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Analysis of real experiences using different sized bike sharing schemes in Irish cities

Pilar Jiménez[a]*, Maria Nogal[b]

[a]*Faculty of Civil Engineering and Mining Engineering, Technical University of Cartagena, Paseo Alfonso XII, 52. Cartagena, 30203, Spain*
[b]*Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinewg, 1. 2628 CN Delft, Netherlands*

Abstract

The first Irish public Bike Sharing Scheme (BSS) was launched in Dublin in 2009. Dublinbikes has been internationally recognised as one of the most successful bike-sharing rental schemes in the world. For this reason, among others, the cities of Cork, Limerick and Galway launched their own BSSs at the end of 2014.
The objective of this paper is to compare the performance of the four BSSs during the first two years of implementation in each Irish city according to endogenous factors, such as the physical design of the schemes, and exogenous factors, such as city size and population density. In terms of population, Limerick and Galway are small cities, Cork is a medium-sized city and Dublin is a large city. In consequence, the results cover the main relevant aspects of BSSs according to the size of the scheme, pointing out similarities and differences among BSS of different sizes. The main findings indicate that the number of daily rentals per bike is a good metric from the point of view of the transport operator. However, a higher density of bikes, stations and docking points does not imply greater usage, whereas the size of the deployment area could be a key factor in improving bike usage. Finally, a synopsis of the essential aspects to consider when designing a BSS deployment based on types of users in small cities is provided.

Keywords: Bike-sharing; cycling; small cities; Ireland; annual users; occasional users

1. Introduction

The expansion of Bike Sharing Schemes (BSSs) across the world accelerated when the third generation (based on Information Technology) of such systems emerged. Moving around the city by bicycle has several advantages; for

* Corresponding author. Tel.: +34 868 071276; fax: +34 968 338805.
E-mail address: pilar.jimenez@upct.es

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example, it reduces carbon footprints, reduces car use, provides a last-mile connector mode of transport or develops tourism. These are some of the main reasons why BSSs have grown exponentially around the world (see DeMaio (2009); Shaheen and Guzman (2011) or Midgley (2011) for more detail).

Following this general trend, the first Irish public BSS (Dublinbikes) was launched in Dublin in 2009. Dublinbikes has been internationally recognised as one of the most successful bike-sharing rental schemes in the world, surpassing initial predictions and reaching one million journeys 11 months after its launch. Twenty months later, the two-million mark was attained (according to the reports of the Dublin BSS website: www.dublinbikes.ie). Besides the several advantages cited above, Dublinbike's success inspired the cities of Cork, Limerick, and Galway to launch their BSSs at the end of 2014. These four Irish cities: Dublin, Cork, Limerick and Galway, are the cities under study in this paper.

Recent works have addressed the multi-city scenario of BSSs. BSSs in European cities (for example, London, Barcelona, Paris or Dublin) and North-American cities (Denver, Chicago, Washington D.C. and Miami, among others) are compared to try to understand aspects such as the diffusion patterns of BSSs, considering the characteristics of cities and operator models (see Parkes et al. (2013); Austwick et al. (2013); Sarkar et al. (2015)). A global view of bike-sharing characteristics based on data analysed from 38 systems located in Europe, the Middle East, Asia, Australasia and America can be found in the research conducted by O'Brien et al. (2014). In this study, the BSSs are characterised on a city level, comparing them in terms of system size, daily usage and compactness, to eventually build a hierarchy of cities sharing similar characteristics. Besides this, Chardon et al. (2017) provide a comparison of 75 BSSs, mainly in Europe and North America, using the metric of trips per bike per day.

These studies have attempted to compare very different BSSs, and their main common results are; (i) BSSs are attractive and adaptable urban-mobility systems that are showing rapid development and expansion; (ii) there are a good number of quantitative factors characteristic to BSSs that are easily measurable, however, it is difficult to provide a benchmark to determine the success of BSSs, even when they have no explicit or measurable target; and (iii) the success of a BSS surviving over time depends on policy-makers' goals or other external inputs, such as inclusion within an effective public transport system.

In relation to the lack of a measurable target for some BSSs and their survival over time, this paper aims at pointing out similarities and differences arising from the different sizes of BSSs, mainly in small cities. It generates an open discussion about what the target users of a BSS should be according to the size of the city and its characteristics, in order to achieve a successful BSS that could be maintained over time.

Insights on these issues will be obtained from the study of real BSSs in the same country; Ireland. Specifically, the BSS of Dublin, Cork, Limerick and Galway will be analysed, corresponding to the first two years of their implementation in all the cases. The paper compares how each BSS has performed according to the following differentiating factors: scheme size and density of bikes, stations and docking points (endogenous items) and city size and population density (exogenous items). These observed quantitative factors facilitate a simple comparison of many BSSs to understand each BSS in general terms. From this general perspective, it will be easier to conduct future detailed research, for example, how improve BSS performance in small cities, which usually enjoy ease of pedestrian and cycle movement.

2. Characteristics of the bike sharing schemes studied

Several articles can be found about Irish BSSs; mainly about the Dublin BSS due to its success. For example, O'Neill and Caulfield (2012) and Caulfield (2014) analysed the mobility patterns of Dublinbikes during the first stage of the system, and Jiménez et al. (2016) focused on understanding the use of the bike stations according to user mobility patterns in 2015. With regard to Cork, Limerick and Galway, a Technical Feasibility Study was conducted on the introduction BSSs in these regional cities, which is very useful for understanding the basis of these systems (Jacobs (2011)).

Dublinbikes, is a public bicycle rental scheme which has operated in Dublin city since September 2009. During its first stage, Dublin Bikes consisted of 44 bicycle stations and 550 bicycles, a deployment area of 2.5 km per 3.5 km, which provides an appropriate distance to cross the city by bicycle with an average travel time of 12 minutes. The subsequent extensions counted on up to 101 bike stations and 1,500 bikes (www.dublinbikes.ie). However, in

order to compare results at the same level as other cities; that is, after two years of the BSS implementation, the data collected from Dublin are related to the year 2011, considering the data of the first period of the scheme.

Cork's Coca-Cola Zero Bikes has operated in the city since December 2014. At its launch, the scheme used 330 bicycles with 31 stations spread across Cork city centre. The extension of this deployment area of 2.5 km per 1 km also provides the appropriate distance to cross the city by bicycle with an average travel time of 7 minutes; probably shorter distances than the Dublin scheme, but still efficient for bicycles.

Limerick's Coca-Cola Zero Bikes has operated in the city since December 2014. The scheme uses 215 bicycles with 22 stations spread across Limerick city centre. The extension of this deployment area of 1.5 km per 2 km is within the limit of an appropriate distance to go by bicycle. This means that to ride 2 km across the city takes 8 minutes with an average speed of 15 km/h (comfortable speed), whereas walking these 2 km across the city takes 24 min (average speed of 5 km/h for pedestrians). Generally, half an hour is the maximum time commuters will consider walking. Thus, it can be said that a distance of 2 km is the lower limit for the use of bicycles because distances lower than 2 km are also comfortable to walk, and people would not have to change their mode of transport.

Galway's Coca-Cola Zero Bikes has also operated in the city since November 2014. The scheme uses 195 bicycles with 15 stations spread across Galway city centre. The extension of this deployment area of 1 km per 1.2 km is also remarkable because the possible distance covered by bicycle (an average travel time of 5 min from extreme to extreme) can also be done by walking; thus, people might not be encouraged to use bicycles in the same way as in Limerick.

Note that in these specific cities, university campuses are relevant to understanding current and future BSS usage because (i) the scheme is used by students, faculty and staff members to access the university, (ii) the bike stations related to these universities become part of the general scheme of the city, (iii) the universities are tourist attractions, especially in Dublin and Cork, and (iv) the students living on university campuses use bikes to move around the city.

Table 1 provides data about population density, the area of the city occupied by the scheme and the number of bikes, stations and docking points of each BSS for each city. From this table two aspects are highlighted: (i) Dublin, Cork and Limerick have greater population density than Galway, and (ii) the percentage of the city area with bike stations during the first stage in all the cities could be considered to be similar, except for Galway. Galway has a low value with 2.4% of the area with bike stations; 5 points below the percentage of the first stage of Dublinbikes, and 8 points below the Limerick BSS. Both issues are important because they could affect the usage of the system in each city.

3. Research context and dataset description

This paper focuses on a multi-city scenario (most of them small to medium-sized) within a country to identify similarities and differences among the different sizes of BSSs. Also, the role of BSS target users in relation to a city's size and its characteristics are investigated to see what makes a BSS successful over time.

An estimation of the degree of success of a BBS will depend on the point of view of the stakeholders. In this case, the point of view is the transport company's, based on the usage and efficiency of the systems, which is understood as the number of daily rentals per bike.

To achieve these objectives, the European research study, Optimising Bike Sharing in European Cities – A Handbook (OBIS, Büttner et al 2011) has been taken as a reference. This project collects relevant information (endogenous and exogenous factors) about more than 50 BSSs from different European countries. Data are analysed and the results presented according to city size, providing a good overview and guidance for cities with similar conditions.

Table 1. Basic demographic data and number of bikes, bike stations and docking points for each Irish city studied. Data source: Census 2011 and 2016 of Ireland and Northern Ireland. Central Statistics Office. Dublinbikes. Coca Cola Zero bikes.

	Dublin 2011	Cork 2016	Limerick 2016	Galway 2016
Population (inhabitants)	527, 612	125, 657	94, 192	78, 888
Area of the city (km^2)	116.58	38.59	28.38	50.00
Population density (inh/km^2)	4, 526	3, 256	3, 319	1, 578
Area of the city with bike stations (km^2)	8.75	2.50	3.00	1.20
% area of the city with the bike stations over all area	7.51	6.48	10.57	2.4
	BSS basic data			
Number of bikes	550	330	215	195
Number of stations	44	31	22	15
Number of docking points	1, 145	574	406	250

Therefore, according to their population and the definition of the OBIS project, Limerick and Galway are small cities because their population is between 20,000 and 100,000 inhabitants, Cork is a medium-sized city because its population is between 100,000 and 500,000 inhabitants and Dublin is a large city with a population greater than 500,000 inhabitants (Table 1).

Regarding endogenous factors, only the physical design of the schemes (size and density) is analysed because it is the main differentiating factor among the BSSs involved. The rest of the endogenous items are similar for the four BSSs. All the services are available all year round, 7 days a week, from 5 am to 00.30 am, though a bike can be returned to available stands at any time of day or night. They all offer two types of registration; annual subscription and 3-Day subscription for occasional short-term use or for visitors to the cities.

With reference to exogenous factors, city size is the most relevant. The other exogenous factors such as climate, topology, economy and policy exhibit secondary importance because all of them are similar in all four cities. Thus, the cities depart from a similar starting point in terms of local conditions. However, the size of the deployment area and its extension into residential areas or university campuses are different in each city, and these will be the aspects to compare and explain.

The dataset has been obtained by open sources and previously published manuscripts. The data related to Dublinbikes are obtained through the reports available on its website (www.dublinbikes.ie), and in the cases of Cork, Limerick and Galway BSSs, from the reports available on the common website (www.bikeshare.ie). In addition, the provided data from Caulfield et al (2017) and McBain and Caulfield (2018) are consulted to complete Cork bike information, whereas for the BSSs of Limerick and Galway, data from Jiménez et al (2018) are also used.

The proposed approach is not data-intensive. Thus, it is easily scalable by adding new cities, and allows a good picture of the main BBS characteristics without overwhelming the analyst with an overly extensive list of indicators.

4. BSS infrastructure and usage

In order to compare the four BSSs, the density of bikes, stations and docking points of each BSS are calculated. Table 2 provides the main results in relation to the density of each bike, station and docking point over the population, over the entire area of the city and over the deployment area of the scheme. The ratios regarding docking points based on the figures of Table 1 are also analysed.

In relation to the density of bike/station/docking points over the population, the Cork, Limerick and Galway BSSs (the medium-sized and the two small-sized, respectively) have approximately double the value than the Dublin BSS. This means that they provide more physical components per inhabitants. The figures of these three cities are also

higher than the average values indicated in the BSS key figures of the OBIS sample (14.8 bikes per 10,000 inhabitants and 1.5 stations per 10,000 inhabitants), whereas Dublinbikes is below these references.

Table 2. Scheme size and density of bikes/stations/docking points of BSSs for each Irish city studied.

	Dublin 2011	Cork 2016	Limerick 2016	Galway 2016
Bike/station/ docking point density over population				
Number of bikes / 10, 000 inhabitants	10	26	23	25
Number of stations / 10, 000 inhabitants	0.8	2.5	2.3	1.9
Number of docking points / 10, 000 inhabitants	22	46	43	32
Bike/station/ docking point density over the whole city area				
Bike density (unit/km^2)	4.72	8.55	7.58	3.9
Station density (unit/km^2)	0.38	0.80	0.78	0.30
Docking point density (unit/km^2)	9.82	14.87	14.31	5.00
Bike/station/ docking point density over the city area with bike stations				
Bike density (unit/km^2)	62.86	132.00	71.67	162.50
Station density (unit/km^2)	5.03	12.40	7.33	12.50
Docking point density (unit/km^2)	130.86	229.60	135.33	208.33
Ratios regarding docking points				
Number of docking points / bike	2.1	1.7	1.9	1.3
Average number of docking points / station	26	18	18	17
Standard deviation of docking points / station	5.5	6.6	4.5	3.8

When comparing the schemes according to city area or the deployment area of the BSSs, two aspects are highlighted. The first one is that Cork and Limerick's ratios of bike/station/docking point density over the entire city area stand out above the rest, and the second one is that the ratios of bike/station/docking point density over the deployment area of the BSSs are similar between Cork and Galway, and, in turn, higher than Dublin and Limerick's.

Ratios of docking points show that each bike has roughly two docking points. However, the ratio in Galway is close to one; the minimum value required to be able to operate. However, it corresponds to the figure in the OBIS document (1.2) for this item in small cities. Concerning the capacity of the stations, the Dublin bike stations are bigger than the bike stations in the other cities; that is, they have more docking points. Interestingly, the capacity data are opposed to the sample given in the OBIS project, where results show an average of 9.5 docking points per station for large cities and 23.5 and 22.9 docking points per station for medium-sized and small cities, respectively.

Regarding the usage data shown in Table 3, two aspects are highlighted. The first feature to point out is the share of annual and occasional users. Dublin and Galway BSSs have a large number of tourists since occasional users are 40% of the total. However, the Limerick BSS has high annual user demand, with these users making up 90% of the total. Similarly, regarding the total number of trips during the two first years of implementation, the average number of daily trips is greater in Dublin, and this value decreases according to the size of the BSS.

The second aspect to highlight is related to the daily rental ratio per bike. Specifically, the low values in Limerick and Galway show practically no daily use of bikes. This indicates that the trips and users are insufficient to keep a steady level of usage throughout the year, and use is concentrated over several months in spring and autumn. Thus, neither of these systems are considered to be efficient in terms of the regular usage of the scheme.

Table 3. Usage of each BSS studied. (N.A. – Not available)

	Dublin 2009-11	Cork 2015-16	Limerick 2015-16	Galway 2015-16
Total number of trips	2, 500, 000	518, 000	71, 595	32, 460
Total number of users	62, 000	N.A.	3, 230	2, 743
% Annual users	60	N.A.	90	64
% Occasional users	40	N.A.	10	36
Average daily trips	3, 425	710	98	44
Daily rental per bike	6.2	2.2	0.5	0.2
Average number of trips per user (all types of users)	40	N.A.	22	12

5. Discussion

Dublinbikes, a large city scheme, has been well received by society. Proof of this is the second enlargement of the system in 2014. Some of the main reasons are (i) Dublin's high population density, 4,526 inh./km2 in 2011 (see Table 1), and (ii) the size of the deployment area of the BSS; that is, the extension area where the bike trips are efficient and can be combined with trips on foot and by car to access work or when enjoying leisure activities. However, the values of the density of bikes, stations and docking points over the population and the entire city area are lower than the values of the other three cities and the reference values of the OBIS document.

Related to Cork, a medium-sized city, the deployment area of the BSS is within the limit of efficient bike trips; that is, an area of 2.5 km2 providing appropriate distances to cross the city by bicycle with an average travel time of 7 minutes (in an area smaller than 2.5-3.0 km2, the possible routes are also appropriate for walking, and the impact of the scheme might be lower due to the low level of usage). Usage is reinforced with the university connection, which provide an important group of system users.

The findings of this paper show that usage in Galway and Limerick is lower than in the other Irish schemes, with average daily bike rental near zero (Table 3). One possible strategy to increase this usage could be to expand the scheme. This coverage growth could result in an upturn in usage numbers. Considering that both cities have small deployment areas in the schemes, a modal shift from pedestrians to cyclists is complicated. Moreover, a large group of potential demand, the staff and students of the universities, are outside of both BSSs. However, the cities have different characteristics. Limerick has similar population density to Cork, whereas Galway has lower population density than the other cities. The type of users in each city is also different. This indicates that the development of each BSS for the short-term should be addressed from different perspectives according to the characteristics of each target group.

The identification of a successful BSS is indeed a difficult issue to solve because each city is conditioned by many aspects such as the characteristics of the surrounding area, the initial scenario of implementation and operational management. Moreover, the success of a system cannot be based only on a single ratio (e.g., number of daily rentals per bike) despite its good performance. In fact, the success of a BSS will depend on the desired goals of the council or the promoting body of the project in the short and long term and on the indirect benefits expected. That is, assessing whether a BSS is successful or not will depend on what and who it is for. Therefore, and according to the obtained results, the question to answer is how to improve the performance of BSSs in small cities. To answer this question, some considerations were analysed, from which Figure 3 emerges.

Figure 1 shows a synopsis of key aspects and recommended questions to consider before designing a BSS deployment or when improvements are desired after a few years of working. The identification of city characteristics from the point of view of the offer available, attraction and generation areas, along with possible geographical barriers and the identification of the potential users (residents and tourists) are required. For example, the main attraction areas for residents are the business areas and third-level campuses because they make these trips on a daily

basis, although they also visit the rest of the identified attraction areas during their leisure time. However, tourists are usually interested in visiting all types of leisure areas and places with cultural activities.

Once all these elements have been identified according to the target user of the BSS, some questions should be considered to design an adequate deployment area able to attract users and make the BSS profitable. As the lower part of Figure 1 shows, if the main target users are residents, the key is the extension of the deployment area to make bicycle trips efficient; that is, the distance should be far enough to make the trip by bike worthwhile. This type of user guarantees a steady level of usage, although detailed studies on seasonality and student mobility patterns should be developed to continue improving the scheme. If the target users are tourists, becoming aware of the seasonality of their visits is essential to understanding the usage of the system, as might be Galway's case in the first stage. In this case, the deployment area would be less important because tourists usually make circular trips, enjoying the city while stopping for sightseeing and shopping, so they use the BSS in a different way than residents. Finally, if the BSS covers both types of users, in addition to the two previous questions, it is important to identify possible overlapping between resident and tourist attraction areas to be able to take advantage of this overlapping and make the BSS more profitable. Obviously, these are general considerations that help in initiating the layout of a BSS in small cities. They should be complemented with specific studies for each city.

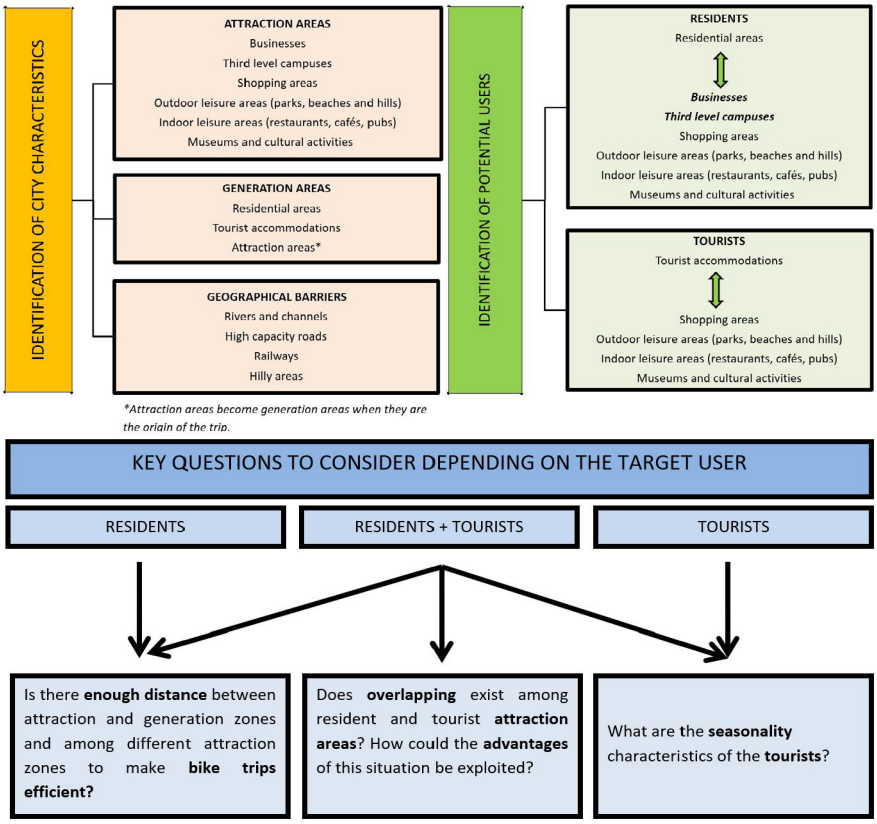

Fig. 1. Synopsis of key questions to consider when designing a BSS deployment area in small cities.

6. Conclusions

The number of daily rentals per bike is a good metric from the point of view of the transport operator. However, a higher density of bikes, stations or docking points does not imply greater usage, whereas the size of the deployment area could be a key factor in improving bike usage. In general terms, the development and operation of BSSs in medium-sized to large cities are usually satisfactory because of the high population density, the several groups of

interest and the suitable distance covered by bicycle trips. In contrast, the usage level of BSSs in small cities is different from large cities because the deployment area is usually inefficient for bicycle trips and the management of potential users is not adequate. Thus, based on these current experiences, to extrapolate general results by means of only quantitative data, from the BSSs of large cities to schemes in small cities would not be recommendable.

In fact, studying the first two years of BSS implementation in small cities is very helpful to be able to understand the mobility patterns of users and how to manage a BSS to obtain successful operation in the future. Developing a BSS depending on the characteristics of the main group of users registered during the studied period, i.e., annual or occasional users, to achieve the desired results in the short term, and then expanding the system to other types of users if desired, is recommended. Thus, studies on each group of specific users and how to adapt BSSs to them in small cities will be the next topic to research in order to improve the knowledge in this area and to be able to adapt better schemes to achieve efficient and profitable results. For these studies, not only the identified critical issues should be considered, but also how to improve cycling infrastructure, new 30 km/h zones or communication campaigns for the development and operation of small BSSs.

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