THE ECONOMIC IMPACT OF BIKE SHARING IN EUROPEAN CITIES

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Executive Summary

The concentration of the world's population in and around cities implies challenges related to mobility, sustainability and inequality. Public authorities have to tackle these challenges using specific policies. Bike-sharing systems can be part of the policies and thus provide solutions to the challenges. This report aims to analyze the impact of bike-sharing systems promoted by public authorities (institutional bike sharing). The analysis will focus on the socioeconomic dimension of bike-sharing systems, which will enable the positive effects of this service on the economy to be observed. New business models related to bike-sharing systems, functioning mostly as dockless solutions, are being introduced in major urban areas by private operators. These noninstitutional systems are having an impact on the bike-sharing market by offering new services that are disruptive compared to the institutional ones. In that context, this study makes a qualitative analysis of the impact of the noninstitutional dockless bike-sharing systems and of how public authorities are dealing with them.

The socioeconomic dimension has been analyzed for 13 bike-sharing systems in European cities. The results emphasize that every euro invested in bike-sharing public services generates an average impact that ranges from 79 cents to €1.14.

The 13 bike-sharing services analyzed prevented more than 90 premature deaths between 2014 and 2016. Furthermore, when putting these figure in economic terms and merging them, it is evident that the aggregated socioeconomic value of the effects of each euro invested in the 13 bike-sharing programs has an average effect that ranges from €1.37 to €1.72.

The results have been achieved thanks to an analysis that estimates a single and multidimensional monetary indicator capturing the economic effects of the 13 European bike-sharing programs. This indicator consists of two differentiable parts. First, the country-level economic impact of these programs is computed using Leontief input-output techniques in order to estimate the extent to which investment in the bicycle sector mobilizes the other sectors of each country's economy. This appraisal is merged with the estimation provided using the health economic assessment tool (HEAT) created by the World Health Organization. The tool shows the economic value of the health benefits, already translated into monetary terms—that is, the value of a statistical life. A value is obtained for the 13 European bike-sharing programs analyzed in this report.

The success of these public initiatives is of course determined by public support and can form the basis of a niche market to be exploited by private companies. This window of opportunity has been used by large e commerce businesses as part of their marketing strategy and their big-data departments have invested in dockless bike-sharing companies, which have spread their characteristic bikes into many European cities. The emergence of such a disruptive situation has led to several questions with regard to the potential side effects produced by those private initiatives, including their relation with already established public bike-sharing systems. In an effort to shed light on these concerns, this report uses a qualitative methodology based on a short survey and personal interviews in order to learn from the municipalities about how they are facing the situation. The results highlight how dockless models have significant competitive advantages, with the users being able to park bicycles wherever they want (if not regulated). These models' positive effects might be shared for the most part with the institutional and regulated models, although to a different degree, but the negative effects experienced by the unregulated dockless bike-sharing models are not shared. Nevertheless, problems such as the mass saturation of public spaces by noninstitutional dockless bicycles could be solved by implementing several policies, as proposed by public authorities. (These policies can be summed up as improving the regulatory frameworks, in order to guarantee fair competition between the different systems.) Possible policies include creating specific parking areas dedicated to dockless systems, limiting the areas where dockless bicycles can circulate, enhancing the collaboration between public and private agents, and promoting fair competition through a licensing system. All these measures have been proposed by public authorities, with the will to improve the positive externalities of the non-institutionalized and non-properly managed dockless bike sharing and to reduce its negative impacts. The implementation of these measures has yet to be analyzed to assess their effectiveness.

Finally, this report sets out some introductory recommendations. First, institutional bike-sharing seems to be a positive policy, in terms of environmental and health benefits, that public authorities should consider. Second, noninstitutional dockless bike sharing is a reality and, in Europe, there are examples of dockless schemes that are managed correctly thanks to close cooperation with the authorities. Therefore, regulation, negotiation and institutional agreements seem to be the solution whereby public authorities can overcome the challenges that noninstitutional dockless bike sharing poses to mobility in their cities.

1. Introduction

A United Nations report has stated that 54% of the world's population lives in cities and, moreover, conservative projections have estimated that 66% of the entire world population will be living in cities by 2050 (UN 2014). This scenario means that urban mobility, equity and sustainability are socioeconomic and political challenges to be addressed in urban areas. Bike-sharing public systems emerge with the very purpose of confronting these three urban challenges. The main goal of such policies is to increase the public availability of an intraurban mode of transport that would counteract the increasing levels of traffic congestion and the pollution that it brings (ITDP 2013). Under this value proposition, publicly shared bicycles have spread all over the world, especially in Europe, where the number of such systems has increased exponentially rather than in a linear way. (See **Figure 1**)

In an effort to address this gap, this report analyzes the impact of bike-sharing systems in 13 European cities using a two-sided technique. First, it analyzes the impact of investments destined for the implementation of a bike-sharing project on each country-level economy using Leontief input-output matrices Second, this economic analysis is complemented by a quantification of the health benefits that these bike-sharing systems provide to users living in the cities analyzed (Büttner et al. 2011), using the World Health Organization's health economic assessment tool (HEAT) (WHO 2014). Therefore, this document provides a single indicator quantifying the economic value of two of the externalities produced by bike-sharing systems: the economic activity generated by the investment to implement the project itself and then the health benefits obtained by using the service. Thus, this part of the project analyzes the impact of setting up a bike-sharing project and the consequences of its development.

Moreover, the evolution of this service, generally supported by public administrations, has been marked by increased demand, and already the service has resulted in a market niche on which private enterprises have focused their market strategy. The strategy of these private companies has focused on dockless bike-sharing systems, which has spread throughout the world's cities since 2015. Even before 2015, institutionalized dockless bike-sharing systems existed, with companies having partnerships with cities. The disruption of the market has led to a new challenge: How can private initiatives coexist with public bike-sharing systems? Is this a new case of a public administration addressing a challenge first, then driving forward the generation of a private market?

This essay complements the analysis of public bike-sharing systems' socioeconomic effects with an examination of the potential consequences of the disruption of non-institutionalized and non-properly managed dockless bike-sharing systems for city residents and the relationship between the private companies and the public administration. The analysis of those potential consequences has been carried out using a qualitative methodology based on a short survey and personal interviews conducted with individuals in public administrations in order to find out how these organizations evaluate the emergence of private dockless bike-sharing providers, how they deal with the potential externalities produced by these services and what road map they should follow in the process of achieving coexistence between the public and private services .

This document is structured as follows. First, it provides a brief review of the historical evolution of station-based bike-sharing models. Next, the sample of 13 cities with bike-sharing systems is presented, with a detailed explanation of the methodology employed to calculate the economic effects provided by these programs. Then the economic impact of and the health benefits provided by these systems are set out, followed by an analysis of the consequences of improperly managed non-institutionalized dockless bike-sharing programs and their relationship with the public administration.

Finally, to simplify matters, this document defines "institutional bike-sharing systems" as those bike-sharing services that have been implemented or leased by municipalities, regardless of the contractual tool used (outsourcing or public-private partnership). And when this document talks about "noninstitutional dockless bike-sharing systems," this refers to those bike-sharing services that use a dockless model. It should be made clear that some dockless bike-sharing systems are implemented or leased by municipalities but, with the aim of simplifying concepts, this report includes these services in the category of institutional systems.

2. The Evolution of Bike Sharing

Bike-sharing solutions are being implemented in many cities around the world. Europe has been promoting the proliferation of these transportation systems, and many European cities have started their own public bike-sharing services. With some exceptions, the mass adoption of these solutions has taken place since the year 2000. The city of Paris was a turning point, with the great European metropolis opting for a public bike-sharing system in 2007 and pointing the way forward for many other cities on the old continent. However, Paris was not the first, as other cities had already experimented with this type of public-transport solution.

2.1. The First Generation of Bike Sharing (Mid-1960s)

Amsterdam, in the mid-1960s, was where the first generation of bike-sharing systems was implemented (Parkes et al. 2013). The service consisted of dozens of bicycles painted white and spread throughout the city so that anyone could use them for free. The initiative, pioneering at the time, did not have its origins in public institutions wanting to offer a service to city residents. Instead, it was a popular initiative in protest at pollution and fatal accidents caused by motor vehicles, mainly cars. In addition, it served to criticize the quality of public transport at the time. Considering that their purpose was to protest, the white bikes were a success and had a great media impact but the scheme was short-lived because of the city's ban on leaving bicycles in public places without security measures such as a padlock. Nowadays, Amsterdam is widely considered the bicycle capital of the world and, in the Netherlands, there is more than one bicycle per inhabitant.

2.2. The Second Generation (Early to Mid-1990s)

Although its duration was limited, the Amsterdam scheme was not anecdotal but laid the foundation for future, more sophisticated models to appear in later years. In that sense, it was not until the beginning of the 1990s in Denmark that local authorities promoted various local bike-sharing systems (Parkes et al. 2013). The most significant case occurred in Copenhagen, where the city government, with the support of other public administrations and the participation of the private sector, managed to implement a bike-sharing system for mass use. The system started with more than 1,000 bikes and the number had increased to 2,500 by 2003. The model was one of the most representative of the second generation of bike-sharing systems. It introduced docking stations, which were distributed throughout the city, and these were where bicycles had to be parked when they were not in use. As in Amsterdam, it was a free service but users had to make a coin deposit in the docking stations in order to undock bikes each time. The money was refunded when the bike was returned to a docking station so it was a free service that aimed to reduce the use of motor vehicles without seeking to be self-financing.

The fact that the service was free was very attractive from the users' point of view but this proved to be inefficient because it facilitated the emergence of moral hazard. Some people made improper use of the bicycles, monopolizing them for long periods of time without being penalized. The model did not consider any limit to how long someone could use a bicycle. The introduction of docking stations made the system more resistant to theft but, once a bike had been undocked, there was nothing to prevent or discourage theft. This situation could be attributed to user anonymity because only a token amount of a coin deposit was required to undock the bikes.

The models that appeared in the mid- and late 1990s are usually referred to as the second-generation schemes of bike sharing. They were operated and funded by local authorities, many of which needed to search for external revenue streams so they could afford to provide the service. The solution came from the advertising sector. The second generation was characterized by the incorporation, for the first time, of private advertising directly on the bicycles. This helped to finance the service without the need to charge users. That was how the bike-sharing system operated in the city of Copenhagen, the scheme being owned and operated by the local government itself. Copenhagen's bike-sharing system was the first large-scale system in Europe where the bikes had private advertising on their wheels and frames. The participation of private companies in the funding scheme of this particular bike-sharing program and in other second-generation models meant direct collaboration between the public and private sectors. This laid the foundations for further and more extensive partnerships between both sectors in the following years. However, private participation was still limited. Private companies only paid for the advertising space on bicycles, while the local government was in charge of providing and maintaining the docking stations and bicycles. However, the revenues from the advertising did not cover the overall costs of the service because users were not paying anything. The external revenues were helpful and mitigated some of the costs but the role played by private companies was not as significant as it would be in future generations.

The inclusion of advertising affected the bicycle design. Now, bicycles were designed with four main purposes. The first was to provide user-friendly bicycles that could be docked and undocked easily from the docking stations. Second, a minimum degree of comfort was required, so the bicycles had to be comfortable to ride and ergonomically designed to an acceptable standard. The third purpose was to achieve a unique design to identify the bicycles as part of the bike-sharing program. It would help prevent theft if anyone could associate the bicycles with the service. A special design with unique pieces also eliminated any compatibility with other designs. Because some of the pieces could be used only by the bicycles of the bike-sharing system, the bicycles would be less attractive as a source of spare parts for other bicycles. The aim of getting rid of reasons for stealing the bicycles was achieved but only partially, due to the anonymity of the user, as explained previously. A fourth purpose was to allow private companies to place their advertising on bicycles, which became a marketing tool, a factor that determined their structural design. For example, the spokes were replaced by discs, facilitating the incorporation of advertising on the wheels.

2.3. The Third Generation (Late 1990s to Present)

In later years, newer models appeared and tried to improve two key aspects of bike-sharing systems. The first aspect refers to the profitability of the model. Second-generation models could not be profitable by themselves as they were free services that depended on public subsidies, with grants covering 80% of the costs (Coles 2012). However, from the operator's perspective, third-generation models proved to be more profitable and financially sustainable due to the diversification of the revenue streams. Bike sharing became a paid-for service, funded by its users, public authorities and advertising. The second aspect refers to the quality of the service in all its facets, such as the quality of the bicycles and the docking system. The goal in that respect was to attract users with a more competitive value proposition.

The incorporation of technological solutions throughout the entire conceptualization of the model can be considered the most defining characteristic of the third-generation models. The first model in this category was implemented in Rennes, northwest France. It launch in 1998 coincided with the huge increase in Internet use among the public, with the installation of the Internet in many homes. The system in Rennes was the first to take advantage of the opportunities that the Internet and technology in general brought to the bike-sharing industry.

With this typical payment model, users need to create a personalized account on the Internet and use this to carry out any transactions. The introduction of technological interfaces completely revolutionized bike sharing in a positive way. The two aspects targeted for improvement in the third-generation models—service quality and profitability—were satisfied thanks to technology. As third-generation models were implemented and their technologies improved, web services offered more possibilities and improvements as well. Nowadays, users can access a website to check the status of the service, inquire about the availability of bicycles in a specific docking station or manage their user accounts and interact with the operating company.

In the case of Rennes, the users did not have to pay for the service as it was not yet a paid-for service. However, the program was a pioneer in forcing people to register and create their own user accounts in order to use the service. This eliminated one of the problems of first- and second-generation models, where users were totally anonymous.

In terms of the operator, the business model also evolved. The private sector was fully involved, presenting its own proposals for operating the bike-sharing public service. In some cases, the service was awarded as a concession by local administrations to private operators, which then became responsible for all the operations of the service—that is, providing and maintaining bicycles and docking stations and charging users fees. In some cases, advertising companies would bid for the concession. There are several examples of advertising companies with the role of service operators that indeed managed to maximize their revenues by combining fees paid by users with advertisements on bicycles. (See **Exhibit 1** for more context on the different business models of third-generation institutional bike sharing.)

2.4. Dockless Bike Sharing: The New Mainstream?

New and disruptive business models, capable of meeting some of the demand that the previously existing institutional models cannot satisfy, have appeared in different cities in Europe, North America and China. Dockless solutions, as the term indicates, do not depend on docking stations. Therefore, people living far away from such stations might represent potential new demand. These noninstitutional and privately managed models have penetrated European cities in ways that are sometimes unexpected both for the city authorities and the operators of bike-sharing programs with docking stations. This has generated a paradigm shift in terms of how people use public bicycles and in terms of how those bicycles are provided to them. A fully independent bicycle that can stay locked while waiting for a user, without the need to be in a docking station, characterizes this new type of business model. Each bike has its own locking mechanism, which immobilizes the rear wheel when no customer is using the cycle. Using a mobile-phone application and a QR code, people can unlock a bike and use it without having to go to a docking station. The noninstitutional versions of such dockless bike-sharing models are based fully on private funding, with, in many cases, no public involvement of any kind. Free-floating dockless business models are, in fact, real locking systems without docking stations. In that respect, is this model sufficiently disruptive to become the next mainstream generation of bike sharing?

2.5. Direct Beneficial Effects and Positive Externalities of all Bike-Sharing Types of Systems

This section lists some of the potential benefits and positive externalities of a bike-sharing system. Some of them are more realistic, such as a real increase in bicycle use, but other effects, such as a reduction in congestion levels, are more debatable for all types of bike-sharing models, as noted below. While it is possible to argue in favor of institutional bike sharing in terms of its economic impact, as analyzed in this document, it might be more of a challenge to do so in favor of dockless noninstitutional and improperly managed bike-sharing proposals. The benefits described below can occur to a greater or lesser extent depending on the city and should not be attributed to all bike-sharing systems (Wang and Zhou 2017). For this reason, it might be advisable to study each case individually in order to determine whether each of the following effects and externalities is present.

Increased bicycle use: Bike sharing might stimulate and incentivize people to use bicycles in preference to other means of transportation. Such initiatives might also increase the absolute numbers of people using public-transport solutions, since bike-sharing services are often connected with other means of public transport.

Urban mobility: Bike-sharing programs may help to increase the overall attractiveness of a public transport system. The more options there are to choose from, the better in terms of mobility and complementarity among means of transport. In this regard, the different models of bike sharing represent another transport option, potentially benefiting the entire system of public transport. Municipalities can opt for bike sharing as an incentive for modal interchange between the various public transport services. Institutional systems can be very useful for making collective means of transport less congested, while a dockless model can be especially attractive for the first and final miles of a trip because the fact that it does not depend on docking stations makes it more versatile.

Health benefits: This document has already highlighted the potential benefits of institutional bike-sharing solutions, based on the data collected from 13 different cities. All kinds of dockless solutions, both institutional and noninstitutional, could result in or at least enhance positive externalities with regard to people's health. Some studies (Cavill et al. 2006; Rojas-Rueda et al. 2011; Shaheen et al. 2010) relate improvements in public health to an increase in cycling.

Reduction in traffic congestion: Bike-sharing programs may also help improve road-congestion levels in a city. However, this assumption must be viewed with caution since only a few studies (such as Hamilton and Wichman 2017) back it up. To infer that bike-sharing solutions can translate directly into a reduction in road congestion levels can generate some controversy. Midgley (2011) argued that, on average, there was no significant transition from private vehicle users to bike-sharing systems. López Casasnovas (2009) estimated that, for the city of Barcelona, most users of bike sharing had switched from other types of public transport. That is, bike sharing substituted collective transportation systems such as the bus and metro.

Increased road safety for public and private bicycle users: Some studies (Castro 2011; Anaya and Castro 2012) have noted that an increased presence and visibility of bicycles on the streets makes drivers of motor vehicles respect them more and so makes cycles safer.

Impact on noise reduction: Assuming a potential improvement in traffic congestion caused by the implementation of a bike-sharing system, it may be argued that the fewer motor vehicles on the streets, the less the noise pollution deriving directly from such vehicles.

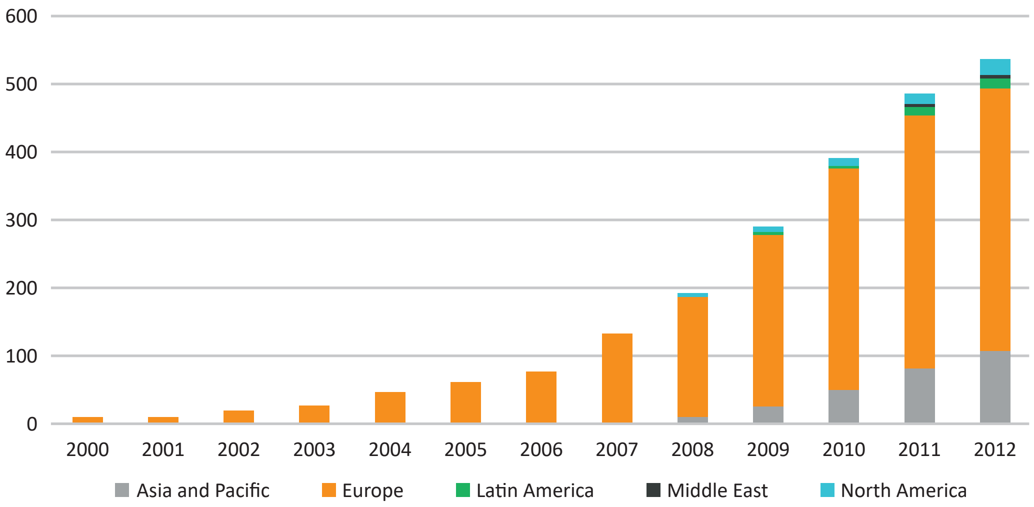
Reduction in polluting emissions: Assuming a positive impact on traffic congestion thanks to the implementation of a bike-sharing solution, the different models of bike sharing can generate positive externalities in the form of fewer emissions by reducing the absolute number of motor vehicles on the streets. Policies favoring bike sharing could also be included in the road maps aimed at fulfilling the United Nations' sustainable development goals from an urban perspective. Nevertheless, further investigation is needed in order to draw conclusions about the cause-effect relationship between bike sharing and a reduction in contaminant emissions in urban areas. DeMaio (2009) attributed a reduction in greenhouse gases directly to bike sharing in the city of Montreal. In parallel, it would be of interest to consider the environmental footprint of manufacturing the bicycles for the publicly operated bike-sharing programs as well as for the dockless models. Many bicycles are produced to deliver the value proposition—that is, the bike-sharing service being offered to potential users to fulfill their transportation needs.

Impact on the economy: In the following analysis of institutional bike-sharing programs, we can see the importance of bike sharing and its potential positive externalities when it comes to the economic impact and value generation. The total economic impact of the public bike-sharing programs might be superior to the required financial investment, which will be the conclusion reached for the 13 cities being studied. With a similar value proposition, it may be possible to draw the same conclusion for the dockless bike-sharing models but cautiously. A real positive economic impact of dockless bike sharing is included in this document's list of potential positive externalities but this cannot be assured without specific and in-depth analysis. Future studies could develop their own theses. The business models applied by some noninstitutional dockless operators also mean there are some obvious negative externalities to consider. Section 5.2 of this document is dedicated to describe some of these inefficiencies.

Sample: 13 European Cities

As mentioned in the previous section, dock-based bike-sharing systems have spread over Europe more than over any other area of the globe. The near-exponential growth of the number of European cities with bike-sharing systems (see **Figure 1**) justifies the selection of European cities to analyze such systems' economic impact.

Figure 1. Number of bike-sharing programs by region (2000–12)



Source: Prepared by the authors using public data from Earth Policy Institute.[1]

This section focuses on describing the cities in the sample. The original sample had 30 cities. Difficulties at the time of contacting the public and private authorities responsible for providing the bike-sharing service reduced the sample to 20 cities. The low response rate and the lack of available data from the various city-level public authorities led to the number of cities being cut further to the 13 now being analyzed. As **Table 1** shows, cities with different socioeconomic and demographic features have been included—from regional capitals such as Bilbao and Turin to some of the largest European capitals such as London and Paris. However, the disparity within the group is limited by three basic requirements that all the selected cities meet:

- Each city is in a member state of the European Union.
- Each is a capital of the member state or at least a large city in the country.
- Each has a bike-sharing system (whether for pedal bikes or electric bikes).

Table 1. Main socioeconomic features of the 13 cities in the sample

	City	Population (inhabitants)	Population density (inhabitants per m²)	Average monthly net salary (2015)	Unemployment rate (2012)
1	Barcelona	1,608,746	15.92	€ 1,394.97	16.8%
2	Madrid	3,165,541	5.4	€ 1,615.60	16.4%
3	London	8,630,000	1.51	€ 2,738.16	6.2%
4	Berlin	3,520,031	3.94	€ 2,042.63	10.0%
5	Paris	2,220,445	21.61	€ 2,356.16	11.8%
6	Vienna	1,766,746	4.55	€ 1,975.43	12.3%
7	Bilbao	345,122	8.73	€ 1,574.51	19.1%
8	Cologne	1,060,582	6.8	€ 2,350.00	6.6%
9	Milan	1,345,851	2.78	€ 1,557.67	6.9%
10	San Sebastián	186,064	3.68	-	12.6%
11	Hamburg	1,787,408	6.01	€ 2,236.67	5.0%
12	Copenhagen	1,268,000	6.8	€ 2,817.11	7.7%
13	Turin	890,529	6.93	€ 1,420.00	9.8%

Source: Prepared by the authors, using sources listed in subsection 3.3, "Data Collection."

[1] Based on research by the urban transport adviser Peter Midgley, email message to Janet Larsen of the Earth Policy Institute, March [date], 2013.

Table 1 provides information about the socioeconomic profile of the cities in the sample. As shown, the average salary and the unemployment rate can vary substantially among the cities. The average salary of the sample cities for 2015 was €1,895.69. The city with the lowest salary was Barcelona, at €1,394.97, and the highest salary corresponded to Copenhagen, at €2,817.11. Regarding the unemployment rate, significant differences were found between German cities with unemployment rates lower than 7% and Spanish cities with rates above 16%.

This study also incorporates different bike-sharing systems. **Table 2** provides information about several categories defined in the previous section. It is worth observing how the operators contracted by the city councils vary in nature. Several private operators are prevalent in the sample while some cities provide the service through a fully public system or rely on a public-private partnership (PPP). The number of bikes is shown, with a minimum of 125 and a maximum of 18,200. The average for all 13 cities in the sample is 4,109 bicycles per bike-sharing system. The launch year refers to the first year in which the service could be used by the public. The final column reveals which bike-sharing systems coexist with private dockless bike-sharing systems in the city. This dockless dimension is analyzed in section 5.

Table 2. Main features of bike-sharing systems in the sample cities

	City	Name of the bike-sharing system	Launch year	Operator	Type	Stations	Number of bikes	Dockless program (as of 2018)
1	Barcelona	Bicing	2004	JCDecaux	PPP	477	6000	No
2	Madrid	BiciMAD	2014	EMT Madrid (municipal transport company)	Public	165	2028	Yes
3	London	Santander Cycles	2010	Transport for London	Public	800	12000	Yes
4	Berlin	Call a Bike	2005	Deutsche Bahn AG	PPP	150	2000	Yes
5	Paris	Vélib’	2007	Smovengo	Private	1229	18200	Yes
6	Vienna	Citybike Wien	2004	Gewista	Private	121	1500	Yes
7	Bilbao	Bilbon Bizi	2011	Bilbao City Council	Public	31	200	No
8	Cologne	KVB-Rad	2015	KVB (Kölner Verkehrs-Betriebe)	Public	23	1410	Yes
9	Milan	BikeMi	2008	Clear Channel	PPP	283	4650	Yes
10	San Sebastián	dBizi	2013	JCDecaux	Private	16	125	No
11	Hamburg	StadtRAD Hamburg	2009	Deutsche Bahn AG	PPP	212	2450	Yes
12	Copenhagen	Bycyklen	2016	GoBike	PPP	105	1860	Yes
13	Turin	[TO]Bike	2010	Municipality of Turin	Public	133	1000	Yes

Source: Prepared by the authors, using sources listed in subsection 3.3, “Data Collection.”

The amount invested in each program is one of the most important dimensions of this study because it is used to calculate the economic impact of bike-sharing systems on the country-level economy. The quantity used in the analysis of the economic impact consists of the whole amount invested throughout the project so the quantity cannot be assigned to a specific year. This makes it impossible to express amounts in purchasing parity power for the euro in a single, common year. For instance, the amount invested in the Vélib’ system in Paris is calculated in 2007 euros, while the quantity invested in Barcelona’s Bicing has been expressed in 2004 euros. This disparity is justified because the bike-sharing projects did not all start in the same year. However, the health benefits resulting from the use of bike sharing are calculated for the years from 2014 to 2016 inclusive.

In addition to the variations among the cities in the sample, a caveat about this study could be the lack of representativeness of the sample. This enables us to approach the project only as a case study of the 13 cities. Further research should address this issue by including more cities and a larger amount of data. However, this research provides a first insight for a case study about the quantification of two economic effects (the effect on the economy and the monetary value of the health benefits obtained by using the bike-sharing system), combining different techniques and methodologies. As stated in the introduction, the success of these programs generated a market window for the appearance of a new generation of private companies providing bike-sharing services, most of them on a dockless basis. The disruption of these companies in European cities not only had consequences for public bike-sharing systems but also altered patterns of mobility and public order. This disruptive phenomenon is also analyzed for the cities described previously.

3. Economic Impact of Bike-Sharing Systems

The high predicted levels of populations concentrated in cities present an infinite set of questions and challenges to be solved, as stated in the introduction. Pollution, traffic congestion and mobility are some of the most important. Bike-sharing programs have been mentioned as a solution. As indicated in **Figure 1**, this recipe has spread to cities across the globe to a remarkable degree. More than 800 cities have bike-sharing systems (Earth Policy Institute 2013). Furthermore, as **Figure 1** also shows, many of these bike-sharing programs are in European cities.

In line with the challenges arising from the urban concentration of the world's population, the spread of bike-sharing programs had several consequences on society. This section aims to quantify two positive social effects caused by bike-sharing programs:

1. The impact of bike-sharing programs on each country-level economy, including the economic activity generated.

2. The health benefits deriving not only from the provision of the service but from its use, which in the long run affects the levels of pollution and traffic congestion by changing city residents' mobility patterns.

This exhaustive methodology has been applied to analyze the effect of 13 European bike-sharing programs. As described below, the integration of both dimensions makes it possible to estimate some of the effects of the 13 bike-sharing systems with regard to tackling certain social first-order challenges.

The rest of this section is structured as follows: first, there is a short review of the academic literature on the effects of bike-sharing systems. Then the data-collection process is explained and the sources of information used for the analysis are detailed, before the two-sided methodology is set out. The section ends with a presentation of the results obtained using the methodology and the data previously put forward.

3.1. Literature Review

Before the methodology used in this case study is described in detail, it is worth setting out the state of the literature focused on the impact of bike-sharing systems, which can be divided into three main categories:

- Authors in the first category regard cycling as a source of potential savings to public health systems thanks to the prevention of specific premature diseases and deaths (de Nazelle et al. 2011; Rojas-Rueda et al. 2011; Ricci, 2015; Fishman et al. 2015). The World Health Organization (2013) created a tool for evaluating this impact in monetary terms using the value of a statistical life of each country. The present work uses this specific methodology to internalize this positive externality by quantifying it and aggregating the impact in economic terms into the economic impact indicator provided by this work for the 13 cities being analyzed.

- There is another field of literature that examines the impact of bike-sharing programs, as well as cycling in general, with a focus on the mobility problems produced by the existing high concentrations of people in cities. The authors in this category test the improvements provided by bike-sharing systems on transit connectivity and urban mobility (Shaheen et al. 2013) by looking at the average time spent commuting and then translating the time savings into economic terms. This methodology requires survey-level data in order to gather inferential statistics to make it possible to identify the causal relationship between bike use and car use and then that between bike use and savings in time spent commuting. The lack of public surveys on mobility for the 13 cities in the sample prevents this document from including such analysis.

- Some of the latest work on the economic impact of bike-sharing programs has noted the spillover effect produced by the new flows of transport and people generated by the presence of bike-sharing stations near specific local businesses or neighborhoods. The results, some of which are obtained from survey data (Wang et al. 2016), show that local businesses close to bike-sharing stations sell more on average than they did before these mobility flows were in the vicinity. Moreover, it has also been shown that the presence of new means of transport, such as the bicycles in bike-sharing stations, tends to push up apartment prices (Pelechrinis et al. 2017).

Departing from the analyses described above and lacking representative individual city-level survey data, this report provides a new perspective for analyzing the economic impact of bike-sharing systems. The best scenario would have been to have individual-level data, gathered through city-level surveys, about commuting and transport patterns before and after the launch of a bike-sharing system. With such data, it would have been possible to test for the existence of differential transport behaviors and therefore to estimate time savings and real mobility patterns.

The economic impact assessment has been carried out by merging the effect of the investment needed to implement each bike-sharing system in the country-level economy with the health benefits arising from the systems' use. This report presents this analysis for the public bike-sharing systems in the 13 European cities studied.

One of the added values provided by this methodology is the inclusion of the project's impact on the overall economy, which is assessed using the Leontief input-output matrix technique. The academic use of this methodology is quite extensive in the economic-impact literature. For instance, the technique has been used to examine the impact of tourism programs (Atan and Arslantürk 2012) and the coal industry (Ivanova and Rolfe 2011). The Leontief input-output methodology relies on the interdependence of different economic sectors of a closed national economy to estimate the economic effect of increased demand in a specific sector on the whole economy. The cross-sector coefficients of interdependence are calculated at the country level. This is why the Leontief methodology assumes that the economies are "closed." The assumption is that investment is injected into the national economy and therefore affects the various national economic sectors. This approach is not without weakness but it is useful for finding out how the investment used to launch the bike-sharing programs affects the seven European economies being analyzed.

3.2. Methodology

As discussed previously, the purpose of this essay is to provide a picture of the effects of bike-sharing systems. For this task, it includes the purely economic impact of each bike-sharing project on the country's economy, together with the health benefits obtained by the physical activity resulting from the use of public bike-sharing systems.

The first part, on the economic impact, is obtained by applying Leontief input-output matrices that capture the economic interdependence between the different economic sectors. This makes it possible to assess the economic activity generated by each bike-sharing project for the whole country's economy.

For the health effect, this analysis relies on the WHO tool HEAT to compute the impact of bike-sharing use on the number of premature deaths prevented. This tool also provides the monetary value of the number of premature deaths prevented thanks to physical activity by translating the value of each life using the country-level estimations of the value of a statistical life presented by the Organization for Economic Cooperation and Development (OECD).

Both calculations, once translated into monetary terms, are aggregated into a single indicator, expressed in euros.

To avoid possible mismatches, the following section describes in detail how the two different dimensions are computed and integrated.

3.2.1 Analysis of the Economic Impact: Leontief Input-Output Technique

To evaluate the infrastructure's economic impact, the use of input-output tables is proposed. This methodology makes it possible to assess how changes in one sector affect the economy as a whole (Kweka et al. 2003).

The input-output framework's fundamental purpose is to analyze the interdependence of industries in an economy (Miller and Blair 2009). The basic idea is to represent all the transactions of an economy in an input-output (IO) table. Essential data in the analysis include the monetary values[2] of transactions between pair of sectors. The data are completed with the sectors' sales to the final demand (households, the government, exports, etc.), inputs that are not purchased from other sectors (labor, capital, imports, etc.) and imported goods[3].

The rows of the matrix represent the final sales of each sector *i* to the other sectors of the economy *j* (z_{ij}) and to the final demand sector *(f)*; the columns, the purchase of each sector *j* of intermediate goods and payments to labor, capital and others. The structure of the IOT implies that the total value of inputs purchased (q_j) is equal to the total value of output (Kweka et al., 2003). Given z_{ij} and q_j, the ratio z_{ij} / q_j represents the share of the input of sector *i* in the total output of sector *j* and is known as the technical coefficient a_{ij}:

$$a_{ij}=\frac{z_{ij}}{q_j} \qquad (1)$$

Technical coefficients represent fixed relations between inputs and outputs. This means that, in the input-output framework, economies of scale are ignored and constant returns to scale are assumed. Then the total structure of the economy could be represented as:

$$q = Aq + f \qquad (2)$$

Where q and f are vectors of total output and final demand, respectively, and A is the matrix of technical coefficients.

Moreover, this equation could be arranged as follows to assess the total change in output due to a change in final demand:

$$f = (I - A)q \qquad (3)$$

With I being the identity matrix. *(I – A)* is a singular matrix and its inverse exists:

$$q = (I - A) - 1 f \qquad (4)$$

And

$$q = Lf \qquad (5)$$

L is known as the Leontief inverse or total requirements matrix. Each element of $L(l_{ij})$ measures the impact in the total output of sector *i* when the final demand of sector *j* changes ($l_{ij}= \delta q/\delta f_j$). The total output multiplier of a sector *j* is the sum of the intra-industry impact and inter-industry impact of a change in the final demand of sector $j(Lj= \sum i\ l_{ij})$. Intra-industry when *i=j*; and inter-industry for all *i≠j*.

Hence, the Leontief matrix shows the extent to which the demand worth an extra euro in a given sector involves an increase in economic activity in the same sector and in the other economic sectors.

The multiplier notion is supported by the difference between the initial effect of an exogenous change and the total effect of that change. The total effects can be defined either as direct plus indirect effects in an open model or as direct plus indirect plus induced effects in a closed model with respect to

[2] Monetary values are used to solve measurement problems, although physical measurements would better reflect the use of one sector's product by another sector.
[3] For a detailed explanation of the input-output model, see Miller and Blair (2009). For an explanation of the OECD matrices used in the analysis, see "Input-Output Tables (IOTs)," OECD, 2018, http://www.oecd.org/trade/input-outputtables.htm.

households (Miller and Blair 2009). Recall that direct effects refer to the direct impact on the sector that initially received the investment associated with the project. Indirect effects refer to the impact arising from changes in activity among suppliers in the sector that received the investment in the first place. Finally, the induced effects reflect the boost provided by the relative increase in consumption, estimated based on the increase identified in the number of newly employed workers resulting from the initial exogenous change. **Table 3** provides a brief outline of each type of impact.

Table 3. Simplification of the different economic effects identified using input-output tables

Direct effect	Presents the value of the net economic activity generated by the bike-sharing project into the economic sector "*C35 – Other transport equipment*" itself.
Indirect effect	It refers to the impulse that the investment provided by the bike-sharing project gives to the economic sectors interrelated to the bicycles' production economic sector. Using the Leontief input-output table of multipliers, the impact is presented in monetary terms. This effect can be defined as the new demands originated in the rest of the economic sectors to satisfy this new and external investment.
Induced effect	This third and last effect constitutes the increase in the overall demand provided by the relative increase in household's consumption identified in those new jobs.

The analysis shows both options. That is, the total impact is set out taking into account induced effects as an upper bound and without induced effects as a lower bound for multiplier effects. The reason for considering both scenarios is twofold. Excluding induced effects might underestimate the total impact on the economy, while including induced effects might overestimate the impact. Recall that the calculation of induced effects assumes that new salaries are spent entirely on consumption when, in reality, some of the expenditure goes on taxes and some of the salary goes on savings (Kweka et al. 2003). This is of particular importance here as the analysis deals with European cities[4]. Additionally, the analysis assumes that the average propensities to consume the output of sector i are constant and equal the marginal propensity to consume (Miller and Blair 2009). So far, the overestimation of the economic impact when induced effects are included have made researchers consider only the simple multipliers when choosing the impact (Kweka et al. 2003).

These economic effects are quantified using the latest Leontief input-output tables publicly provided by the OECD Structural Analysis (STAN) databases, corresponding to the 2010–15 period. The data used correspond to the symmetric Leontief matrix for the domestic economies involved in the analysis. This study follows the United Nations Statistical Commission (2002) classification of economic activities per sector to assort the investment related to bike-sharing projects within the economic activity that involves bicycle manufacture, which is in economic sector C35.9, "manufacture of transport equipment." The matrices correspond to the national economy structure and not to the regional level. The impact calculated, therefore, cannot correspond with the actual economic impact of the investments within the sampled cities[5]. However, the analysis benefits of using OECD matrices as the source of information are the same for every country involved in the analysis. Moreover, using these matrices makes it possible to compare the economic impact of institutional bike sharing among the seven countries in the analysis.

To complement the matrices, Eurostat figures on the total employed population in the year 2016 and the domestic final expenditure of households in 2010 are used to estimate the induced effects and the number of jobs generated by the bike-sharing projects in the economy. Different dates are used for the two sets of figures because of a lack of data for most of the sample.

The estimations are worked out using a two-step method. The first things to be calculated is the country-level output ratio resulting from the direct and indirect economic impact on the total gross

[4] The OECD estimated the saving rate in the Eurozone for 2015 at 5.6% of GDP, with significant differences between countries. For example, the saving rate in Germany was estimated to be 10.1% of GDP, compared to 2.6% in France.
[5] The impact within a region is equal to the impact at national level only if the region's economic structure matches the national structure.

domestic product at country level. Once this ratio has been obtained, it is multiplied by the total number of jobs at country level in order to estimate the employment generated by the project. Likewise, this ratio is multiplied by the total country-level household consumption figures in order to provide an estimation of induced effect, understood as the proportional increase of household consumption resulting from the growth in economic activity. So the estimated induced impact represents the proportional increase in final household consumption with respect to the ratio of the direct and indirect effects on gross domestic product at country level.

The limitations of this estimation highlight how it is assumed that the rated value of direct and indirect effects as a percentage of gross domestic product would be employed in a linear way on jobs and therefore on household consumption. Moreover, the full application of this methodology would assume that the entire value of direct and indirect effects would flow to the consumption of goods and services, with none remaining as savings.

To analyze the project's impact on the economy using the intersector multipliers, it is necessary to know how much has been invested in each bike-sharing project. The project-based nature of this kind of investment led to the methodology being used to test the overall investment instead of the yearly costs. This information has been provided, subject to a confidentiality clause, mostly by public administrations or private operators in the case of PPP relationships between the provider and the public authorities. Subsection 3.3, "Data Collection," shows the each city's sources for each dimension relevant to this study.

3.2.2 Analysis of the Health Benefits

The analysis of the impact on the overall economy is complemented with the quantification of health benefits obtained from using the bike-sharing systems (de Nazelle et al. 2011). In an effort to translate the effect on city residents' health of using bike-sharing systems into euros, this research uses the World Health Organization tool HEAT. The tool provides a specific configuration for assessing the specific impact of cycling. The estimation provided by the tool can be broken down into three parts, as shown in **Table 4**.

Table 4. Components of the HEAT estimation

Physical activity	This dimension estimates the reduction of risk of all-cause premature mortality for commuters using bicycles with respect to other modes of transport. HEAT tool corrects by each city's average distances.
Traffic mortality risk (discount)	This discount coefficient is obtained from the difference between the all-cause mortality in road traffic for cyclist and car drivers' mortality risk.
Exposure to air pollution (discount)	This value discounts for the extra quantity of polluted air inhaled by cyclists with respect to other modes of transport.

Quantifying these three effects using the methodology involves three main steps:

- First, the number of premature deaths prevented by the physical activity is quantified. In line with the conclusions of Rojas-Rueda et al. (2011), the HEAT methodology applies a specific weight to the results, which depends on the number of users of bike-sharing systems whose previous mode of transport already involved them being active. HEAT also weights the number of deaths prevented by the physical activity according to the age distribution of the bike-sharing systems' users, which is basically concentrated in the population aged 16 to 30 (Celis-Morales et al. 2017).
- In a second stage and in order to get a realistic estimation of bike use in cities, HEAT applies the two discounts already shown in **Table 4** to the weighted estimation of the physical benefits obtained by using bike-sharing systems. First, this coefficient is discounted for the extra crash risk of cyclists with respect to car drivers, taking the latter as the base category. A second discount is applied to account for the greater amount of polluted air inhaled by riders as a consequence of doing physical activity in highly polluted contexts (de Nazelle et al. 2008).

- The last step is to translate the value of preventing premature deaths through physical activity into euros using the value of a statistical life (Fishman et al. 2015; Lindsay et al. 2011). Obtaining this final value in euros allows this analysis to get a single and multidimensional monetary indicator of bike-sharing programs' socioeconomic effects.

3.3. Data Collection

The reliability of the numbers provided by this study rests basically on the source of the figures and the matrices and algorithms used to obtain the results. For that reason, this subsection details the source of every piece of information used in this essay.

First, the socioeconomic information about the cities in the sample has been obtained mostly from Eurostat, specifically from the Urban Audit and Urban Europe sections. This information has been complemented by the Numbeo free-access data set to complete the information about the average net salary in each city. These sources are detailed in **Table 5**.

Table 5. Sources of the main city-level socioeconomic figures used in the essay

	City	Population [urb_cpop1]	Population density at the regional level [reg_dempoar]	Average monthly net salary (2015)	Total deaths under 65 years old (2014) [urb_cfermor]	Unemployment rate (2014) [urb_clma]
1	Barcelona	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
2	Madrid	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
3	London	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	-	Office for National Statistics - LFS: ILO unemployment rate
4	Berlin	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
5	Paris	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
6	Vienna	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	-	Eurostat - Urban audit
7	Bilbao	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
8	Cologne	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
9	Milan	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
10	San Sebastián	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit
11	Hamburg	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit (year 2011 for the sake of availability)
12	Copenhagen	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	-	LSE Cities - Copenhagen. Stat from 2012
13	Turin	Eurostat - Urban audit	Eurostat - Urban Europe	Numbeo: Free-access data sets	Eurostat - Urban audit	Eurostat - Urban audit (year 2011 for the sake of availability)

These figures are used in this work to provide a sociodemographic description of the cities in the sample. However, these descriptive statistics are not involved in any of the various steps used to calculate either of the two main economic effects of bike-sharing systems—that is, the health benefits and the impact on the economy—set out in this essay. The estimations of the socioeconomic effects of bike-sharing systems have been obtained using tools and data from a variety of sources.

The health benefits obtained by using bike-sharing systems have been calculated using HEAT, the free-access tool created by the WHO. This tool has provided the estimation for each of the 13 cities in the sample. The data used to obtain these estimations were the number of rides per day and inhabitant. The data sources for the cities are shown in **Table 6**, together with the other descriptive dimensions of the 13 bike-sharing programs analyzed.

Table 6. Data sources for bike-sharing features in this analysis

	City	System name	Project investment	No. of users and rides per year	Launch year	Operator	Type	No. of bikes and stations	Existence of dockless companies
1	Barcelona	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
2	Madrid	bikesharingmap.com	Official reports	Public authority	Public authority	Public authority	Public authority	Public authority	Media
3	London	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
4	Berlin	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Media
5	Paris	bikesharingmap.com	Media: New York Times	Academic sources	Academic sources	Academic sources	Academic sources	Academic sources	Media
6	Vienna	bikesharingmap.com	Media: interview with the official operator	Public authority	Operator	Operator	Operator	Operator	Operator
7	Bilbao	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
8	Cologne	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
9	Milan	bikesharingmap.com	Operator	Operator	Operator	Operator	Operator	Operator	Media
10	San Sebastián	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
11	Hamburg	bikesharingmap.com	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority	Public authority
12	Copenhagen	bikesharingmap.com	Estimated from academic research paper	Public authority	Public authority	Public authority	Public authority	Public authority	Media
13	Turin	bikesharingmap.com	Official reports	Official reports	Official reports	Official reports	Official reports	Official reports	Media

Meanwhile, the economic impact of each bike-sharing project combines three main sources of information:

1. The country-level Leontief input-output inverse matrices of intersectorial multipliers, which are obtained from the OECD Data website (https://data.oecd.org/)
2. Country-level figures on employment and household consumption extracted from Eurostat. The origins of the data concerning these two dimensions are detailed in **Table 7**.
3. The figures for each project's investment were obtained from various sources as detailed in **Table 6** and used to calculate each program's economic effect.

Table 7. Sources of country-level data used to calculate the economic impact

Country	Input-output table (2010–15)	Total employed population (2016)	Household consumption (2010)
Spain	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
United Kingdom	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
Germany	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
France	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
Austria	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
Italy	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10
Denmark	OECD - STAN data sets	Eurostat - LFSI	Eurostat - NAMA_10

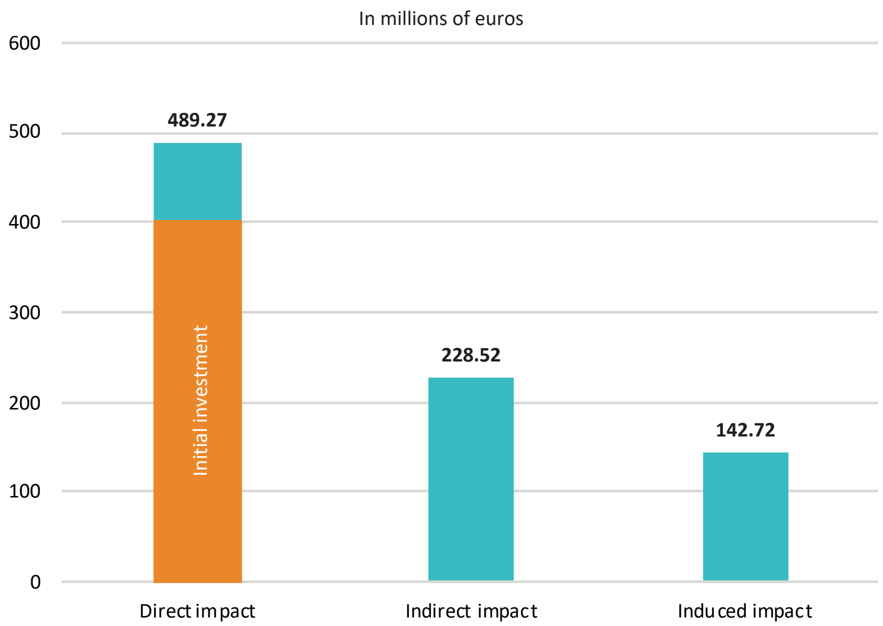
3.4. Results

This subsection shows the results obtained from applying the methodology and the data detailed above. While respecting the confidentiality clause signed with each city in the sample in order to get the financial details of their public bike-sharing systems, this section presents aggregated and anonymized figures for the 13 systems' estimated economic impact. (Sum aggregations are used.) Following the path described in the methodology subsection 3.2, the economic impact results obtained using the Leontief input-output tables will be presented and then the health benefits identified using the WHO tool HEAT. Finally, a complete picture of the multidimensional impact of the European bike-sharing systems will be provided and this can be compared with the investment required, with the purpose of elaborating a first economic balance of bike-sharing systems.

3.4.1 Estimated Impact on the Economy

Figure 2 shows three relevant facts relating to the economic impact of the investment used to implement the 13 bike-sharing systems in the sample.

Figure 2. Economic impact of bike-sharing systems by categories



Source: Prepared by the authors.
Note: The direct impact includes the initial investment.

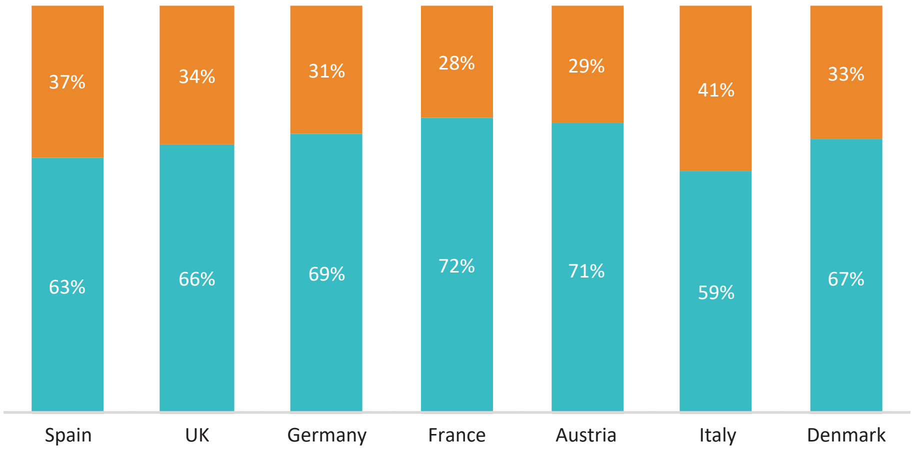
As can be seen in **Figure 2**, the results are broken down into the direct, indirect and induced effects generated by the investment in the 13 projects in the respective country-level economies. Most of the effect relates to the direct impact, at more than €489 million. This includes an initial investment of more than €401 million and a derived impact of more than €87 million. As a result, €2229 million benefits the other sectors of the economy. The direct effect of implementing the bike-sharing system, including investment, in the 13 cities represents 0.004% of the 2016 GDP of the seven countries analyzed. Without the investment, the direct impact is about 0.001%. Moreover, the estimated spillover effect of the project on the whole economy—the indirect effect—would represent 0.002% of the GDP of the seven countries.

The impact on job creation is that around 3,400 jobs are created directly and indirectly as a result of the investment in the 13 bike-sharing systems. The third column of **Figure 2** shows the induced effect, the effect of those new jobs on final household consumption.

Hence, the total estimated impact of the bike-sharing systems in the seven economies has a lower bound of around €718 million, representing 0.006% of the aggregate countries' GDP, and an upper bound of around €860 million, 0.008% of their GDP.

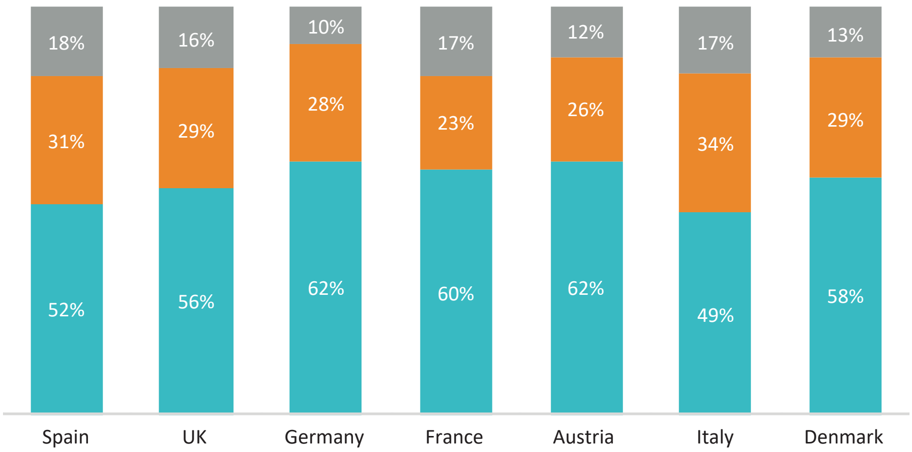
Moreover, the application of the input-output matrix methodology at the country level enables the identification of differences between how European economies react to such investment. **Figure 3** shows the distribution of the economic impact, taking into account only the direct and indirect effects on the seven European countries in the sample. **Figure 4** also takes into account the induced effects. The direct effects include the initial investment in both figures.

Figure 3. Share per category of the total economic impact per country: Direct (blue) and indirect (orange) effects



Source:
Prepared by the authors.

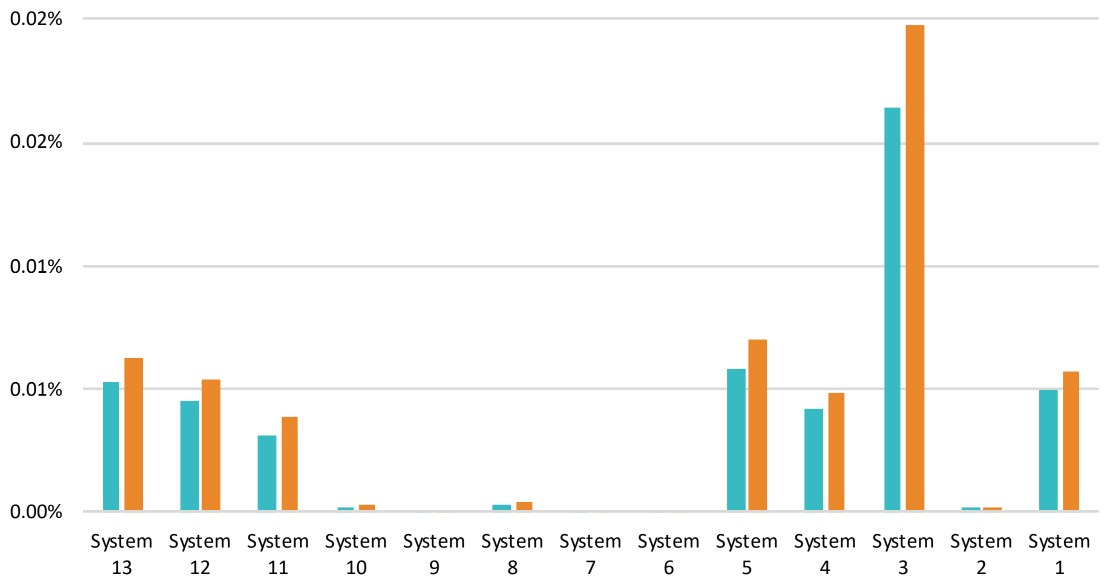
Figure 4. Share per category of the total economic impact per country: Direct (blue), indirect (orange) and induced (grey) effects



Source:
Prepared by the authors.

As can be observed in **Figure 3**, in every case, excluding the induced effects, the impact on the sector of "other transport equipment" (C35) exceeds 50% of the total impact. Nevertheless, the distribution is not homogeneous across the countries. The direct effects account for 59% of the total impact in Italy but 72% in France. The induced effects, as shown in **Figure 4**, vary from a minimum of 10% in Germany to a maximum of 18% in Spain.

Figure 5. Economic impact as a percentage of country-level GDP (2016)

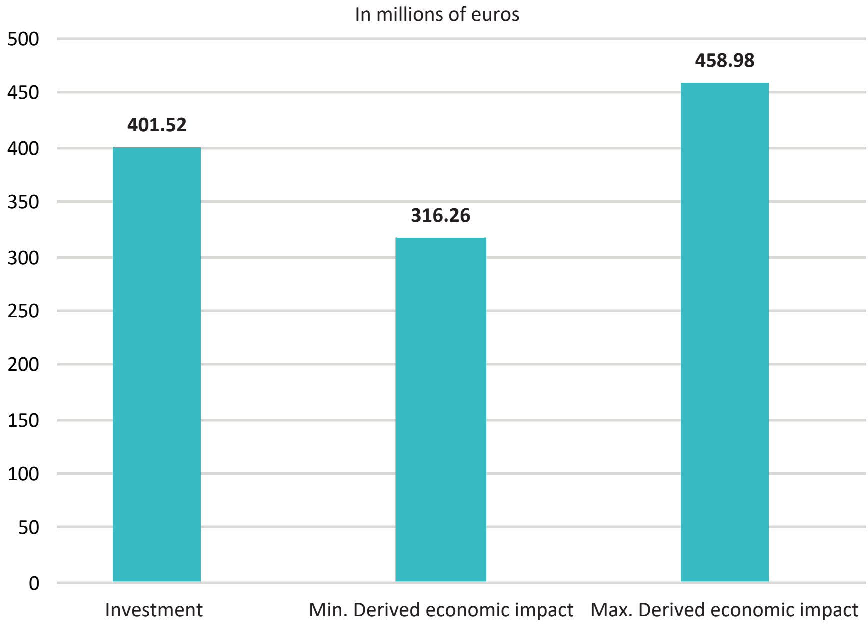


Source: Prepared by the authors.
Note: The lower bounds are blue and the upper bounds are orange.

Figure 5 shows each bike-sharing project's estimated overall economic impact as a percentage of each country's GDP. Recall that the investment is included in the impact estimation. To keep the information provided by the participating cities confidential, the figures have been anonymized. Taking into account the induced effects, the impact as a percentage of GDP is around 0.02% at the maximum. Nevertheless, the 13 systems being analyzed differ significantly in their economic impact. Of course, the share of GDP is conditioned by an infinite list of city and program-level determining factors but it also depends on the dimensions of the country.

With **Figure 5** having shown the heterogeneity of the estimated economic impact of the 13 cities being analyzed, **Figure 6** shows the balance between the estimated lower and upper bounds of the economic activity generated by the investment in bike-sharing systems in the 13 cities as well as the overall amount invested. Recall that the total economic impact includes both the initial and the derived effects. As can be observed, the derived economic impact ranges from around €316 million to almost €459 million. This means that, using Leontief methodology, it is estimated that every euro invested in the 13 bike-sharing programs generates an average impact ranging from €0.79 to €1.14. The Leontief investment multipliers are estimated to be €1.79 and €2.14 respectively.

Figure 6. Comparison between the total derived economic impact and total investment

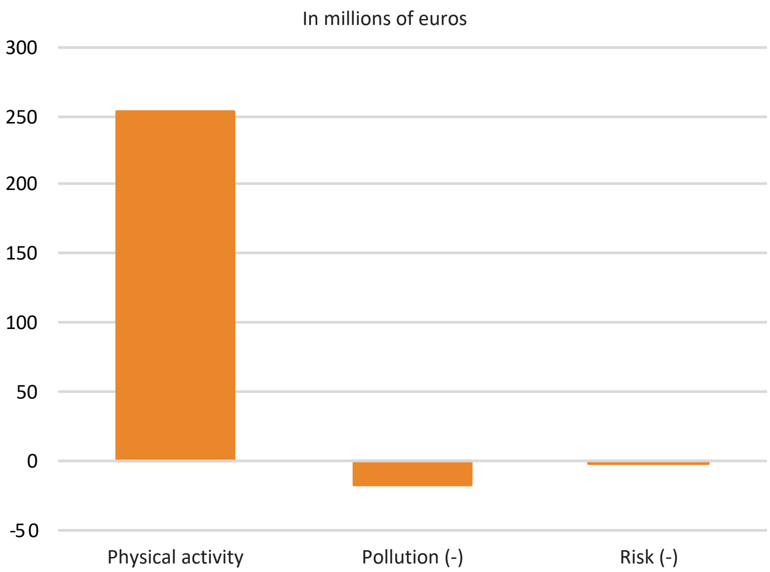


Source: Prepared by the authors.

3.4.2 Health Benefits

This part of the analysis shows the estimated health benefits provided by the physical activity involved in using bike-sharing systems. The figures were obtained using HEAT methodology, a tool that expresses the health benefits in monetary terms.

Figure 7. Health impact of bike-sharing use



Source: Prepared by the authors with usage information.

Although several capital cities[6] are included in the sample of analyzed cities, the effects of inhaling more polluted air and the increased risk of having an accident that exist in such large cities are far from eclipsing the health benefits obtained from the physical activity that bike-sharing systems make possible.

[6] Large European cities have greater levels of air pollution than medium-sized cities or regional capitals so these large cities, on average, have higher discount rates for the increased inhalation of polluted air by those riding bikes rather than walking.

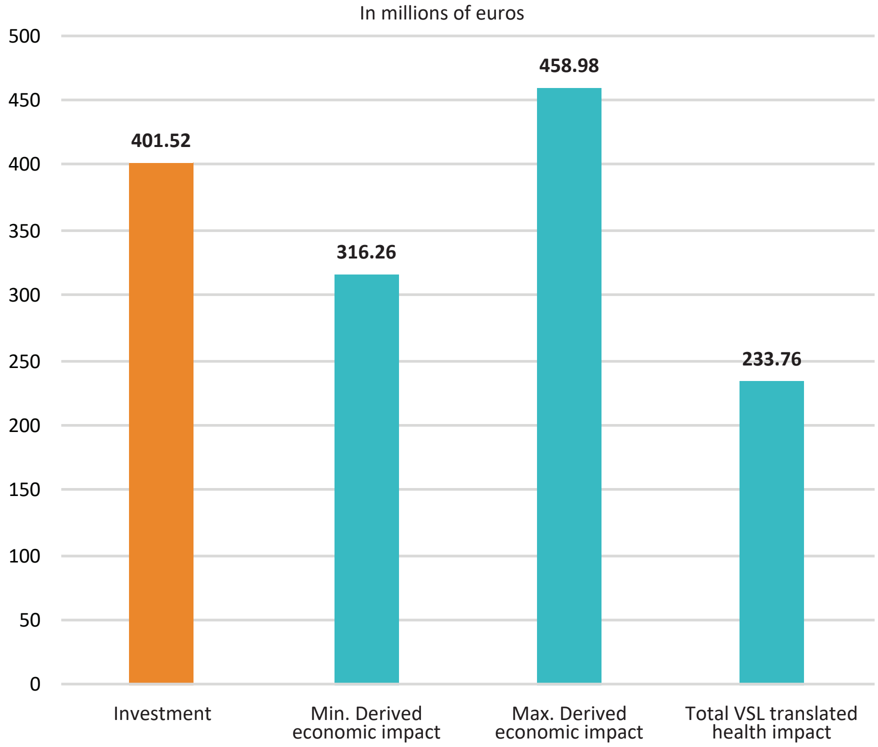
The estimated health benefits obtained by using bike-sharing systems, as calculated using HEAT, are shown in **Figure 7**. The average European value of a statistical life, which is €2.5 million per life according to a report by the WHO (2014, 3), is applied. The HEAT results then indicate that the use of the 13 bike-sharing systems analyzed prevented more than 90 premature deaths between 2014 and 2016 in the 13 cities analyzed. This represents 0.12% of the estimated number of deaths of people under 65 years old[7] in the 13 cities during that time.

Therefore, the application of HEAT methodology identifies the economic value of not only a positive externality but also one of the essential reasons for implementing this kind of public policy. The results provided by the official WHO tool HEAT have shown the value of using bike-sharing systems, in both absolute economic terms and relatively, between 2014 and 2016 in the 13 cities in the sample.

3.4.3 Overall Impact

This subsection brings together the previously presented estimates in a single figure that gives the multidimensional economic value created by the 13 bike-sharing systems analyzed.

Figure 8. Bike-sharing effects and costs in economic terms



Source: Prepared by the authors.

The estimated socioeconomic balance of the 13 bike-sharing systems is shown in **Figure 8**. More specifically, complementary figures are compared in the graph. On the one hand, the investment is shown in green. On the other hand, the estimated positive externalities generated by the 13 bike-sharing systems analyzed are shown in blue: the health benefits obtained from using the systems and the economic activity generated by the investment, according to the input-output methodology's lower and upper bounds. According to the estimations of the two positive externalities provided by the two methodologies, every euro invested in bike-sharing programs has an average that ranges from €1.37 to €1.72 in the 13 bike-sharing programs analyzed.

The results provided by the twofold methodology identify some positive externalities of bike-sharing systems and quantify them. According to the conclusions, the estimated value of these externalities exceeds the investment costs related to the implementation and the service maintenance involved in providing the service.

[7] Eurostat, "Fertility and Mortality – Cities and Greater Cities," data set 1990–2018, https://ec.europa.eu/eurostat/web/products-datasets/-/urb_cfermor.

4. The Noninstitutional “Dockless” Bike-Sharing Systems

New and disruptive business models, capable of meeting some of the demand that previously existing institutional models cannot satisfy, have emerged in different cities in Europe and North America. The way in which these models have penetrated European cities has sometimes been unexpected, both for the city authorities and for the operators of the existing bike-sharing program. This has generated a paradigm shift in terms of how city residents use public bicycles and in terms of how a public bike-sharing solution is deployed. The new type of business model is characterized by a bicycle that is fully independent bicycle of a docking station and can lock itself when waiting for a user. This is possible because each bike has its own embedded docking mechanism, so the rear wheel is immobilized when no customer is using it. Using a mobile-phone application and a QR code, people can unlock a bike and use it without having to go to a docking station. For this reason, such systems are called dockless bike-sharing models. Usually, they are based on entirely private ownership, with no type of public involvement. There are some institutional bike-sharing programs that function with dockless bicycles but there are only a few such exceptions, some of them operating for more than 10 years. These should not be included in the mainstream along with the most recent dockless bike-sharing models, which are characterized by their use of public spaces in an uncontrolled or unregulated way.

Free-floating dockless business models are, in fact, real locking systems without docking stations. In that respect, is this model sufficiently disruptive to become the next generation of bike sharing?

The first objective of this section is to analyze the noninstitutional dockless models, pointing out their strengths and weaknesses in comparison with the traditional docking-station models, as well as their positive and negative effects and externalities in relation to cities and all the agents involved. This analysis will help to contextualize and achieve an understanding of how the municipalities react to the emergence of the noninstitutional dockless bike-sharing models. The cities’ actions and solutions are discussed in subsection 4.3.

This analysis has been made possible thanks to the information obtained from the still scarce literature on dockless systems and to academic studies on bike sharing. In addition, a brief survey (see **Exhibit 2**) was prepared so that representatives of the cities in the sample could express their points of view on noninstitutional dockless bike sharing. Finally, detailed information has been obtained through interviews and the exchange of emails with representatives of some local authorities.

4.1. Competitive Advantages and Disadvantages of Non-Institutionalized Bike-Sharing Dockless Systems

Systems based on a free-floating model represent a paradigm shift for the bike-sharing industry. These are disruptive models, with clear competitive advantages, basically based on their independence of docking stations. However, they also have competitive limitations in comparison with traditional third-generation or institutional models of bike sharing. This subsection summarizes the potential advantages and disadvantages of a noninstitutional dockless model regarding its position in the bike-sharing industry.

4.1.1 Competitive Advantages

No docking stations needed: Dockless models, as the term indicates, do not depend on docking stations and instead bicycles can be docked individually thanks to an embedded locking mechanism. In comparison, conventional docking systems, with bicycles in a regulated system and operational criteria determined by public institutions, can be stored only in predetermined locations. Users may be forced to pick up or park bicycles in places that are not so close to their point of departure or final destination. A docking station also has a limited capacity, forcing users to move to another station if it is already full. Or, on the contrary, users could be left with no bicycles if there are none left. In some cases, institutional dockless systems, or dockless systems functioning in a regulated context, require bicycles to be parked in areas predetermined by the municipality. Virtually no infrastructure is needed for this although it could dilute somewhat the competitive advantage of being able to park anywhere.

Learning curve and scalability: Dockless customers can use the same platform in different European cities without having to download specific mobile applications for each city. As a consequence, they do not have to learn how to operate a different bike-sharing system every time. The more cities to which a dockless company expands, the more significantly users will benefit. Furthermore, private operators of institutional bike-sharing models can also take advantage of a single platform if they operate in different cities.

4.1.2 Competitive Disadvantages

Bicycle redistribution services: Docking stations might be an advantage when managing bicycles and redistributing them according to demand. With a station model, bicycles are concentrated in specific and delimited places, which also facilitates the control and maintenance of the bicycle park. In contrast, dockless bicycles, by definition, are totally independent of docking stations so they do not have such an advantage. Furthermore, as happens with the availability of bicycles in third-generation docking stations, the bicycle distribution depends on the aggregate demand for public bicycles—that is, users' mobility behavior. Therefore, there could be a lack of dockless bicycles in places with high demand and a glut of bicycles in locations with low demand. Noninsitutional dockless operators try to compensate by filling cities with bicycles in quantities that far exceed the demand at the highest point.

Reliability and deterioration: According to Hsu (2017), noninstitutional dockless bicycles have a life span of only two or three years. Vandalism and lack of maintenance may be among the reasons.

Financial sustainability: With a short-term expansionist strategy, aimed at achieving a significant critical mass, dockless companies incur high initial investment costs. To carry out such an intense expansionist strategy, these companies rely on external sources of funding, competing among themselves for the investment they need (Bulled 2017). However, their financial sustainability has yet to be proven since the returns on investment may not be high enough considering the highly competitive policy prices the companies are applying and also due to the short life span of their bicycles and the ongoing need to invest in new bicycles as the number of users continues to increase.

Hidden costs: Some of the bicycles may be underused, remaining parked for most of the day. For this reason, a strategy of increasing capacity can generate hidden costs, in the form of the exponentially rising opportunity costs of the capital invested in new bicycles. In such a case, the marginal costs of increasing the number of bicycles throughout a city—both the investment and the marginal benefits—would hinder the dockless company's long-term financial sustainability.

Hoarding: Noninstitutional dockless bicycles are being monopolized and "privatized" by some users so that others cannot use them[8]. Some bicycles are being parked in private properties. Predefined parking stations for improperly managed and wholly privately owned dockless bicycles, as is the case with some institutional systems, could avoid this inefficiency.

4.2. Potential Harmful Effects and Negative Externalities of Noninstitutional and Non-Properly Managed Dockless Systems

This section summarizes the negative effects and externalities of noninstitutional dockless bike-sharing systems. The objective is to describe some of the reasons why European cities do not prohibit these bike-sharing systems but do tend to limit them through regulatory reforms. It can be argued that a noninstitutional dockless system can be counterproductive as its negative effects could overwhelm the positive ones, as summarized in subsection 2.5.

[8] Chih-Hsuan Wu, "Evolution of Dockless Bike/Bikesharing Designs and Thoughts on the Industry," Hacker Noon, October 8, 2017, https://hackernoon.com/evolution-of-the-dock-less-bike-bikesharing-designs-and-thoughts-of-the-industry-32e41da1dfaa.

Unlike the previously described benefits, the following harmful effects and negative externalities of noninstitutional dockless bike sharing can hardly be attributed to institutional bike-sharing systems. As a consequence of a free-floating value proposition and, more specifically, a possible lack of dedicated regulatory frameworks for this type of disruptive business model in the bike-sharing industry, some cities might unexpectedly be enduring the negative impacts described in this subsection, which in turn become challenges to face. Nevertheless, each impact should be studied individually in each case and it may or may not occur, depending on the environmental factors and social circumstances of each city and on its bike-sharing model.

This subsection also describes the problems caused by the presence of a noninstitutional dockless model of bike sharing in some of the 13 cities in the sample. A brief survey was prepared and sent to each of the cities, with valuable responses being received from Barcelona, Bilbao, Cologne, Hamburg, Turin and Vienna. The problems highlighted by the survey respondents include the mass occupation of public spaces, overcrowding in regular parking spaces and the inadequate parking of dockless bicycles, the negative impact on road safety, uncivil behavior, unfair competition among operators, the lack of adequate regulation determining how people must use dockless bicycles, the presence of broken bicycles in the streets and, according to the municipalities, a potential increase in accidents as a result of the previously mentioned problems. These negative effects must be added to others described in this document.

Impacts on institutional bike-sharing systems: Noninstitutional dockless bike-sharing systems can be direct competitors of institutional systems, attracting users thanks to a potentially more convenient business model in terms of flexibility for users. That is, without relying on docking stations, they can offering an arguably more straightforward payment method using a mobile-phone platform and a QR code (although institutional dockless models are also using these technological solutions) and they can provide the flexibility that the average user is looking for. Traditional models will always rely on docking stations, even though they can introduce the same technological tools as most dockless models use, and this limits their overall score in terms of flexibility for the end user.

Increased competition should not be understood as a negative effect in itself but, when the new competition is unfair because it does not compete with the same market and regulatory conditions, this could be understood as a market inefficiency and therefore as a negative situation for society.

Mass occupation of public spaces: Disruptive bike-sharing schemes could negatively affect welfare levels in the sense of public spaces being improperly occupied by badly parked or damaged dockless bicycles. Some cities have piles of bicycles abandoned in the middle of an urban area (Taylor 2018).

Presence of social opportunity costs: The occupation of public spaces may imply social opportunity costs, meaning that public spaces are effectively being privatized by the presence of badly parked dockless bicycles.

Impact on the number of traffic accidents: The number of accidents caused by or involving bike-sharing bicycles could increase because of the negative impact on public spaces, or a lack of maintenance on the part of noninstitutional dockless solutions.

Impact on the existing urban infrastructure: The existing urban infrastructure in some cities may not be ready to accommodate dockless bicycles—for instance, due to a lack of suitable places for parking, the saturation of public bicycle parking lots, or the hypothetical saturation of cycle lanes. Although this problem is not linked directly to noninstitutional bike-sharing systems, the presence of more bikes in the city could put the existing public infrastructure under stress, especially if bicycles are not being managed and sited properly by the scheme owner.

Lack of accountability: The lack of communication between noninstitutional dockless companies and public administrations could be considered an inefficiency in itself, due to the problems that this situation might generate for the city. The experiences of London and San Francisco (Yang

2017) are clear examples in this respect. A lack of regulatory control by the public administration could act as an open door to some of the problems cited in this subsection. In that case, public-private agreements could be desirable.

Uncivil behavior: Some cities have noticed a certain lack of civic responsibility or good behavior toward noninstitutional dockless bicycles. In addition, some users do not use the service well, hoarding bicycles for themselves, treating them badly or parking them in inappropriate places, resulting in other problems that need to be highlighted.

Bicycles parked in unsuitable places: Parking in unsuitable places can be explained by a lack of control over bicycles, hindering their possible collection and redistribution. In turn, this could cause other inefficiencies such as the obstruction of sidewalks and other passageways.

Lack of control over the bicycles: The large number of bicycles scattered around the city may mean that the noninstitutional dockless operator does not find it easy to control how its bicycles are used and where they are located.

Overcrowding in regular parking spaces: The mass occupation of public spaces by noninstitutional dockless bicycles could affect regular parking lots, harming people with their own personal bicycles.

Presence of broken bicycles: Cities are suffering from the presence of broken bicycles on the streets. Possible causes of this problem are a lack of bicycle maintenance, theft, vandalism and an absence of civic responsibility. Unusable bicycles can be considered urban waste and therefore a negative effect with a large impact.

- **Lack of maintenance:** A noninstitutionalized dockless private operator may ignore its vehicles once these have already been spread throughout the city. Its policy of minimizing operational expenses and bicycle manufacturing costs might not take account of the possibility of maintaining the bicycles effectively.

- **Theft and vandalism:** Because of its free-floating nature independent of a docking station, a dockless bicycle could be more prone to theft and vandalism. According to Ram, Keohane, and Yang (2018), dockless companies have been working to solve this problem, which has caused difficulties in Europe especially. Precise geolocation and other measures generate significant costs, which can aggravate the companies' financial sustainability. Nonetheless, city regulations could force private operators to solve the problem using geolocation. Uncivil behavior by dockless users has been explained already in this subsection.

Negative impact on road safety and increase in accidents: As municipalities reported in the survey, based on the cities' experiences with noninstitutional dockless models, the presence of broken bicycles from those systems could not only result in an increase in the number of bicycle accidents but also in an increase in accidents caused by the obstruction of public space.

Unfair competition among noninstitutional dockless operators: Without adequate, clear and specific regulations on the use of public spaces and for free-floating services, some operators could have legal advantages (specific licenses) compared to others. A lack of legal standardization can generate inefficiencies in the form of imperfect markets.

Lack of adequate regulation on how people should use dockless bicycles: A lack of regulation affects not only the regulator but also the customer. Penalties could act as incentives not to misuse the service but a lack of regulation means there are no such penalties to help prevent uncivil behavior.

4.3. Solutions Proposed by Cities

The previously cited survey, in order to gain an understanding of how cities were reacting to these systems, asked city representatives about the measures implemented by municipalities to tackle the potential negative impact of noninstitutional dockless bike sharing. In addition, precise, publicly available information was obtained about what policies were being applied in London, in order to analyze descriptively the current situation of noninstitutional dockless bike-sharing systems in the British capital. For instance, the city has brought in a code of practice, through which it seeks to control and benefit from the expansion of bike-sharing operators throughout London's boroughs. Furthermore, various meetings have been held between IESE and Barcelona's local authorities,, which have provided information on regulations that the Catalan city intends to implement in the near future, to be applied to dockless operators.

Although the overall amount of feedback from the cities was scarce because few cities were involved in the survey, the information obtained has made it possible to draw some lines of action to combat the previously cited problems generated by noninstitutionaland non-properly managed dockless bike-sharing schemes. Some municipalities stated that it was unnecessary for them to change municipal ordinances or draw up specific regulatory frameworks for noninstitutional dockless bicycle schemes. Those local administrations attributed this to the fact that the private operators of noninstitutional free-floating services still did not represent a problem for their cities, since the level of implementation was either incipient or limited. Nonetheless, a widely shared opinion among the public authorities in the sample is that regulation must serve to neutralize the negative effects of noninstitutional dockless bike-sharing systems, with emphasis on the objectives of reducing the use of private motor vehicles, guaranteeing the right to mobility and making mobility more efficient and sustainable, improving the intermodality of the transportation system, and reducing the number and severity of accidents.

Table 8. Problems of noninstitutional dockless bike sharing and some of the solutions proposed by public authorities.

<table>
<tr><th colspan="2">Problems</th><th>Solutions</th></tr>
<tr><td colspan="2">Impacts on the bicycle industry</td><td>Promoting fair competition and limiting the dockless value proposition through regulation</td></tr>
<tr><td colspan="2">Impacts on institutional bike-sharing systems</td><td>Limiting the area where dockless bicycles can circulate by establishing maximum and minimum areas of coverage. Promoting fair competition and limiting the dockless value proposition through regulation. Introduction of a licensing system</td></tr>
<tr><td rowspan="5">Impacts on public spaces</td><td>Mass occupation of public spaces</td><td>Limiting the number of dockless bicycles operating at the same time. Prohibiting or limiting the circulation of dockless bicycles in certain areas. Introduction of a licensing system</td></tr>
<tr><td>Bicycles parked in unsuitable places</td><td>Creation of specific parking areas for dockless systems. Forcing dockless bicycles to use regular car parks</td></tr>
<tr><td>Overcrowding of regular parking spaces</td><td>Creation of specific parking areas for dockless systems. Prohibiting or limiting the circulation of dockless bicycles in specific areas</td></tr>
<tr><td></td><td>Introduction of measures on bicycles' technical aspects of bicycles. Establishing good practices for operators, specifying time limits for fulfilling public-sector requirements</td></tr>
<tr><td>Impacts on the existing urban infrastructure</td><td>Prohibiting or limiting the circulation of dockless bicycles in specific areas</td></tr>
<tr><td colspan="2">Increase in traffic accidents</td><td>Limiting the number of dockless bicycles operating at the same time. Prohibiting or limiting the circulation of dockless bicycles in certain areas. Bicycle designs that comply with legal safety standards</td></tr>
<tr><td colspan="2">Lack of accountability</td><td>Public-private collaboration. Installation of management software and a GPS device in each unit. Exchanges of data between the private operator and municipality</td></tr>
<tr><td colspan="2">Unfair competition among private dockless operators</td><td>Introduction of a licensing system</td></tr>
<tr><td colspan="2">Lack of adequate regulation on how people must use dockless bicycles</td><td>Regulatory reform. Better understanding of the terms and conditions of service by the user. Clearer explanations of these from the operator</td></tr>
</table>

Source: Prepared by the authors, based on interviews and a survey with public authorities.

Table 8 summarizes the solutions proposed by different cities and connects them with the problems that the solutions aim to solve. As can be observed, most of the measures are cross-disciplinary and these could seek to solve more negative effects and externalities. Such solutions are described below.

Preparation of a specific regulation on the obligations of the operator and the customer: A dedicated regulatory framework for operators could force them to collect broken bicycles from public spaces or penalize them for a lack of maintenance. By setting fast response times to act quickly to solve the problems just described, a suitable regulatory framework could serve as an effective tool. Regulation would partially solve problems related to the persistent occupation of public spaces by dockless bikes. In addition, there should be appropriate regulations on how customers should use the dockless service, clarifying their duties and obligations as users of the service.

Better understanding of the terms and conditions of the service: Users should know how to use the service and also the conditions that apply. The private operator should provide customers with a more detailed explanation of the contract it gives them to make sure they understand it.

Creation of specific parking areas for dockless bicycles: This measure could be used to solve the problem of this type of bicycle being parked in unsuitable locations. In addition, a municipality could introduce regulations to force users of dockless bike sharing to park in the regular bicycle-parking lots scattered throughout the city.

Enhancing the collaboration between public and private agents: By promoting agreements between both agents, the public sector could set conditions on the operations of a dockless service more clearly and directly. In addition, operators could get rid of some uncertainty by coming to an agreement with the municipality on how to start operating in a city, such as doing so gradually.

For instance, a code of practice could be introduced for private bike-sharing operators with guidelines on how they should interact with users and the urban environment. Or getting public certifications to private operators should be required to be publicly certified, according to the services they are offering. The municipality could recognize operators that are offering a safe, efficient and environmentally friendly bike-sharing solution. London is a good example in this regard. An example of good practice, which could be made mandatory, is a 24-hour toll-free hotline for all customers.

The usage data collected by a technological device in the bicycles could be shared with the municipalities as long as data protection legislation was respected.

Promotion of fair competition through a licensing system: This measure could solve problems related to institutional bike-sharing programs and the use of public spaces. By using the same type of license as institutional operators, private noninstitutional dockless operators would compete under the same conditions, with neither type of operators having an advantage. For this to be effective, companies might have to pay a fee for each bicycle. The municipality could use this measure to limit the number of bicycles per operator, granting licenses according to the local authority's criteria. This could help make the mass saturation of public spaces unlikely. To determine how many licenses would be an appropriate number, the municipality might have to conduct studies to estimate the potential demand of dockless bicycles. Such studies should give the municipality a clearer idea about the maximum number of dockless bicycles that the city can absorb without causing distortions or harming the different social actors in it.

Limiting the area in which dockless bicycles can circulate: Municipalities could establish maximum and minimum operational areas. The creation of special zones or circulation corridors could also be considered. These would connect the dockless bike-sharing system with urban collective transportation solutions, such as a metro system and urban buses, and seek to improve the intermodality level of the entire transportation system.

Introduction of technical requirements for dockless bicycles: The use of bicycles with designs that comply with legal safety standards could lead to a significant reduction in the number of accidents involving noninstitutional dockless bicycles. In the authors' survey of cities, respondents highlighted how some private noninstitutional operators failed to take care of their bikes, pointing to the presence of spare parts and entire bikes left abandoned on the streets. Without proper maintenance, bicycles may no longer comply with the necessary safety standards and therefore stop being safe. Furthermore, the introduction of such measures, making the safety and technical requirements the same for both institutional and noninstitutional bike-sharing operators, could make dockless bicycles from noninstitutional operators more durable and safer for users, with longer life spans. Other possible measures in this respect include making it obligatory for all bicycles to have an identification number, for them to be geolocatable using GPS technology and for their designs to comply with legal safety standards.

5. Conclusions and Recommendations

More and more public bike-sharing programs are being implemented in Europe to help combat mobility problems or pollution in cities. However, significant amounts of investment are required to set them up and then operate them, which could be an argument against such public programs. The real extent of their impact on the economy, as well as on the health and well-being of city residents, is part of a debate in which there are conflicting opinions. This document is presented as a research work aimed at providing some answers in this debate.

Regarding the economic impact, it can be concluded that, in aggregate, the estimations obtained using the Leontief input-output technique identify the multiplier of the investment intended for the implementation of the 13 bike-sharing systems analyzed as being between 1.79 and 2.14. Hence, every euro invested in those bike-sharing programs generates average country-level economic activity valued at between €0.80 and €1.14. This economic activity means approximately 3,400 jobs have been created in the seven countries in the sample, according to the estimates obtained using the Leontief approach. Therefore, it can be argued that the initial investment in a bike-sharing program is worthwhile.

In terms of health benefits, the results obtained using the HEAT methodology show that the use of the 13 bike-sharing systems analyzed prevented more than 90 premature deaths between 2014 and 2016. This represents 0.12% of the estimated number of deaths of people under 65 years old between 2014 and 2016 in the 13 cities analyzed. Nonetheless, further research should be done to provide different insights into this kind of impact.

Finally, the translation into euros and the merger of both the project's impact on the economy and the health benefits obtained through the use of bike sharing show that the aggregate value of the socioeconomic effects of each euro invested in the 13 bike-sharing programs is estimated to be between €1.37 and €1.72.

In parallel, this document has also taken into account the challenge that new and disruptive business models represent for public bike-sharing systems. By analyzing the potential positive effects of bike sharing, the competitive advantages and disadvantages of the noninstitutional dockless models and the potential negative effects of such systems, we can conclude that noninstitutional free-floating solutions for bike sharing could be counterproductive if their inefficiencies and overall impacts are not taken into account properly. It can be argued that noninstitutional dockless systems have significant competitive advantages if they are not regulated but their negative externalities demand regulation and may need the direct involvement of the municipalities and other public administrations. The positive effects may be mostly shared with institutional models of bike sharing but, for the most part, the negative ones are not.

Problems such as the mass saturation of public spaces by noninstitutional dockless bicycles could be solved by using appropriate regulatory frameworks. These frameworks could limit the number of noninstitutional dockless bicycles in circulation through a system of licenses, minimum and maximum operational areas or the introduction of a code of practice.

Public-private collaboration seems unavoidable to neutralize the negative effects of noninstitutional dockless operators. Therefore, effective engagement policies between the two players could be recommended for both parties. A benefit for the private side would be that a clear regulatory framework and the ability to exchange opinions with the public sector could reduce the uncertainty it would face.

A final conclusion is that the implementation of these measures could be advisable to a greater or lesser extent depending on the city and the private operator. Regulatory reforms of this kind could considerably limit the competitive advantages of the noninstitutional dockless bike-sharing model and, therefore, the social need to implement it. However, the robustness of this conclusion is limited, so we recommend more in-depth studies into this aspect.

Taking these results, some basic recommendations can be made, as follows.

First, the positive economic impacts—estimated on the basis of the results obtained using the different methodologies—suggest that institutional bike sharing is a positive policy that public authorities should consider. This premise is not affected by the kind of contracting instrument that the public authorities might use, such as using their own assets to provide the service, contracting a private company to operate the service or allowing several private partners to provide it.

Second, as the information shared by the public authorities shows, the increase in noninstitutional dockless bike sharing might be a threat to institutional bike sharing in terms of competition as well as from a logistical point of view because the noninstitutional systems do not abide by the same rules as the regulated and institutionalized systems. Nevertheless, in Europe there are also examples of dockless schemes that are managed properly thanks to close cooperation with the authorities. In other words, noninstitutional dockless bike sharing, despite its positive externalities, have negative ones that should be tackled by public authorities—obviously if those schemes are not managed properly.

Finally, regulations, negotiations and institutional agreements seem to be the solutions proposed by public authorities to overcome the challenges that noninstitutional dockless bike sharing represent for local mobility.

The reality is that bike-sharing systems, regardless of who is providing them or how, form a new mobility model that looks set to have a greater presence in urban areas in the coming decades. Public authorities can overcome several of the 21st-century challenges faced by urban areas, such as traffic congestion and climate change, by taking advantage of new business models related to the sharing economy. Public authorities need to enter negotiations and partnerships with these new services to build alliances to improve residents' quality of life.

6. Exhibits

Exhibit 1. Understanding Third-Generation Institutional Bike-Sharing Business Models

In third-generation models, frequently the municipality or local authority that wants to offer a bike-sharing service in a city prefers to put a bike-sharing contract out to tender, so that private companies can submit bids in a public contest. In the contract, the city council offers a sum of money to the operator to compensate for the negative difference between potential revenues and costs. Therefore, third-generation models, although they are more financially robust, cannot offset their costs solely with the revenues generated by operations. A public contract or public contribution is needed so that private companies can realistically provide the service. Under these conditions, private companies can find it attractive to provide a bike-sharing system while, on the other hand, the city council can achieve its goal of taking advantage of the positive benefits and externalities generated by a bike-sharing program. When it comes to bike-sharing business models, the parties try to internalize positive externalities thanks to an institutional improvement in the form of public-private partnerships.

1.1. Publicly Owned and Privately Operated Systems

The contract between the French city of Rennes, to return to that example, and a private operator committed the private player to provide a bike-sharing system in exchange for advertising on bicycles and also in public spaces in the city such as billboards and bus stations. Therefore, the contract was based purely on the benefits of marketing, with the city offering the advertising company more advertising possibilities in addition to the advertising space on bicycles. This was the first system completely operated by an advertising company, Clear Channel, a US corporation specializing in outdoor marketing.

It was not until 2005, in the French city of Lyon, that the first version of the current generation of institutional bike-sharing models was implemented, using a public-private partnership. Since then, the model has evolved and been adapted to each city. There are different models of publicly owned and privately operated systems, including institutional dockless models, that are regulated and function without causing some of the negative impacts listed in this document. There are many different contractual forms of PPP, changing according to each city's needs and legislation. Therefore, each city can represent a different type of model. However, the experience in Lyon is worth noting since it was the site of the first PPP to be deployed on a mass scale in a large city and so it became an example for other cities that were willing to implement similar bike-sharing solutions.

Because the Lyon system was the first of its generation to be implemented in a large city, it is now one of the most developed models. It has more than 3,000 bicycles and is open to nonresidents. The advertising company JCDecaux won the contract to develop the city's bike-sharing program. The system was the first of its kind, a pure public-private partnership, in which the private company assumed the costs of implementation. Significant amounts of initial investment were needed, taking into account the fixed costs of the bicycles, the construction of the docking stations and other infrastructure, and the service's maintenance costs. In return, the advertising company achieved a de facto monopoly of advertising in public spaces in the city such as bus stations, billboards and public canopies. In absolute terms, the volume of advertising spots increased noticeably as well, with advertisements appearing in places that previously had not been exploited for commercial purposes.

In Lyon, the terms agreed in the public-private partnership included that the city would cede all advertising rights for public spaces to the private operator. Therefore, it was an agreement in which, in addition to implementing a bike-sharing system, the private company would manage the city's outdoor advertising spaces. Although the contract included a payment from the operator to the municipality, the amount was much lower than the revenues stipulated in previous contracts for managing advertising spaces. Moreover, the new contract covered a greater number of advertising spaces than previous contracts. Hence, the city renounced significant amounts of advertising revenue in exchange for a bike-sharing program but, at the same time, it avoided taking on the financial risks. All of those risks were assumed by the advertising company and the service operator, which had to pay the high initial investment costs, in addition to the operating costs, that such a system might entail.

This example contrasts with other cases in which the city in question did not want to include advertising on the bicycles. In Barcelona, which has an advertisement-free bike-sharing system, the relevant public body pays the private operator, represented by Clear Channel, an annual fee agreed at the beginning of the contract period. Some of the revenues obtained from parking meters go toward this fee. Therefore, the advertising company operates the service because of its previously acquired knowledge as an operator, its know-how, and not because it has any rights to advertise in the city's public spaces or on the program's publicly owned bicycles.

1.2. Privately Owned and Operated Systems

Privately owned and operated systems are probably the most common type of business model as far as the third generation of bike sharing is concerned. There are various pros and cons, some of them already pointed out in this document,that can help a public authority when opting for one type of model over another. As emphasized previously, if a private company is in charge of implementing and providing the service, usually the municipality does not have to pay for the infrastructure or operating costs. It pays only the amount, if any, that has been agreed with the concessionaire company, which eliminates the inherent uncertainties that arise when resources have to be allocated from the public budget for unforeseen expenses.

The innovation factor can be another advantage of these privately owned models. Most of them, like many other public-private partnerships, involve long-term contracts, in which the physical assets are usually owned by the private company. Therefore, the private agent has an incentivize to innovate the system constantly with, for example, better bicycles and to incorporate newer technologies throughout the system, putting the company in an advantageous position when the contract comes up for renewal.

However, with bike-sharing contracts in which the private company owns and manages the system, there can be some weak points, especially from the public service point of view. There are no incentives to expand the network of docking stations in places where there is not enough demand to offset costs, taking into account criteria of operational profitability. Consequently, discrepancies can arise between the priorities of the private operator and those of the municipality because the public authority has other criteria beyond the system's economic sustainability, such as promoting mobility between the city center and the outskirts, reducing the number of motor vehicles, and encouraging residents to exercise to get healthier. Therefore, the municipality is interested in providing the bike-sharing system in places with less demand.

Knowing about this kind of inefficiency beforehand, public authorities can reach an agreement with the private operator about the boundaries of the operational area. In additional, the authorities can offer the operator a contract that effectively neutralizes the opportunity costs. Paris is a clear example in this regard. The system covers all of the city's arrondissements and many parts of the metropolitan suburbs but, as compensation, the private partner has alternative revenue streams, such as outdoor advertising in the city.

Another problem that could arise as a result of a possible desire by the private operator to maximize its benefits rather than what would be useful for the user is a lack of quality of the service. To counteract this risk, specific clauses can be included in the public-private partnership agreement, such as making the operator's income conditional on user satisfaction indicators.

1.3. Publicly Operated Systems

In other cases, the public sector continued to be the operator of the service. The business model's focus was in a different direction but the model incorporated the same new features of third-generation bike-sharing schemes, which were, as discussed previously, the diversification of the revenue streams, better-quality bikes, and the extensive incorporation of technology. In publicly owned and operated systems, the municipality designs and plans the system but also is responsible for implementing and operating the system. The physical assets related to the bike-sharing program—basically bicycles and docking stations—are usually owned by the municipality. An exception is where the municipality has rented them but this is infrequent unless a city's publicly operated system is reusing assets that were used in a previous bike-sharing system with a private operator. Since the municipality takes on all the roles in terms of implementation and operations, it obeys only its own criteria when designing and then operating a system. Social criteria, such as the right to mobility or environmental concerns, are given greater weight than criteria based purely on economic profitability. That could help to improve the design of the system in terms of deciding where to place a docking station. However, the city council or corresponding public authority must assume responsibility for any kind of inefficiency that arises in the public bike-sharing system, including all the costs and risks.

1.4. Financial Structure, Costs and Revenues of an Institutional Program

With regard to the typical costs of a third-generation bike-sharing system, in addition to the expense of bicycles and docking stations, other fixed costs must be taken into account, such as the software required and the costs of a control center to manage the system in real time. Another requirement is a maintenance center where badly damaged bikes can be repaired. Sometimes damaged bicycles can be repaired in situ but sometimes they need to be transported to a maintenance facility. The operator needs to have sufficient logistic capacity to transport bicycles for maintenance and, more importantly, to redistribute them among stations in a satisfactory way. This translates into expenses for vehicles, personnel and facilities. In a totally publicly operated system, all of those costs are to be paid by the municipal authority but the cost distribution can be different in other circumstances such as in a public-private partnership. Sometimes, the private company merely operates the system using the city's publicly owned infrastructure and physical assets, including the docking stations. In other cases, the private company both owns the physical assets and operates the system, with the municipality being responsible for ceding public spaces and evaluating the system.

It is also necessary to include the operating costs—that is, the costs related to the day-to-day activity of bike sharing. For example, the redistribution and maintenance of bicycles involve not only part of the fixed costs but are heavily involved in the system's variable costs as well. Bicycles need to be redistributed among docking stations because demand at each station does not remain constant throughout the day. Moreover, the maintenance costs should vary according to the degree of wear and tear of the physical assets deployed throughout the system, bikes and docking stations. This, in turn, depends on how people use the system and how durable the bikes are. Introducing incentives to encourage users to take care of the system, such as penalties for mistreating a bicycle, can help to reduce the overall maintenance costs. Cultural factors such as theft or vandalism also affect the operating costs of a public bike-sharing system. These types of systems, conceived and designed to meet the mobility needs of the general public, entail risks related to vandalism, theft and accidents. Such problems should be solved, at least in part, through the public contract between the municipality and the operator. The contract should provide for procedures and compensation in the event of such acts. If this were done, the operator's uncertainty in this regard would be reduced. Moreover, public authorities often actively combat acts against property by launching awareness campaigns or making the law tougher, thus encouraging the proper use of urban furniture.

The continuous incorporation of technological solutions into the bike-sharing industry has led many programs to introduce electric bicycles as an alternative to mechanical bicycles, at a slightly higher price. The introduction of electric bicycles can help make bike sharing more attractive and competitive than other transportation solutions, since the average distance traveled by users can increase. Moreover, new users can be attracted by the fact that they need less physical effort to propel electric bicycles. However, it costs significantly more to maintain electric bicycles compared with mechanical bicycles because of the more complex technological components.

Other operating costs to be taken into account are those arising from and required by customer service and quality control. Their importance within the "variable costs" accounting line item will depend on how automated those services are. However, the expenses incurred on information, awareness or marketing campaigns to promote this particular system of public transport can be shared with the municipality and such campaigns usually result in a positive return on investment.

Regarding returns on investment and revenue streams, information campaigns could serve to raise awareness among city residents about the importance of using means of transport other than the car or private transport in general. If the goals are achieved, more people can be expected to use the bike-sharing system, so the revenues from user fees will increase as well.

User fees could be considered the main revenue source for citycentric systems. There can be two types of user fee: a subscription fee and a usage fee. The subscription fee can be charged periodically and usually requires the user to be registered with the system. This can put a limit on access for potential users visiting the city for only a few days. Normally, people who pay a subscription fee have unlimited access to the system for a certain period of time, without having to pay an additional amount. Typically, the first 30 minutes of use are free of charge. Most systems apply a usage fee after that, incrementally penalizing longer trips. In some cases, the period of time that is free of charge can be as long as a day, a month or a year. Usage fees are usually applied exponentially. That is, the price increases at a greater rater than the time spent using a bicycle. The objective of this pricing policy, where applied, is to persuade people to use the bicycles properly, since the system is based on the continuous availability of bicycles for all users.

In terms of revenue streams, subscription fees often constitute the majority of the revenues from the system's user members. Some bike-sharing programs offer benefits to those who renew their membership of the system. In some systems, it is mandatory to be a full member and therefore pay a subscription fee in order to take a bicycle. The system's revenue structure should be set up carefully when deciding whether a usage fee is necessary. Then, if this fee is considered necessary, care should be taken when deciding how it should be implemented so as not to drive away potential users to other, less sustainable services.

When a bike-sharing scheme is understood as merely part of an integrated public transport system, this makes it easier to comprehend and justify other types of revenue, such as those from the public authorities. An analysis of the positive direct effects of a bike-sharing system along with its positive externalities shows that public funding could be desirable. The municipality might agree to provide such funding because it wants to capitalize on the social benefits of bike sharing, which would be impossible without the intervention of the public sector since those benefits do not represent any monetary remuneration for the operator. Government funding could be also necessary to secure the initial investment, either through the provision of the required guarantees or through the direct contribution of funds. Otherwise, the company that owns the system's infrastructure or has to invest significantly in the implementation of the system may resort to bank loans. This loan solution could be more attractive to private operators. Moreover, other private agents may be interested in partially funding the system. An example would be a private company that was very interested in having a docking station near its facilities or headquarters.

Finally, private investors may be interested in a bike-sharing system for marketing purposes. A main sponsor could fund the implementation of the system, with direct benefits for the sponsor's name and branding. London is an example of this. On the other hand, sponsored programs can end up being restricted when it comes to including third-party advertising on bicycles. Such advertising can be an important revenue source for the system, which would have to be given up if the system operator was restricted to a single sponsor or patron. For this reason, the use of advertising as a way of supporting a public bike-sharing system can be controversial.

Exhibit 2. Questions From the Survey of 13 Cities

- Does any private company provide a free-floating bike-sharing service in your city?
- Which companies offer this type of service?
- What are the positive impacts of the free-floating bike-sharing service in your city?
- What are the negative impacts, if any, of the free-floating service in your city?
- If the dockless bike-sharing system had any negative impact, how did the municipality solve this?
- How has the relationship between the city council and the dockless bike-sharing companies worked out?
- What would be the ideal relationship between the municipality and the free-floating bike-sharing company?

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