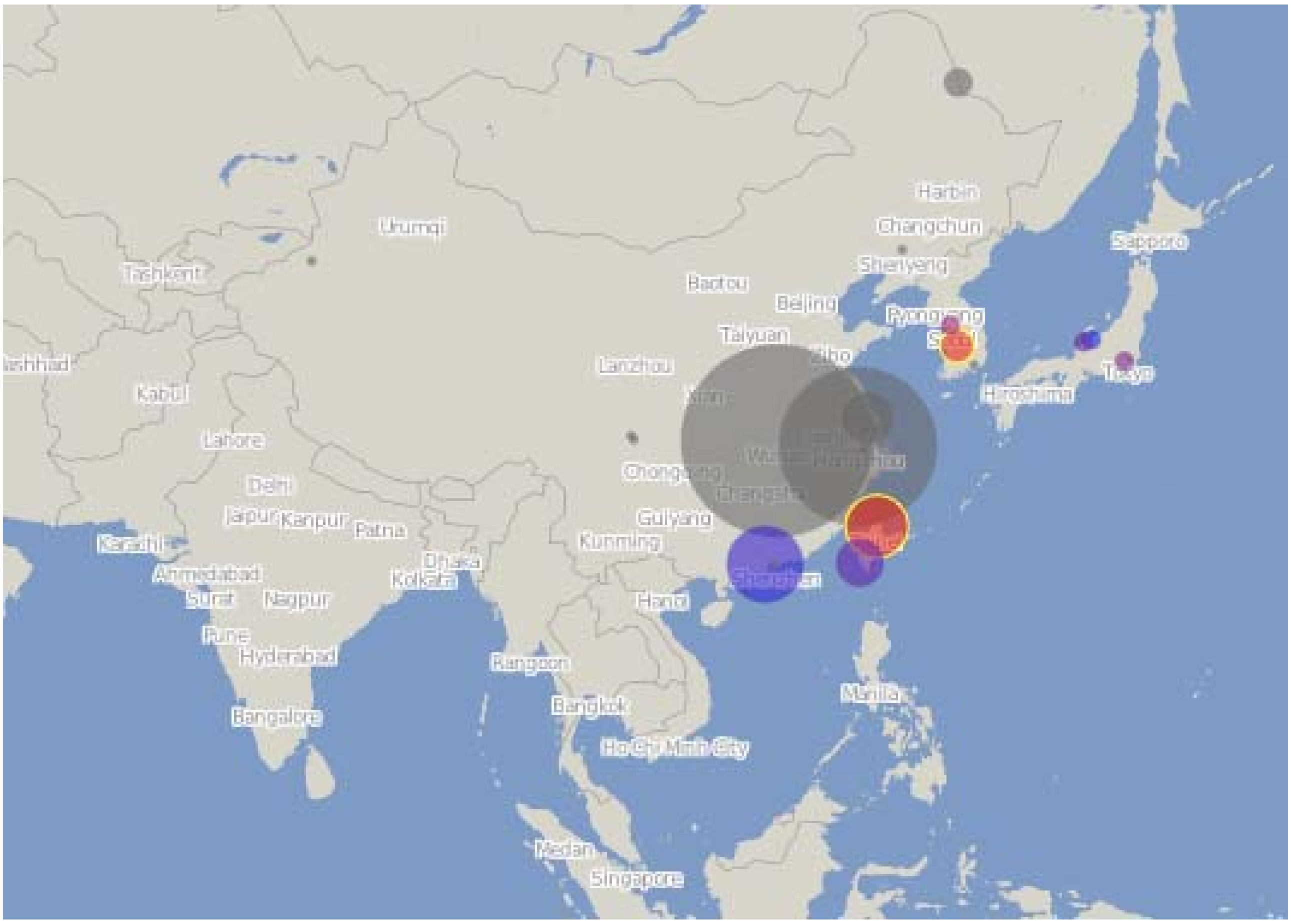


Figure 3: Map of Bike sharing programs in Asia

As we said, bike sharing programs are rapidly diffusing. Figure 4 shows the evolution in the launch of new bike sharing systems (Source: http://en.wikipedia.org/wiki/List_of_bicycle_sharing_systems). It is possible to notice the steep growth that the curve shows after 2005. In fact, 2005 is the year of birth of the program Velo'v in Lyon, the first modern and large program.

Electronic copy available at: https://ssrn.com/abstract=2461179

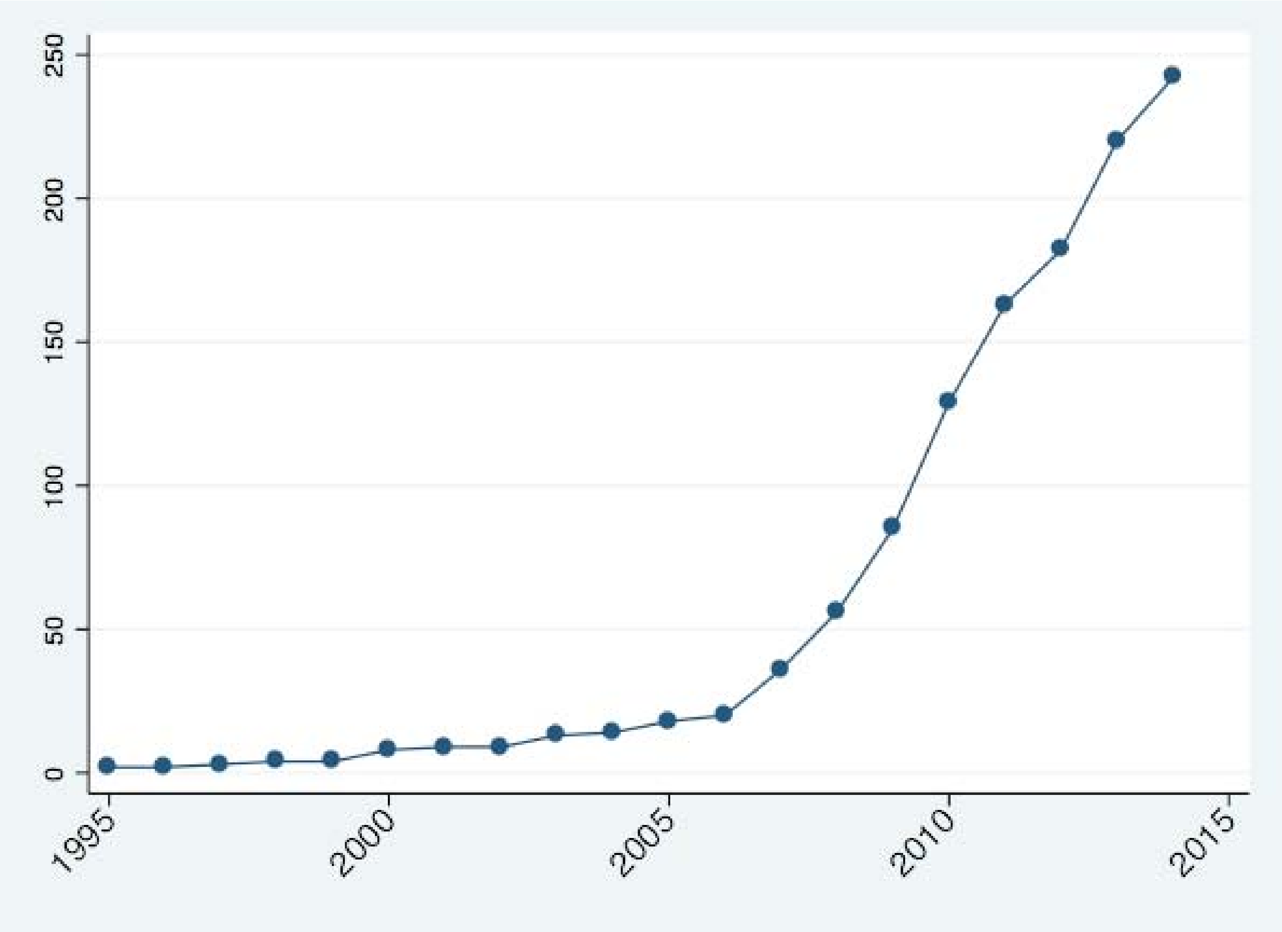


Figure 4: Number of Bike sharing programs

The history of bike sharing began on 28th July 1965 in Amsterdam with the first generation of White Bikes (Witte Fietsen). These were ordinary bikes, painted in white and provided free of charge for public use. The principle was that anybody could find a bike, use it and leave it to the next user. But things did not go as expected: bikes were stolen and kept for private use or, sometimes, even thrown into the channels. This resulted in the abrupt collapse of the program.
After this first experience, a second generation of bike sharing was designed and launched in 1991 in Farso and Grena, Denmark. After this small scale experiment, a large scale program was launched in 1995 in Copenhagen: the City bikes (Bycyklen) program. This experiment introduced many improvements: bikes were specifically made for intense usage, with solid rubber tires and were provided with plates on the wheels, for advertisements. Bikes could be collected and returned to specific locations all over the central city with a coin deposit. Even if this program worked better than its predecessor it still suffered of multiple cases of thefts, due to the anonymity of the users. The need for a solution to this crucial issue brought to the appearance of the third, current, generation of bike sharing system. In 1996, at Porsmouth University in England, students could use a magnetic stripe card to rent a bike. From this point onward bike sharing systems steadily improved technological aspects including electronically locking racks or bike blocks. The Porsmouth experiment signed the slow but steady growth of modern bike

Electronic copy available at: https://ssrn.com/abstract=2461179

sharing systems, as, since then, every year one or two new small programs were launched.
It is only in 2005, though, in Lyon, that the first large program was implemented: the Velo'v. Velo'v involved 1500 bikes and it soon reached 15000 member users. JCDecaux, the second largest global outdoor advertising company, sponsored the program. This program was the second that relied on the management of an advertising company, after Vienna's "Citybike" in 2003. Two years later Paris opened a larger program, the Vélib', with about 7000 bikes and 750 stations, which expanded to 23.600 bikes in a few years.
The success of these last programs brought the bike sharing concept to a whole new level. Starting in 2008, bike sharing systems started diffusing also outside Europe, reaching Brazil, Chile, China, New Zealand, South Korea, Taiwan and the U.S.. In May 2011 could be counted 375 bike sharing systems around the world, with a total of 236.000 bicycles (Source: http://en.wikipedia.org/wiki/Bicycle_sharing_system). In April 2013 there were 535 programs with an estimated fleet of 517.000 bikes (Source: http://en.wikipedia.org/wiki/Bicycle_sharing_system)[1].
Nowadays the Wuhan and Hangzhou Public Bicycle bike sharing programs, both in China, are the two largest in the world, with respectively 90000 and 20000 bikes. While outside of China the largest program is Vélib in Paris with around 20000 bicycles and Citi Bike in New York is the largest bike sharing program in the United States with 5000 bikes.

Bike sharing systems cannot be considered as a niche policy anymore. The number of users and the sizes of the fleets make clear that the potential of these programs is remarkable. Hence it is important to better understand the factors determining the success or failure of these systems and in particular the best criteria to distribute bikes and stations.

4. Mobility in Milan

Milan is the second largest city in Italy with 1.316.497 inhabitants. Milan can be divided in three parts, the city centre, the outer part and the suburbs, also named "hinterland". The entire city (centre and outer part) covers 181.76 km^2, the city centre is 9 km^2.
In the city centre a congestion charge is in operation. It was introduced on 2nd of January 2008 in the form of a "pollution charge" (proportional to PM 10 tail emissions) named "Ecopass", and transformed since 16th of January 2012 in a "congestion charge", named "Area C". Both measures have the effect to limit

[1] The difference in the values with Figure 4 is due to the fact that data come from two different sources. The programs shown in Figure 4 are the programs for which it has been explicitly indicated the date of launch, together with other information, the date of introduction has made possible to create this time graph. This choice has been obligated by the fact that does not exist such thing as a world census of bike sharing programs. Keeping this in mind, we use these data as a proxy of the real number of bike sharing program with the aim to present qualitatively how the rate of diffusion of this transportation service increased in the recent years. Hence, the type of source is not going to interfere with our results.

Electronic copy available at: https://ssrn.com/abstract=2461179

the access of private vehicles to the city centre. The restriction is operating in the time slot 7.30 – 19.30, Monday to Friday.

In the city of Milan there are 4 metro lines for a total of 103 stops, and a length of 94,5km (by far the largest in Italy) and a regional rail system with 10 urban stops interconnected with the metro system. The surface public transportation is composed by 17 tram lines and 62 bus lines.

Milan is not only the first city in Italy for supplied public transportation (seats*km/ab), but it is also the city with the highest level of public transport passengers per habitant. Milan is the third city for number of cars per square km. (Source: Euromobility, Rome, 18/12/2013)

Milan can be considered bicycle friendly for the fact that it is relatively flat: it ranges between 102 and 147 meter over the level of the sea. On the other hand, unfortunately, bicycle paths are not very developed. Indeed, they are very fragmented. Nevertheless, in the city there are 152.000 m^2 of areas with limited traffic and 428.000 m^2 of pedestrian areas. In 2011 the percentage of trips by bicycle on the total number of trips has been estimated equal to 6%. (Source: PUMS 2013, Piano Urbano per la Mobilità Sostenibile Milano)

Milan is characterized by the presence of several universities. With a student population of 180.000 units. (Source: Municipality of Milan)

Moreover, in accordance to the plan of a more sustainable mobility, the city introduced the service of car sharing, the main programs are 3: Car2Go, managed by the namesake company, with 650 Smarts. Enjoy, managed by Eni, with 600 Fiat 500. And GuidaMi, managed by “ATM” (Azienda Trasporti Milanesi), with a diversified fleet of 165 vehicles. The principle is the same as bike sharing’s. Users can pick a car, use it and leave it in another place, with more or less restrictions to parking places according to the program, without restrinction to roundtrips only.

In Milan the public transportation system is managed by ATM. ATM runs buses and trams (surface systems) and metros (underground system) and also a car sharing and the bike sharing system. Two other rail systems are managed by the State railway company (Trenitalia) and the regional railway company (Trenord). Train stops in the city can be divided in ordinary stops and “Passante” stops, an infrastructure which crosses the city from north-west to south-east. Train and Passante stops are respectively:

Train Stops	**Passante Stops**
Centrale	Porta Vittoria
Porta Garibaldi	Repubblica
Porta Romana	Lancetti
Cadorna	Bovisa
Greco Pirelli	Rogoredo
Lambrate	Certosa
San Cristoforo	Porta Venezia
Bullona	Dateo
Quarto Oggiaro	Villa Pizzone
Affori	
Bruzzano	
Porta Genova	

Electronic copy available at: https://ssrn.com/abstract=2461179

Table 1: Train and passante stops

5. BIKE MI

The bike sharing system of Milan was elaborated as part of a sustainable mobility package introduced under Major Moratti in Milan since 2006. A specific study was developed by Politecnico of Milan – Poliedra on behalf of the Municipality of Milan and financed by one of the largest Italian foundations, Fondazione Cariplo. The study defined the ideal number of stations, the distribution of stations, the business model and even the shape of bicycles.

It was planned to build 300 stations in the city center and semi-central area and in correspondence of main attractors all over the city and to operate 5.000 bicycles. The plan was thought to be implemented in three phases. Only the first one has been completed and the second one is still under implementation. At present the bike sharing system covers the entire city centre and some of the outer part and its total operating area is 26 km^2.

The system started thanks to a State contribution of 5 million euros in 2008, covering the investment costs (bicycles and stations) of the full project. The management of the system was assigned from the Municipality to the public transport company ATM (100% owned by the Municipality), which assigned operations through tender to Clear Channel, one of the largest advertising operators in the world. In fact management costs of the system are fully repaid by outdoor advertising in correspondence of stations.

BikeMi is a third generation bike sharing system. Users can choose between three types of subscriptions: annual, weekly or daily, with subscription costs equal to € 36, € 6 and € 2.50 respectively, to be paid through credit card. For annual subscriptions customers receive a magnetic stripe bar card, while for weekly and daily subscriptions they receive a Username and a Password to digit at stations. Bicycles can be rent in any moment from 7 in the morning to midnight.

The first 30 minutes are free, after the first half hour users pay € 0.50 for every subsequent half hour, for a maximum of two hours. If the two hours limit is exceeded, the user is charged a € 2 penalty per hour. The service is automatically suspended if the limit is exceeded three times. Moreover, a € 150 penalty is charged if the bike is not returned within 24 hours of its withdrawal from the station.

In case of sequential uses, at least 10 minutes must elapse between the first and the second use.

The development of BikeMi up to now can be divided in two phases, as can be noticed in Figure 5. The first one, from its start on 3rd December 2008 to 21st June 2009, consisting of 100 stations and 1359 bicycles. In this first part of the program the stations have been introduced mainly in the city centre. On 13th February 2011 phase two of the program started and is still going on, increasing the numbers up to 190 stations and 3412 bicycles. The second phase extended the service to semi-central areas.

The distribution of stations has been based on criteria of proximity to transportation modal interchanges, such as train and metro stations, in order to permit the integration with other transit modes. Moreover, the station

Electronic copy available at: https://ssrn.com/abstract=2461179

planning aimed at proximity to social attractors, like universities and hospitals. Every station is not more than 300 meters far from another station to assure a high density of stations and the possibility to reach a station in a few minutes walking in all the served area.

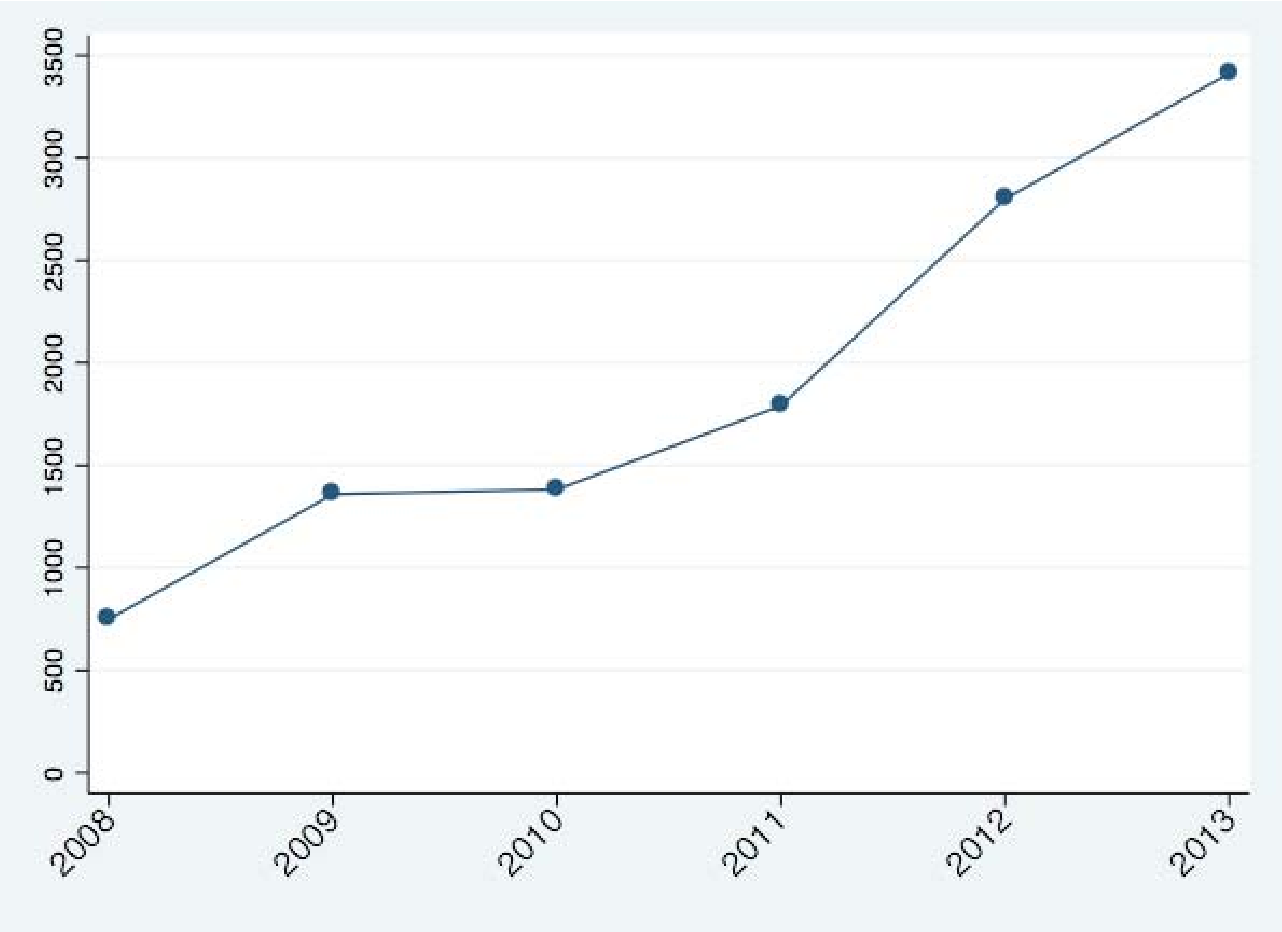


Figure 5: Number of BikeMi bicycles

Since its birth BikeMi registered a steady growth in uses, in 2009 there have been 651.720 trips, in 2010 773.300, in 2011 999.061 and in 2012 it passed the million with 1.284.882 total trips. In accordance, also the number of yearly subscriptions increased, even if with a less linear trajectory, in the December 2008 there has been 580 annual subscriptions, in 2009 11.104, in 2010 4183, in 2011 5.884 and in 2012 6.913.
Considering all the data recorded since 2008, we can say that the level of uses does not distribute uniformly over the days of the week. The pattern observed indicates that bike sharing is used mostly during working days, (Figure 6), where we have average uses around 50, for an imaginary average station, while in the weekend the average use decreases to 20.
Average uses are not constant also with respect to the month of the year. As Figure 7 shows, uses diminish during the winter and are higher during the rest of the year, with the exception of August, month in which most of the citizens of Milan leave the city for holydays. These two figures justify our choice to include dummy variables for days of the week and months of the year.

Electronic copy available at: https://ssrn.com/abstract=2461179

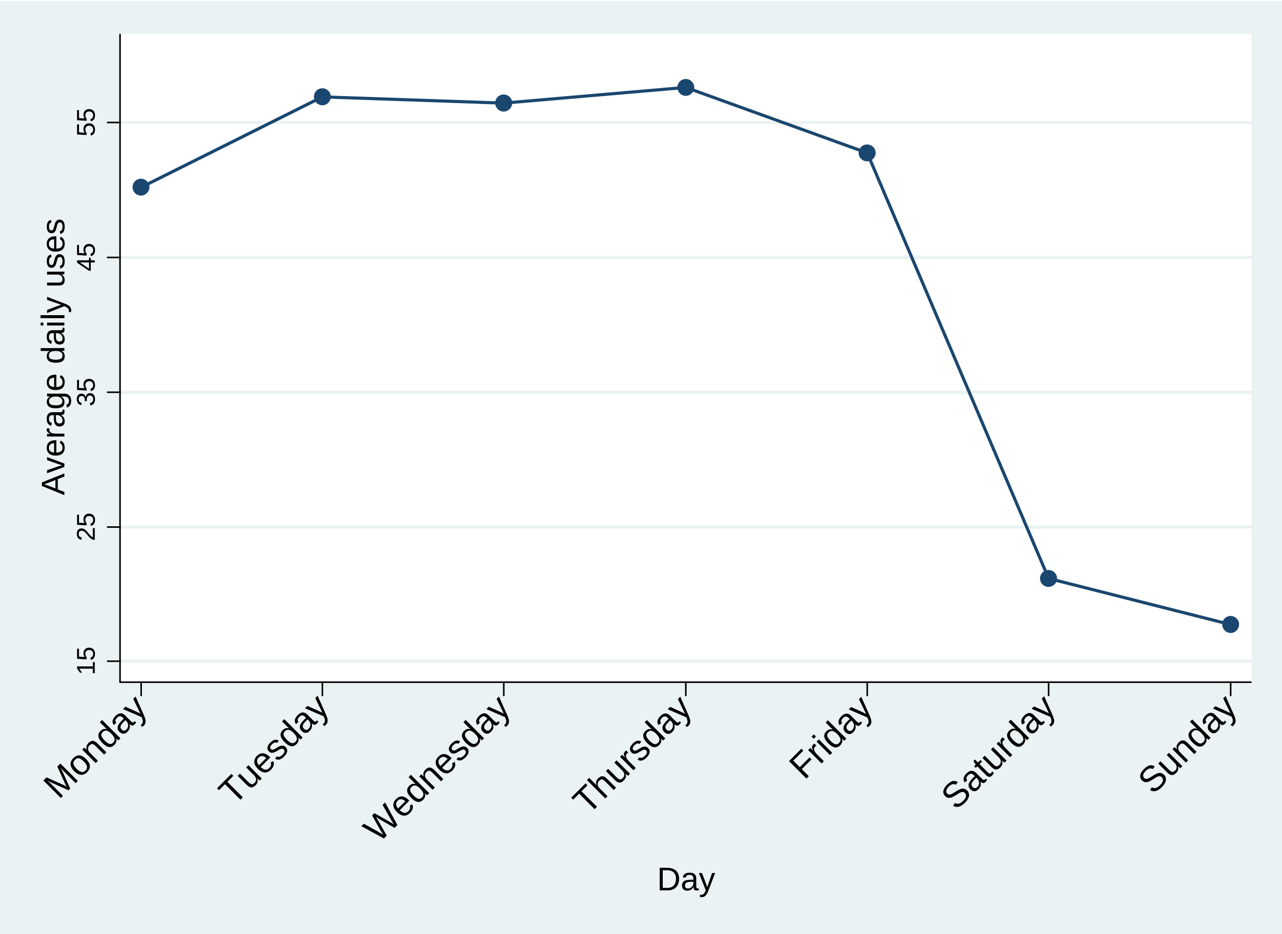
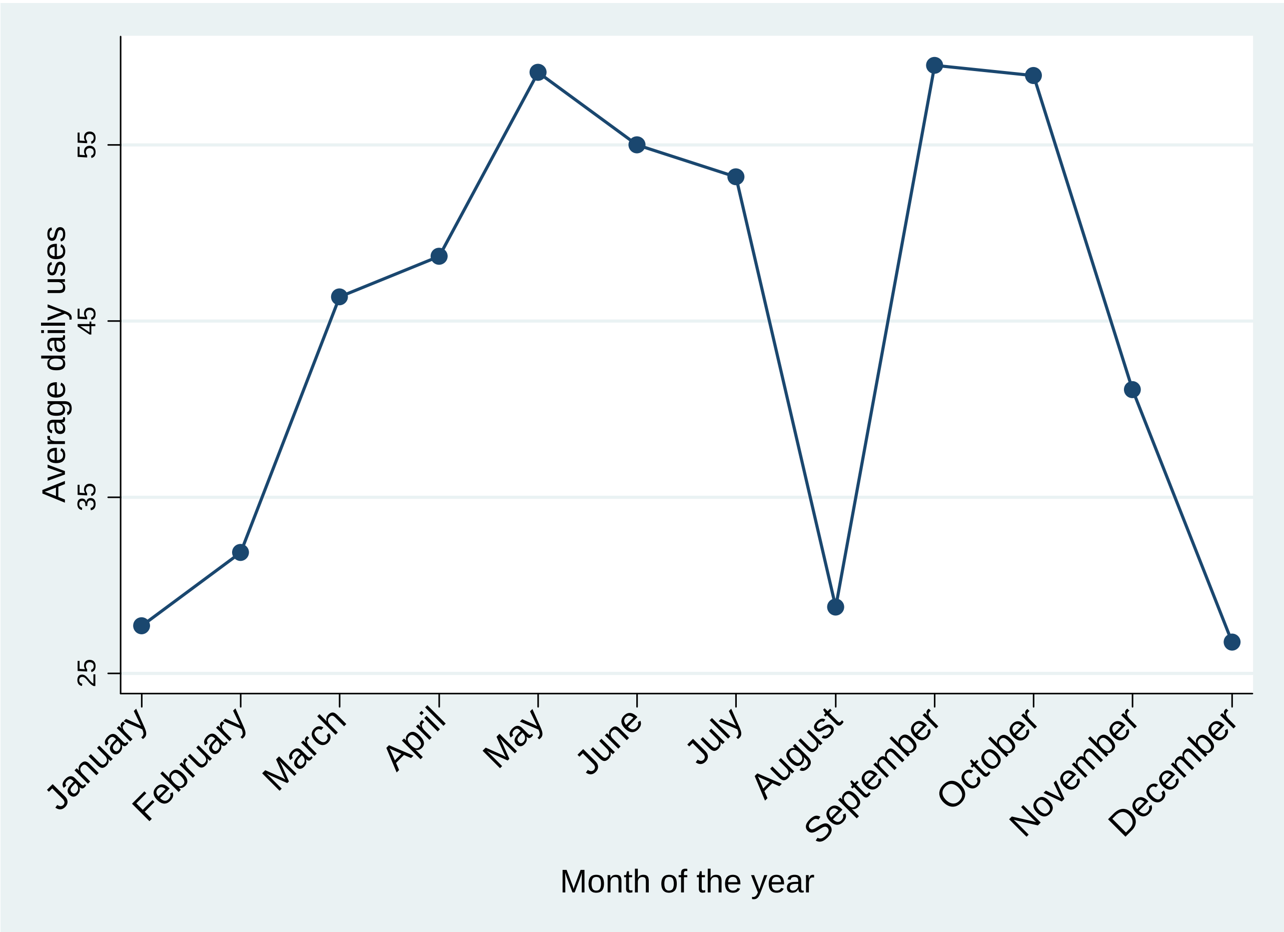


Figure 6: Average daily uses per day of the week



Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 7: Average daily uses per month

6. The model

6.1. Data

We analyse the uses of the bike sharing system in the city of Milan. To do so we consider data on BikeMi (provided by Clear Channel) from 3rd December 2008, date in which the bike sharing system has been introduced, up to 31st December 2012. The initial dataset contained a detailed description of every trip; we grouped them daily and for every station. The result is a panel dataset in which we have the entire daily history of uses for every BikeMi station.
From the open data website of the municipality of Milan we collected the files with the geographical coordinates (shapefiles), for public transportation stops (bus, tram, metro, passante and train),universities, museums, cinema, theatres, parks and pedestrian areas. The choice of the shapefiles has been constrained by the existing available data. We use public transportation stops as transit connectivity is an important criterion in bike sharing accessibility. As attractors we use universities, museums, cinema and theatres. In this paper we do not use data on population, retail and jobs densities and other social variables such as age or income distributions, which could be further considered. The shapefiles have then been projected on the raster of the city of Milan. Thanks to these data and the software QGIS, we have been able to create our explanatory variables of distance and visibility from attractors. In the specific we created a distance dummy for each attractor that takes the value of 1 if it is less than 100 meter, straight distance, far from a bike sharing station, zero otherwise. Thanks to the raster we have been able to create visibility dummies for the attractors, these are equal to 1 if from that attractor it is possible to see the bike sharing station. We also created a dummy variable to distinguish whether the bike sharing station is inside or outside the congestion charge area “Area C”. Lastly we consider the variable called “Security”, which is a variable taking into account the proximity of parks or pedestrian area, in which cycling is more secure (in terms of potential risk of traffic accidents).
To this initial dataset, we added weather data handed by ARPA Lombardia (Regional Agency for the Environmental Protection). The collected data included: raining levels, wind speed and temperature registered in three stations located in the centre of Milan in Via Juvara, Lambrate and Piazzale Zavattori. These data were recorded every hour and cover the period of interest. We used the average of the values obtained from the three stations. In the regressions they are named respectively: “rain_av” for rain average, “wind_av” for wind speed average, and “temp_av” for temperature average.

6.2. Empirical analysis

We study the effects of proximity and visibility of bike sharing stations, with respect to some geographical attractors, on the level of daily uses. We expect that the proximity and the visibility to the considered places have positive

Electronic copy available at: https://ssrn.com/abstract=2461179

effects on the uses of a bike sharing system. To estimate the effects of interest we are going to use linear panel-data models with random effects, which can be represented with the equation:

$$y_{it}=a_i+x'_{it}\beta+\varepsilon_{it}$$

Where the combined error is expressed as $u_{it}= a_i+\varepsilon_{it}$. In the represented equation i indicates the station's id and t indicates the day. The advantage of a random effects model, with respect to a fixed effect model, is that it yields estimates of all coefficients, even those of time-invariant regressors, which is exactly the case of our dummy variables.

Our dataset is composed by 161 stations and up to 1490 observations for every station. These characteristics make our panel data a long panel, this means that we need richer models for the error process than those specified for short-panel cases. We control for some error features, in the specific we control for correlation of the error in the model over i, we then use an AR(1) (autoregressive of order 1) model for the error to control for temporal correlation over t, moreover we control also for heteroskedasticity of the error over it. Given the high frequency of our time series (daily) and the physical proximity of bike sharing stations (less than 300 meters one another), these corrections are fundamental for the precise estimation of our coefficients' standard errors.

Another feature we have to take into account when analysing our dataset is that it is unbalanced. In the specific it means that the time series don't have all the same length. This is due to the fact that not all the stations have been opened the same day, hence for some we have more data, for others less. This can create biased estimations if the observations are missing in a correlated way with variables that are not included in the model. Let d_{it} be an indicator variable equal to one if the itth observation is observed and equal to zero otherwise. Then the random effect estimator is consistent if the strong exogeneity assumption is satisfied, which means

$$\mathrm{E}[u_{it} \mid a_i, \mathbf{x}_{i1}, \ldots, \mathbf{x}_{iT}, d_{i1}, \ldots, d_{iT}]=0$$

Additionally a_i must be independent from the other conditioning variables. We satisfy these assumptions including in our model the presence of the attractors that influenced the choice of the policy makers on the position of the stations, moreover we created a dummy for the phase of the program BikeMi in which the station has been opened.

We will start regressing daily uses on dummies for the presence of bus and tram stops, metro stops, train stops, passante stops, universities, museums, theatres, cinemas and parks or pedestrian areas. Moreover we include dummies for the visibility from bus and tram stops, metro stops, train stops, universities, museums, theatres and cinemas. For multicollinearity problems we had to exclude visibility from passante stops, nevertheless, this is not a

Electronic copy available at: https://ssrn.com/abstract=2461179

problem as we believe that the visibility effect from passante stop is similar to the effect of metro and train. After this first regression we run a second one adding a dummy for the presence of the station within the Area C and a dummy for the phase in which the station has been introduced. Together with these two variables we include weather variables, temperature, rain level and wind speed. In the last regression we add dummies for the days of the week, the months and the years.

Electronic copy available at: https://ssrn.com/abstract=2461179

6.3. Results

VARIABLES	(1)	(2)	(3)
Presence of attractors			
Bus and tram stop	-14.70***	-11.71***	-11.70***
	(0.491)	(0.400)	(0.376)
Metro stop	29.50***	29.73***	30.06***
	(0.901)	(0.877)	(0.839)
Train stop	75.07***	58.98***	58.56***
	(2.681)	(2.268)	(2.115)
Passante stop	17.26***	42.21***	42.41***
	(1.107)	(1.609)	(1.529)
University	-3.246***	5.513***	4.769***
	(0.318)	(0.294)	(0.264)
Museum	13.14***	10.54***	10.36***
	(0.485)	(0.403)	(0.381)
Theatre	-4.593***	-3.808***	-3.559***
	(0.300)	(0.277)	(0.233)
Cinema	9.597***	6.355***	6.500***
	(0.409)	(0.302)	(0.281)
Security	7.599***	6.712***	6.570***
	(0.248)	(0.228)	(0.203)
Visibility from attractors			
Bus and tram stop	15.54***	15.42***	15.52***
	(0.428)	(0.413)	(0.399)
Metro stop	2.875***	6.042***	5.663***
	(0.358)	(0.369)	(0.335)
Train stop	-9.164***	10.72***	10.41***
	(0.626)	(0.744)	(0.746)
University	-6.485***	-8.291***	-7.353***
	(0.303)	(0.269)	(0.244)
Museum	-14.83***	-15.32***	-14.57***
	(0.532)	(0.501)	(0.454)
Theatre	14.01***	10.70***	10.62***
	(0.811)	(0.669)	(0.617)
Cinema	7.558***	5.805***	5.537***
	(0.361)	(0.311)	(0.286)
Control variables			
In Area C		32.07***	31.47***
		(0.920)	(0.843)
Phase 1		-13.53***	-8.448***
		(0.959)	(0.630)
Temperature		✓	✓
Rain		✓	✓
Wind		✓	✓
Day of week			✓
Month			✓
Year			✓
Constant	30.53***	2.965	-59.23***
	(1.104)	(1.991)	(11.17)
Observations	166,256	166,256	166,256
R-squared	0.033	0.092	0.335
Number of id	161	161	161

Table 2: Regression results

Electronic copy available at: https://ssrn.com/abstract=2461179

We studied the effect of proximity and visibility of bike sharing stations with respect to geographical attractors. In Table 2 the results of our work are summarized. For proximity, the variables with a positive effect are metro, train and passante stops, museums, cinemas and security (which includes parks and pedestrian areas). All these variables show strongly significant coefficients in all the regression specifications with values ranging from 6 to 60. Interestingly, bus and tram stops and theatres show negative influences, -12 and -3.6 respectively.
For visibility we estimated positive effect for four variables, visibility from tram and bus stops, metro stops, trains stops, theatres and cinema with coefficients from 5.5 to 15.5. On the other hand universities and museums show negative effects, -7 and -14.5 respectively.

The explanatory variables can be grouped in three types of attractors, as indicated in Table 3. Let's start with transport related attractors (e.g. tram, bus, metro, train and passante stops). Metro, train and passante show positive influences both for proximity and visibility (for passante the effect is inferenced from train results), while tram and bus change sign between proximity and visibility. This is interesting because all the positively influencing transportation modes cover medium/long trips, while trams and buses are used for shorter trips. This means that in the first case, medium/long trips, transportations are used as complement with bike sharing and this increases the uses.
In the second case, trams and buses interact as substitute goods, rather than complement with bike sharing, as refer to shorter range uses, generating a more unstable effect on BikeMi uses. The second group of attractors' refer to social attractors. Their effects, except for cinema (whose effect is always positive), are not stable between proximity and visibility and they change their sign between one and another.
The last type of attractor is the security proxy; it shows a positive coefficient: this means that being in the proximity of places in which it is safer to bike (e.g. parks and pedestrian areas) incentives the uses of bike sharing. These results have shown to be highly significant and robust to the inclusion of control variables (columns 2 and 3 of Table 2) such as Area C, dummy for the phase in which the station has been opened, weather conditions and time trend.

Attractor type	Variable	Proximity	Visibility
Transportation	Tram bus	-11.70	+15.52
	Metro	+30.06	+5.66
	Train	+58.56	+10.41
	Passante	+42.41	
Leisure/People crowding	University	+4.77	-7.35
	Museum	+10.36	-14.57
	Theatre	-3.56	+10.62
	Cinema	+6.57	+5.54
Security	Security	+6.57	

Table 3: Summary of results

Electronic copy available at: https://ssrn.com/abstract=2461179

7. Conclusions and limitations

The level and quality of public transportation is relevant to determine the competitiveness of a city. A relatively recent public transportation mode is bike sharing, in its history this transportation service evolved in various generations. Throughout our work, we present how, in parallel to the diffusion and evolution of bike sharing, the existing literature approached this new transportation mode and tried to answer relevant questions. Albeit choices on models, usage rules, features of bikes, number of stations, number of bikes per station, distribution of stations on a territory in terms of distance and positioning are important research features, ex post analysis on the success factors of bike sharing is equally important. With this job we want to develop this last part of literature, which so far has been covered only by two Master projects. In the third part we presented how the bike sharing system developed and changed, all over the years, to solve the revealed problems and limitations taking advantage of the developing technology. In the fourth part we tried to give a clearer picture of Milan and how its transportation system is developing toward a more sustainable mobility, this includes not only the introduction of bike sharing, but also the diffusion of car sharing programs, both public and private, and the introduction of a congestion charge in the city centre. The fifth chapter was dedicated to explain the features of BikeMi, how it has been introduced, which was the development plan and how it has been fulfilled so far. Moreover, we presented how the uses distribute across the days of the week and the month of the year. In the sixth chapter we presented our analysis and its results, we estimate the effects of surrounding environment on the daily level of uses of BikeMi stations. More specifically we look at the proximity to some geographical attractors and at the visibility of the stations from those attractors. In particular, we look at the presence of public transportation stops (e.g. tram, bus, metro and train), universities, museums, cinemas and theatres in a radius of 100m from the existing stations. We also consider whether the station of interest is visible from those attractors or not. We analyse the uses of the bike sharing system in the city of Milan, where bike sharing, together with the Area C (congestion charge) and car sharing are part of a broader plan to develop a more sustainable mobility. We expect that the proximity and the visibility to the considered places have positive effects on the uses of a bike sharing system.

To perform the ex post analysis we consider data on BikeMi from 3rd December 2008, date in which the bike sharing system has been introduced, up to 31st December 2012. From the open data website of the municipality of Milan we collected the files with the geographical coordinates (shapefiles), for public transportation stops (bus, tram, metro, passante and train), universities, museums, cinema, theatres, parks and pedestrian areas.

According to our results there are some attractors that have a positive influence on the usage level of a given bike sharing station. These results are relevant for policy planners. The optimal distribution of bike sharing stations should first of all cover the stops of medium/long range transportation modes. In fact, these are the variables that show the strongest coefficients and the most stable positive effects, as the bike sharing system can be considered as a

Electronic copy available at: https://ssrn.com/abstract=2461179

complementary part of the transportation system in the target city. Secondly, from results of visibility variables we can say that the most the station is visible, the more effective is the location. Indeed visibility from 5 of the included attractors have positive influence (i.e. tram and bus, metro and train stops, theatre and cinema). This result suggests to place bike sharing stations where their visibility is maximized, in order to capture the users who do not plan in advance which transportation mode to use. For example, if we combine the results for proximity and visibility looking at medium/long range transportations, we can say that if we put a station close to and visible from a metro stop the increase is equal to 35.72 (given by 30.6+5.66). With respect to train stops the total effect is equal to 68.97 (given by 58.56+10.41). Lastly, the security dummy indicates a positive effect suggesting that also parks and pedestrian areas must be covered by the bike sharing stations.

Needless to say, our work has some limitation due to the absence of data for relevant variables that we think could be interesting to include in the model. We are referring to average income distribution over the city, population and shop densities. Another limit is related to the lack of consideration of proximity to cycling lanes that are poor and fragmented in Milan.

Electronic copy available at: https://ssrn.com/abstract=2461179

Tables and Figures

VARIABLES	(1) dep1	(2) dep2	(3) dep3
Presence of attractors			
Bus and tram stop	-14.70***	-11.71***	-11.70***
	(0.491)	(0.400)	(0.376)
Metro stop	29.50***	29.73***	30.06***
	(0.901)	(0.877)	(0.839)
Train stop	75.07***	58.98***	58.56***
	(2.681)	(2.268)	(2.115)
Passante stop	17.26***	42.21***	42.41***
	(1.107)	(1.609)	(1.529)
University	-3.246***	5.513***	4.769***
	(0.318)	(0.294)	(0.264)
Museum	13.14***	10.54***	10.36***
	(0.485)	(0.403)	(0.381)
Theater	-4.593***	-3.808***	-3.559***
	(0.300)	(0.277)	(0.233)
Cinema	9.597***	6.355***	6.500***
	(0.409)	(0.302)	(0.281)
Security	7.599***	6.712***	6.570***
	(0.248)	(0.228)	(0.203)
Visibility from attractors			
Bus and tram stop	15.54***	15.42***	15.52***
	(0.428)	(0.413)	(0.399)
Train stop	-9.164***	10.72***	10.41***
	(0.626)	(0.744)	(0.746)
Metro stop	2.875***	6.042***	5.663***
	(0.358)	(0.369)	(0.335)
University	-6.485***	-8.291***	-7.353***
	(0.303)	(0.269)	(0.244)
Museum	-14.83***	-15.32***	-14.57***
	(0.532)	(0.501)	(0.454)
Theater	14.01***	10.70***	10.62***
	(0.811)	(0.669)	(0.617)
Cinema	7.558***	5.805***	5.537***
	(0.361)	(0.311)	(0.286)
Control variables			
In Area C		32.07***	31.47***
		(0.920)	(0.843)
Phase 1		-13.53***	-8.448***
		(0.959)	(0.630)
Temperature		1.173***	1.104***
		(0.121)	(0.267)
Rain		-17.16***	-18.16***
		(1.017)	(1.379)
Wind		-1.522**	-0.972
		(0.672)	(0.912)
day_week2			33.20***
			(1.290)
day_week3			38.99***
			(1.631)
day_week4			38.19***
			(1.768)
day_week5			38.68***
			(1.772)
day_week6			34.13***

Electronic copy available at: https://ssrn.com/abstract=2461179

			(1.634)
day_week7			2.812**
			(1.291)
month2			-2.445
			(5.664)
month3			8.176
			(6.292)
month4			9.949
			(6.751)
month5			11.03
			(7.377)
month6			2.245
			(7.881)
month7			-2.465
			(8.183)
month8			-17.45**
			(8.270)
month9			8.620
			(7.519)
month10			17.22***
			(6.671)
month11			2.873
			(6.217)
month12			2.751
			(5.655)
year2			20.41**
			(10.22)
year3			24.59**
			(10.39)
year4			30.39***
			(10.37)
year5			36.00***
			(10.40)
Constant	30.53***	2.965	-59.23***
	(1.104)	(1.991)	(11.17)
Observations	166,256	166,256	166,256
R-squared	0.033	0.092	0.335
Number of id	161	161	161

Table 4: Complete regression results

Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 8: BikeMi stations

Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 9: BikeMi stations and cinema

Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 10: BikeMi stations and metro stops

Electronic copy available at: https://ssrn.com/abstract=2461179

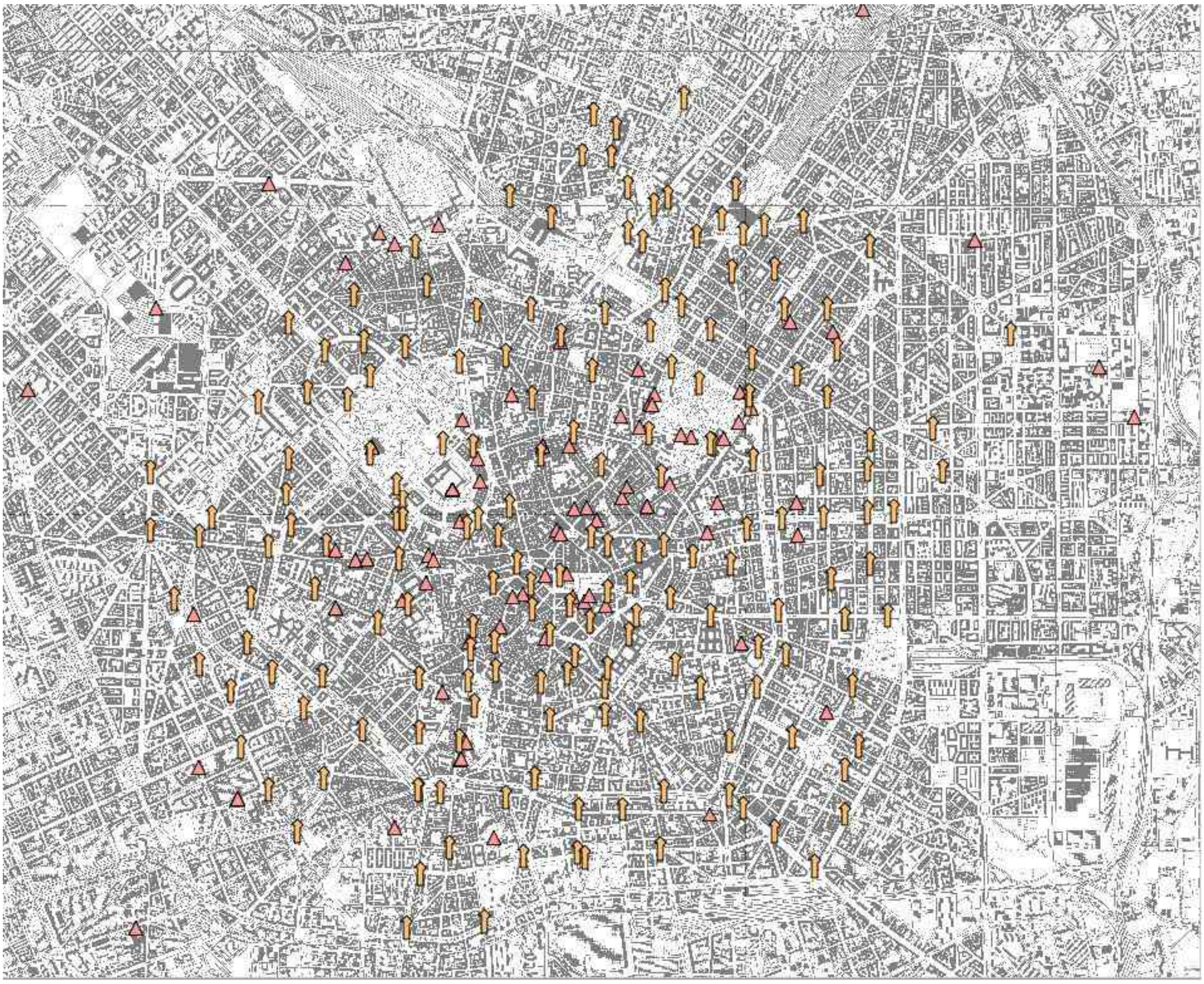


Figure 11: BikeMi stations and museums

Electronic copy available at: https://ssrn.com/abstract=2461179

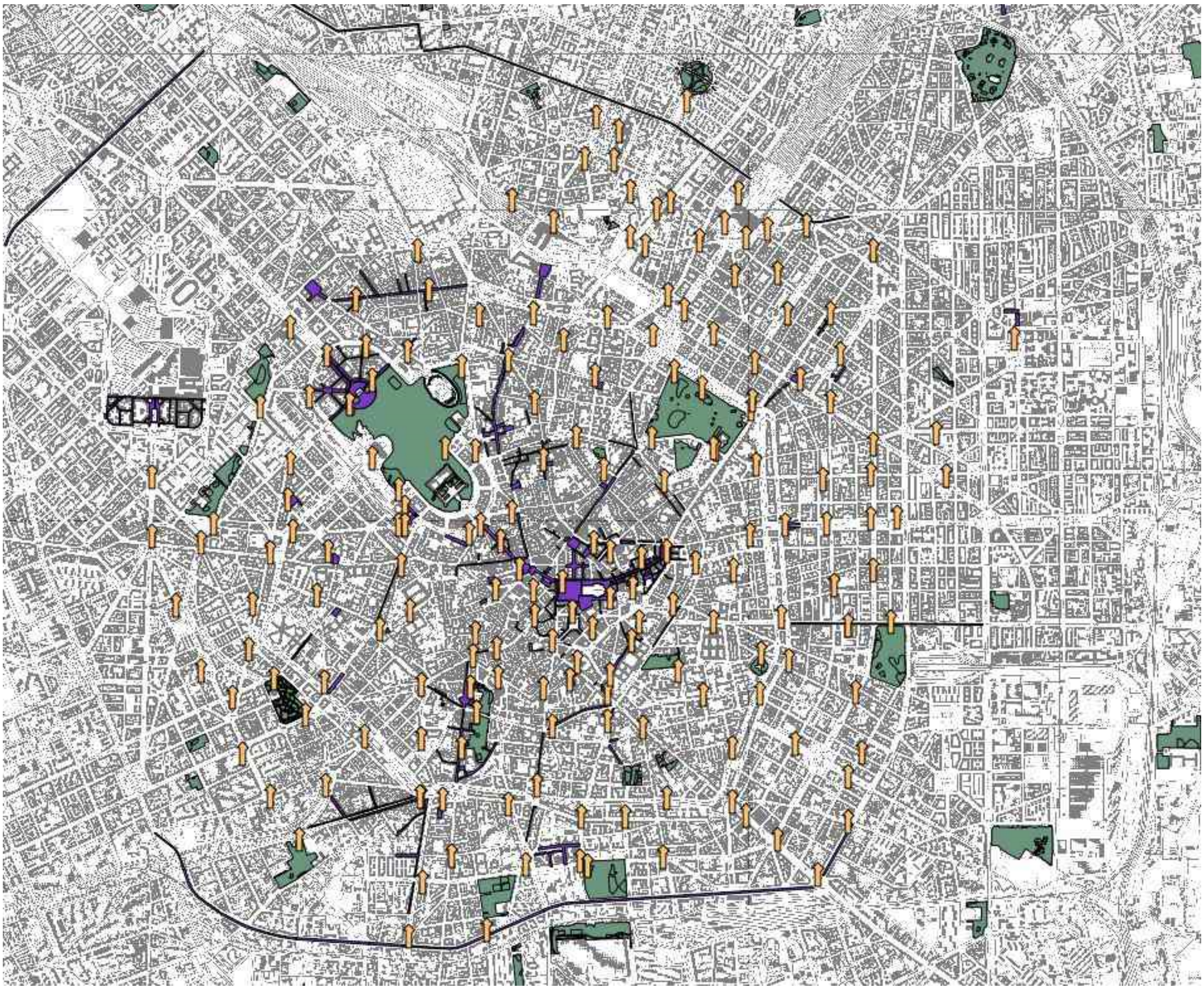


Figure 12: BikeMi stations and parks and pedestrian areas

Electronic copy available at: https://ssrn.com/abstract=2461179

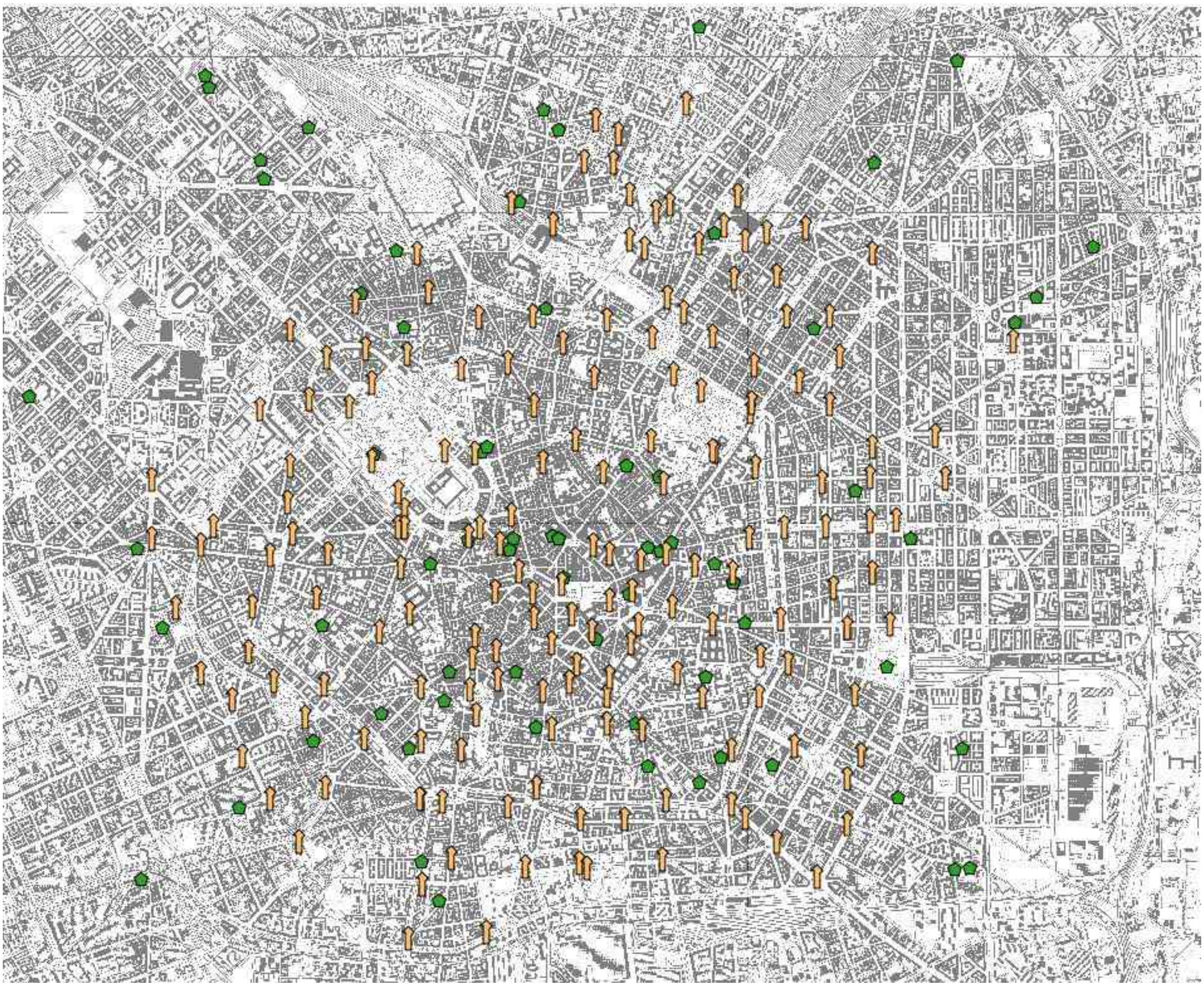


Figure 13: BikeMi stations and theatres

Electronic copy available at: https://ssrn.com/abstract=2461179

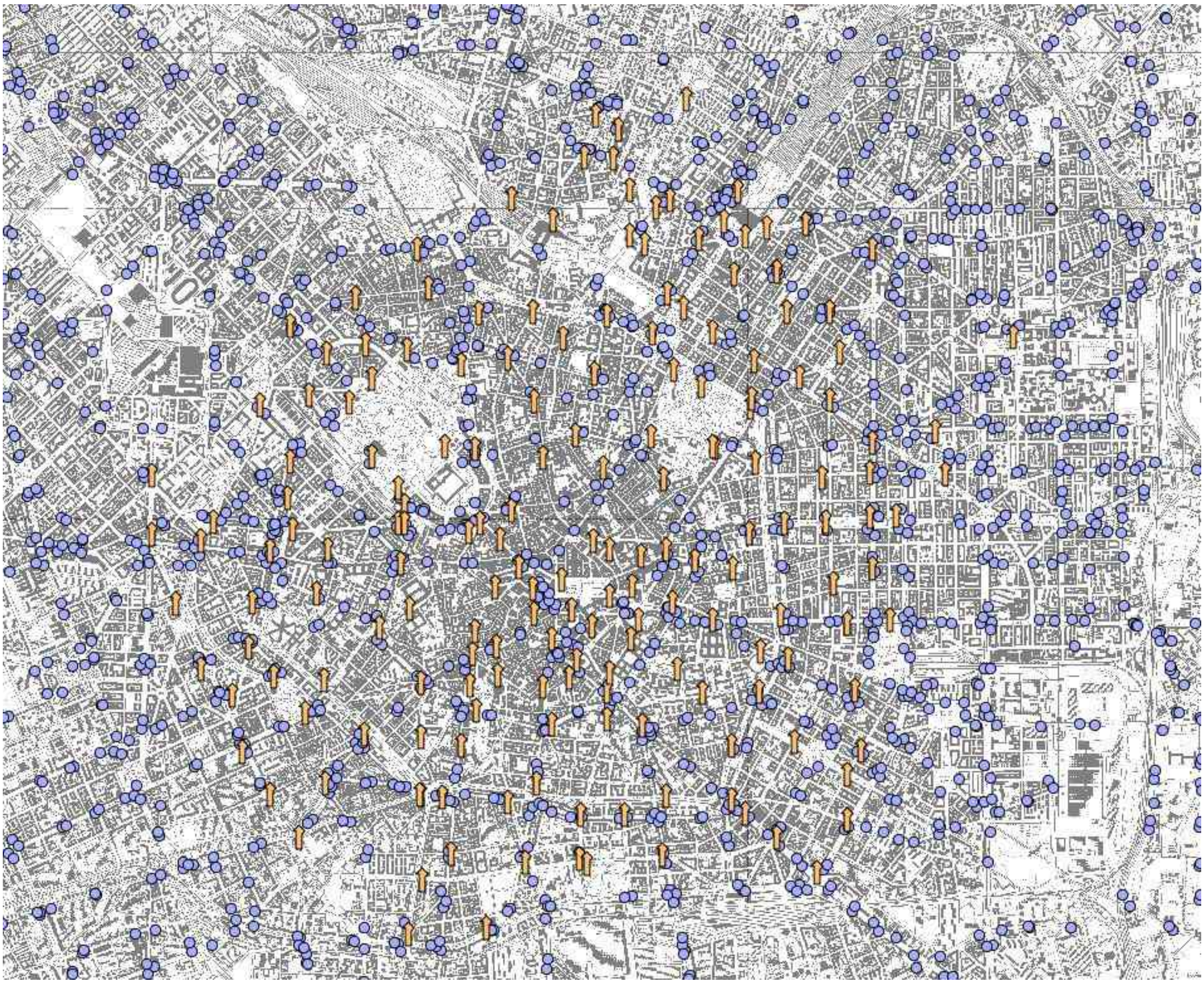


Figure 14: BikeMi stations and tram and bus stops

Electronic copy available at: https://ssrn.com/abstract=2461179

Figure 15: BikeMi stations and train and passante stops

Electronic copy available at: https://ssrn.com/abstract=2461179

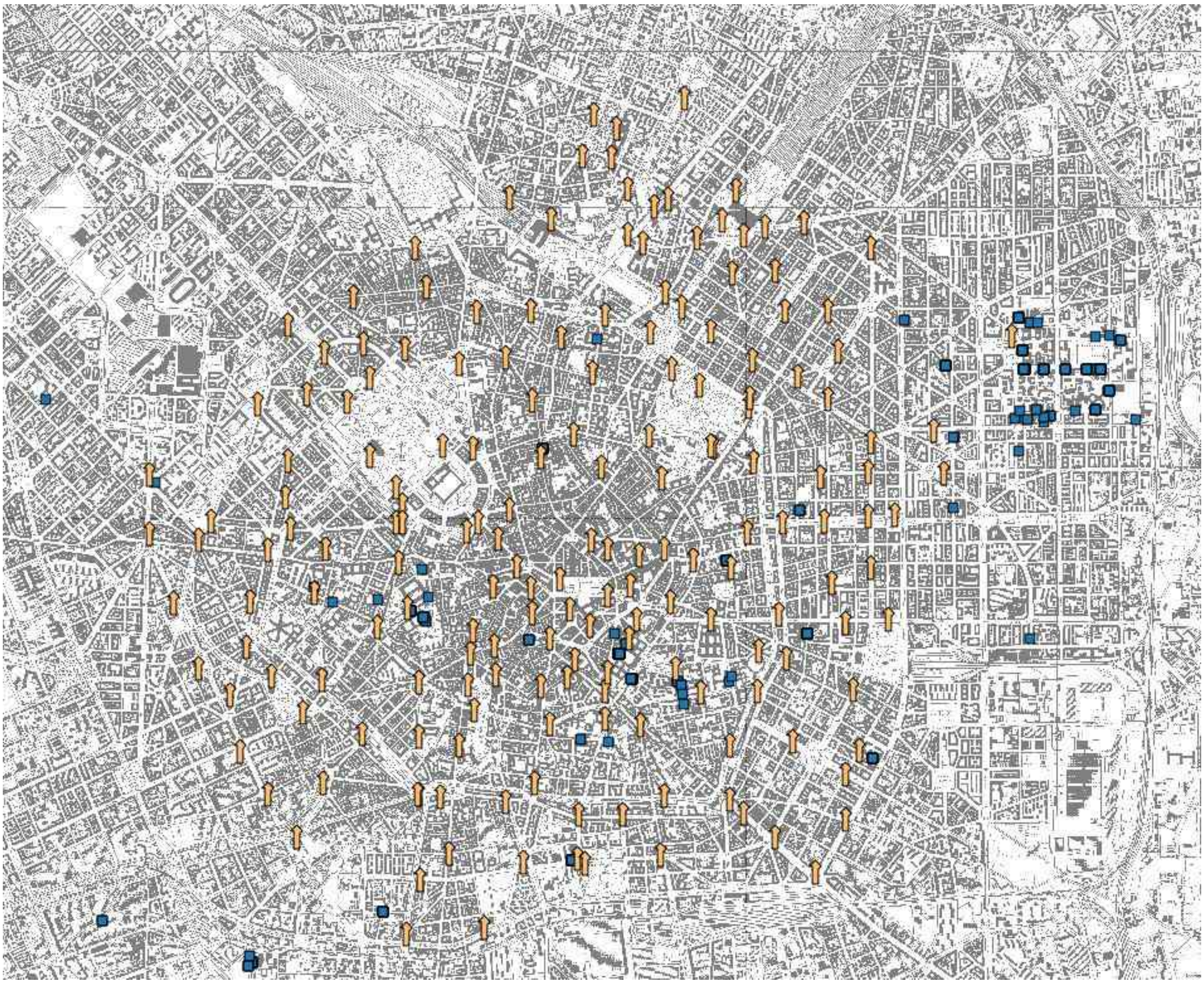


Figure 16: BikeMi stations and universities

Electronic copy available at: https://ssrn.com/abstract=2461179

References:

- Bryant James Jr. (2013), “Finding the optimal locations for bike sharing stations: a case study within the city of Richmond, Virginia”, Thesis submitted to the Graduate Faculty of George Mason University.
- Chen Francis (2013), “A GIS Suitability Model on Optimal Locations for Bike-sharing Stations: A Case Study in the City of San Francisco”, Undergraduate, University of California Berkeley.
- College of Built Environments University of Washington, Bike-Share Studio Department of Urban Design & Planning. “Seattle Bicycle share, Feasibility study”, 2010.
- Daddio David William (2012), “Maximizing bicycle sharing: an empirical analysis of capital bikeshare usage”, A Master’s Project submitted to the faculty of the University of North Carolina at Chapel Hill, 2012.
- DeMaio Paul (2009), “Bike-sharing: History, Impacts, Models of Provision, and Future”, Journal of Public Transportation, Vol. 12, No. 4, 2009.
- DeMaio Paul and Gifford Jonatan (2004), “Will Smart Bikes Succeed as Public Transportation in the United States?”, Journal of Public Transportation, Vol. 7, No. 2, 2004.
- Feasibility Study for the Implementation of a Bike Share Service in Ottawa-Gatineau, November 2009.
- Garcia-Palomares Juan Carlos, Gutiérrez Javier, Latorre Marta (2012), “Optimizing the location of stations in bike-sharing programs: A GIS approach”, Applied Geography, Vol. 35, pp. 235-246, 2012.
- Handy Susan L., Xing Yan and Buehler Theodore J. (2010), “Factors Associated with Bicycle Ownership and Use: a Study of Six Small U.S. Cities”, Transportation (2010) 37, pp. 967-985.
- Heinen Eva, Van Wee Bert and Maat Kees (2010), “Commuting by Bicycle: An Overview of the Literature”, Transport Reviews, Vol. 30, No. 1, pp. 59-69, January 2010.

Electronic copy available at: https://ssrn.com/abstract=2461179

- JZTL and Bonnette Consulting (2010), "Philadelphia Bikeshare Concept Study", City of Piladelphia, William Penn Foundation, Bicycle Coalition of Greater Philadelphia, February 2010.
- Lin Jenn-Rong, Yang Ta-Hui (2011), "Strategic design of public bicycle sharing systems with service level constraints", Transportation Research Part E, Vol. 47, pp. 284-294, 2011.
- Maurer Lindsay Kathryn (2011), "Suitability study for a bicycle sharing program in Sacramento, California", A Master's Project submitted to the faculty of the University of North Carolina at Chapel Hill, 2011.
- Midgley Peter (2009), "The Role of Smart Bike-Sharing Systems in Urban Mobility", Journeys, May 2009.
- New York City Dept. City Planning (2009), "Bike-Share, Opportunities in New York City", Spring 2009
- Politecnico of Milan – Poliedra, "Studio di fattibilità di un servizio di bike sharing per la città di Milano", 2007.
- Pucher John and Buehler Ralph (2008), "Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany", Transport Reviews, Vol. 28, No. 4, pp. 495-528, July 2008.
- Quay Communications Inc (2008), "TransLink, Public Bike System, Feasibility Study", March 2008.
- Rietveld Piet and Daniel Vanessa (2004), "Determinants of Bicycle Use: Do Municipal Policies Matter?", Transportation Research Part A 38 (2004) pp. 531-550.
- Rybarczyk Greg and Wu Changshan (2010), "Bicycle facility planning using GIS and multi-criteria decision analysis", Applied Geography, Vol. 30, pp. 282-293, 2010.
- Schou Dan, Bech Dorte, Kristensen Esther, Brandao Luiza Rabelo and Yosefipor Pedram (2011), "Take the bicycle – a project concerning the potentials and challenges in the implementation of a new Bicycle Sharing System in Copenhagen".

Electronic copy available at: https://ssrn.com/abstract=2461179

- Targa Felip, Clifton Kelly J. (2005), “Built Environment and Nonmotorized Travel: Evidence from Baltimore City Using the NHTS”, Journal of Transportation and Statistics, Vol. 8, No. 3, pp. 55-70, 2005.
- Winters Megan, Brauer Michael, Setton Eleanor M. and Teschke Kay (2010), “Built Environment Influences on Healthy Transportation Choices: Bicycling versus Driving”, Journal of Urban Health: Bulletin of the New York Academy of Medicine (2010), Vol. 87, No. 6, pp. 969-993.
- Winters Megan, Davidson Gavin, Kao Diana and Teschke Kay (2011), “Motivators and Deterrents of Bicycling: Comparing Influences on Decisions to Ride”, Transportation (2011) 38, pp. 153-168.
- Wuerzer Thomas, Mason Susan and Youngerman Riley (2012), “Boise, Bike Share, Location Analysis”, Community and Regional Planning, Boise State University, February 2012.

Websites:

- http://en.wikipedia.org/wiki/Bicycle_sharing_system
- http://en.wikipedia.org/wiki/List_of_bicycle_sharing_systems
- http://it.wikipedia.org/wiki/Bike_sharing
- http://www.euromobility.org/Osservatorio50citta/2013_50_citt%C3%A0/record_2013.html

Electronic copy available at: https://ssrn.com/abstract=2461179