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Understanding the diffusion of public bikesharing systems: evidence from Europe and North America

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ABSTRACT

Since the mid-2000s, public bikesharing (also known as "bike hire") has developed and spread into a new form of mobility in cities across the globe. This paper presents an analysis of the recent increase in the number of public bikesharing systems. Bikesharing is the shared use of a bicycle fleet, which is accessible to the public and serves as a form of public transportation. The initial system designs were pioneered in Europe and, after a series of technological innovations, appear to have matured into a system experiencing widespread adoption. There are also signs that the policy of public bikesharing systems is transferable and is being adopted in other contexts outside Europe. In public policy, the technologies that are transferred can be policies, technologies, ideals or systems. This paper seeks to describe the nature of these systems, how they have spread in time and space, how they have matured in different contexts, and why they have been adopted.

Researchers provide an analysis from Europe and North America. The analysis draws on published data sources, a survey of 19 systems, and interviews with 12 decision-makers in Europe and 14 decision-makers in North America. The data are examined through the lens of diffusion theory, which allows for comparison of the adoption process in different contexts. A mixture of quantitative and qualitative analyses is used to explore the reasons for adoption decisions in different cities. The paper concludes that Europe is still in a major adoption process with new systems emerging and growth in some existing systems, although some geographic areas have adopted alternative solutions. Private sector operators have also been important entrepreneurs in a European context, which has accelerated the uptake of these systems. In North America, the adoption process is at an earlier stage and is gaining momentum, but signs also suggest the growing importance of entrepreneurs in North America with respect to technology and business models. There is evidence to suggest that the policy adoption processes have been inspired by successful systems in Paris, Lyon, Montreal, and Washington, DC, for instance, and that diffusion theory could be useful in understanding public bikesharing policy adoption in a global context.

1. Introduction

Public bikesharing systems as an innovation have become increasingly popular in recent years with a significant portion of this growth occurring over the past decade. These systems are open to the public and serve as a form of public transportation. Their origins can be traced to Europe, but they have since spread across the globe with systems deployed in Asia, Australia, and North and South America (DeMaio, 2009; Shaheen et al., 2010). This growth leads us to consider what role such services may play in future transport systems.

Diewald (2001) identifies an innovation as the development and application of something new. This can be the combination of a series of discrete pre-existing components into a new system. He suggests that two separate processes need to be considered. Research generates the new products, materials, and practices, while "technology transfer" is what enables implementation. In the context of this paper, the innovation is the combination of bicycles with secure storage and electronic reservation/payment systems in the form of information technology (IT)-based public bikesharing systems, the pathway to which is described further in Section 2.

Technology transfer is the movement of know-how among individuals with institutions or companies. In the field of public policy, the technologies that are transferred can be policies, technologies, ideals or systems; this is typically referred to as "policy transfer" (Dolowitz and Marsh, 2000; Marsden et al., 2011). Notions of policy transfer are of potential significance in understanding how bikesharing systems spread. While structural or formal institu-

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tional factors have been shown to be important in determining policy adoption in different contexts (Banister, 2003), it is argued that the movement of policies needs to be understood much better through studying the role of actors in the system (McCann, 2011; Peck, 2011).

Diffusion theory considers the way in which innovations spread through social systems and is important to the study of the spread of public bikesharing over different continents (Rogers, 2003). Almost 50 years of research in diffusion theory across many disciplines identifies some strong recurring themes. Within different policy or practitioner communities there are typically individuals (or organizations) that seek to adopt new policy ideas before they achieve widespread acclaim (e.g., in transport one could consider London's decision to adopt a congestion charging zone as one such decision). Some of these individuals or organizations are seen as "different" and therefore do not connect well to other practitioners or networks to spread their knowledge. Some well networked individuals or organizations that mix with both the innovators and the mainstream community exist; they are critical to demonstrating and disseminating new practices. The "mainstream" adopters can be further classified as "imitators" or "laggards" depending on the timescales over which they subsequently adopt an innovation, although it is a matter of empirical research to establish whether the "imitators" or "laggards" are losing out from later adoption or are making a pro-active choice to reject (perhaps less desirable) innovations. The theory puts social interactions to the fore in explaining knowledge transfer – consistent with organizational learning theory (Boonstra, 2004) and situated learning (learning that occurs in an applied environment) in facilitating the application of practices.

Diffusion theory, however, is better at explaining how an innovation diffuses rather than why it was selected and successful in the first place. Indeed, successful examples populate the evidence base rather than failures or those that achieved only small-scale application (Rogers, 2003). The reasons for adoption are complex and depend on local circumstances. It is likely that innovations will not be equally relevant to different circumstances, and Rogers (2003) highlights the "matching" stage as being important in organizational adoption decisions. Multiple solutions might also be applicable to a particular problem, in which case diffusion will be affected by the extent to which local preferences steer the selection of one system or policy over another (for example light rail versus heavy rail or bus rapid transit). The literature suggests that policy innovations are most likely to be adjusted and tailored more specifically to local needs by early adopters who take a more pro-active role in the policy learning process (Westphall et al., 1997). By contrast, later adopters tend to adopt policies as a response to pressure to do so and are more likely to accept the most common practices (Westphall et al., 1997; DiMaggio and Powell, 1983).

Diffusion theory has been used for a limited number of explorations of planning and transportation policy. Kern et al. (2007), for example, examined the extent to which cities belonging to different regions of Germany had adopted the United Nation's sustainable development policies by adopting a Local Agenda 21 agreement in one of the few organizational diffusion studies with a strong transportation connection. As of June 2006, 2610 local authorities (around 20%) had initiated Local Agenda 21 policies, and the numbers seem to have reached a plateau, perhaps related to a post-Kyoto decline in climate change support. The Local Agenda 21 case study found the S-shaped adoption curve typical of innovation diffusion. Kern et al. found that "the local authorities' capacities (size, wealth, political institutions, and social capital) and location appear to be crucial for Local Agenda 21 diffusion. Local Agenda 21 pioneers tend to be middle-sized or large cities" (p. 610). State capitals and university towns were often pioneers. Thus, it is important to study what types of cities choose to adopt public bikesharing and in what way.

To explore the adoption patterns of bikesharing systems, this paper begins with a description of public bikesharing and discusses how they have evolved over the past few decades. Please note that community-based bikesharing systems, such as those deployed on college campuses, employments sites, and hotels, are not covered in this paper. There has been a significant increase in uptake of IT-based public bikesharing systems in Europe, North America, and Asia. Next, the methodology employed in this research is presented. The study draws upon written reports, questionnaires, and telephone interviews to maximize the understanding of the systems' location, their evolution, and their adoption. To explore the potential of bikesharing as a possible broader global policy innovation, the paper reports data from Europe and North America. The results establish an analysis of the speed and extent of the spread of the systems, which bring together data from a variety of published sources and feedback from system operators and/or cities that have such systems. Next, we describe factors that appear to impact the decision to adopt such a system before discussing the extent to which public bikesharing has the potential to grow beyond a niche market (a more narrowly defined group of end users than the mass market).

2. Public bikesharing system evolution

The principle of bikesharing systems is simple: bikesharing users access bicycles on an as-needed basis. Public bikesharing stations are typically unattended and concentrated in urban settings. They provide a variety of pickup and drop-off locations, enabling an on-demand, very low emission form of mobility. The majority of bikesharing programs cover the costs of bicycle maintenance, storage, and parking (similar to carsharing or short-term auto access). Trips can be point-to-point, round-trip, or both, allowing the bikes to be used for one-way transport and for multi-modal connectivity (first-and-last mile trips, many-mile trips, or both) (Shaheen et al., forthcoming; Shaheen et al., 2012a). The last mile refers to the distance between workplaces or homes and the public transport stops where users have disembarked (Shaheen et al., 2010). If these distances are too great to walk in a reasonable time, bikesharing offers users an option to help them complete their journey.

Generally, trips of less than 30 min are covered through a daily, monthly, and annual pass at no extra charge. They can pick up a bike at any dock by using their credit or debit card, membership card, or key, and/or a mobile phone. When they finish using the bike, they can return it to any dock (or the same dock in a round-trip service) where there is a spot and end their session. By addressing the storage, maintenance, and parking aspects of bicycle ownership, public bikesharing encourages cycling among users who may not otherwise ride bikes. Additionally, the availability of a large number of bicycles in multiple dense, nearby locations frequently creates a "network-effect," further encouraging cycling and, more specifically, the use of public bikesharing for regular trips (e.g., commuting and errands) (Shaheen et al., 2012a).

Bikesharing systems emerged in the mid-1960s with the introduction of the 'white bikes' of Amsterdam in the Netherlands (DeMaio, 2009; Shaheen et al., 2010). This first-generation system consisted of a number of bicycles that were painted white and distributed around the city to be used by anyone, free of charge. Only a limited number of first-generation systems existed, and their success was restricted by the lack of security for the bikes, which meant that they were frequently stolen.

The general failure of first-generation systems was eventually met with the emergence of a second-generation that began to adopt a more structured and secure approach to bikesharing systems. This improved security came in the form of coin-deposit docking stations, although the low fee for deposit meant that bikes were often taken for long periods or never returned (Shaheen et al., 2010). The initial, second-generation systems were in the towns of Farsø and Grenå in Denmark and were both opened in 1991 (DeMaio, 2009). The system in Copenhagen, Denmark – opened in 1995 – is perhaps the most recognized second-generation system and is an early example of the implementation of a system on a large scale.

The first, third-generation system was opened in Rennes, France in 1998 (Shaheen et al., 2010; Midgley, 2011). The advent of this generation was made possible by the use of new technology that enabled greater control over bicycle use. This improved control helped make the systems more viable enterprises and allowed them to garner the success they have, where second-generation systems were less successful. A number of new characteristics differentiate third-generation systems from the previous generations. These include "improved bicycle designs, sophisticated docking stations and automated smartcards (or magnetic stripe cards) electronic bicycle locking and payment systems" (Midgley, 2011, p.3; Shaheen et al., 2010). Third-generation systems also commonly use websites and "apps" (e.g., Spotcycle in North America and Europe) to provide real-time information for users and a portal through which customers can manage their accounts (Shaheen et al., 2012a). Fig. 1 shows a system diagram for a typical third-generation system and illustrates the processes customers experience when using a system.

The evolution of this innovation includes a series of generations that have each improved upon the last. Shaheen et al. (2010) introduce the concept of an emerging fourth generation, which may integrate newer technologies such as solar-powered docking stations, power assisted bikes, transit smartcard integration, and the use of smartphone applications for real-time updates. This section highlights one of the key difficulties in studying the spread of an innovation – the innovation's evolution. A key feature of the investigation must therefore be to look for sites of learning to demonstrate that existing systems have been influential in the spread of adoption.

It is also worth noting that this paper focuses on the adoption of public bikesharing schemes with the characteristics above. Alternative systems exist, which are also seeing more widespread adoption. In the Netherlands, for example, OV-fiets.nl is a smartcard based cycle rental scheme where a user can pick up a bike to make the last leg of the journey from rail to the office or other destination. Abellio, a Dutch rail operator, which runs services in the North and East of England, is rolling out this system to a number of rail stations, which would potentially mitigate some of the need for a public bikesharing system. Similarly, in North America, the San Francisco Municipal Transportation Agency plans on launching a bikesharing system along one its regional commuter rail lines. The program plans to launch in Summer 2013. Another example are dockless bikesharing systems, such as Call-A-Bike in Germany and Social Bicycles (SoBi) in the US, which do not rely on street furniture for bicycle docking and access but rather on GPS technology and geofencing to enable "floating" bicycle access (Shaheen et al., 2012a).

3. Methods

To understand the trends in public bikesharing adoption, it is important to describe the current situation. We collected primary data from operators in Europe and North America and supplemented it with secondary data from the Internet. This was sourced from the 'Bikesharing World Map' (produced by Metrobike, LLC, Washington DC, USA) and, where possible, validated on the individual bikesharing system's website. Further data were used from a recent large-scale study on optimizing bikesharing in European cities (OBIS, 2009) and a comprehensive study of public bikesharing in North America (Shaheen et al., 2012a). This allowed us to analyze the adoption years for a greater number of third-generation systems in Europe, 152 in total, and all 19 IT-based operators in the US (as of May 2012). This provides information on where systems are in operation but does not enable an understanding of the reasons for or mechanisms of diffusion. To understand such mechanisms, a review of third-generation European systems was conducted using short, online surveys. In total 61 systems were approached, which resulted in responses from 19 of these. In Europe, we designed two surveys, the first sent to cities where public bikesharing was already operational and the second to those cities that considering implementing bikesharing. While the use of two separate surveys was necessary for practical purposes relating to the phasing of questions, the purpose of each was identical. This was to collect basic data about the size of the system, identify the involvement of external sponsor(s), and to understand the reasons

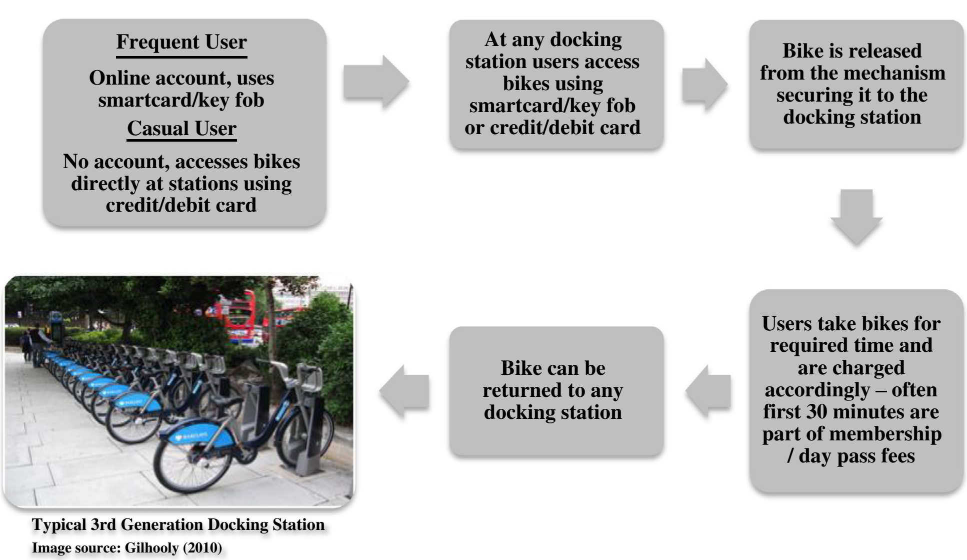

Fig. 1. System diagram – typical third-generation bikesharing system (Gilhooly, 2010).

for system adoption. These surveys were completed August 2011. We encountered difficulty in securing a higher number of completed surveys and believe this was due to the language barriers we faced in working across a range of European countries. Expert telephone interviews were also conducted with all 19 IT-based public bikesharing operators in the US and Canada. As the adoption process is at an earlier stage in the US, it was possible to contact someone directly in each system. This represents a response rate of 100% at that time.

We also conducted 12 telephone interviews within Europe in which a combination of bikesharing systems, policymakers, bikesharing operators, and academics were engaged. Many were conducted in August 2011, while the remaining interviews were carried out in April 2012. Fourteen telephone interviews were held with a combination of urban planning personnel, public transit operators, policymakers, community bike coordinators, and bicycle/bikesharing vendors in North America. Both the operator and stakeholder interviews documented the growth of public bikesharing and provided a greater understanding of its benefits and challenges from a variety of perspectives.

We conducted this qualitative work to ensure that the research identified some of the reasons behind system adoption in different contexts and to document the status of each city in its adoption process. The interviews explored topics including how and why the adoption came about, the role of local government and policy makers in the process and how the system links to existing transport modes. In many cases, further expansion had already happened or was planned following the initial implementation phase. It is critical to document this so that other cities can understand the pathway to full system deployment.

4. Diffusion of systems – findings

4.1. Bikesharing system uptake

A key metric in the diffusion of innovation is the rate and year of initial adoption. Fig. 2 provides the adoption curves for Europe and North America. Fig. 2 shows the initial part of an S-shaped curve where the adoption of bikesharing systems begins with a slow uptake before ‘taking-off’ – a feature of diffusion recognized in the literature (Rogers, 2003).

In Europe, the uptake of third-generation systems was very limited until 2005, with less than 10 in existence. The first such system was in Rennes in 1998 (Vélo à la Carte), which was launched in conjunction with the Clear Channel advertising company. In 2005, the Vélo'v system in the French city of Lyon was launched, which has become one of the most notable third-generation systems. The Lyon system opened with 1500 bikes and was the largest third-generation system at the time with 300 more bikes than the system in Oslo, Norway, which was the second largest. Within the literature, it is regarded as a success story (Bührmann, 2007), and among the European survey respondents in this study, six out of 19 cited Lyon as one of the key cities they learned from during their own implementation process. Of the European systems spoken to, none cited Rennes as a source of learning. This may reflect the relative position of Rennes and Lyon in the technical social networks that promote their transport achievements. It may also be that the Rennes system itself was imperfect as one of the first third-generation systems. A new system “LE vélo STAR,” which operates with 900 bicycles and 81 stations was opened in Rennes in 2009 (Shaheen et al., 2012b).

What is notable about the Lyon system is that after its implementation, system adoption begins to increase. While Lyon cannot claim sole responsibility for this increase, given its prominence among public bikesharing systems, it did play a role in encouraging other cities to adopt a bikesharing system. The diffusion curve illustrates that the adoption of systems began to accelerate in 2003, with the most significant increases in system numbers occurring between 2006 and 2009. Another notable system is the Vélib' system in Paris. Implemented in 2007, Vélib' has quickly become the largest in Europe with 20,600 bikes and 1451 stations (Shaheen et al., 2012b). Along with Lyon, Paris is also regarded among the survey respondents as a key city to learn from. Six out of 19 survey respondents looked to Paris for knowledge and experience when they were creating their own bikesharing systems. It is not clear in Europe whether growth has begun to level off. The curve appears to have reached its steepest gradient with around 20–25 new systems being introduced per year. However, there is significant yearly variation, which means it is too early to project a trend beyond 2012.

A similar diffusion pattern appears to be occurring in North America, although several years behind Europe in the diffusion process. Fig. 2 reflects program launches in the US, Canada and Mexico. The curve for North America highlights two interesting points. First, there has been a recent growth in system adoption, with six new third-generation systems adopted in 2010, and 12 new systems adopted in 2011. An additional seven program loca-

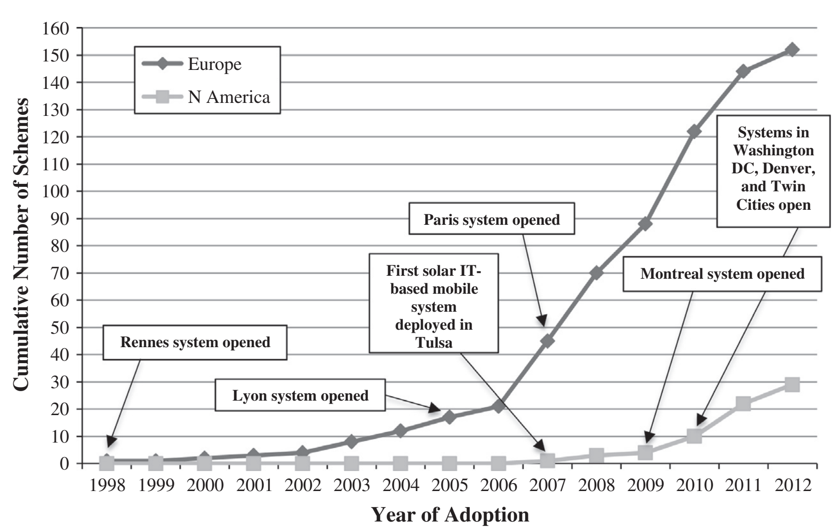

Fig. 2. Diffusion curve for third-generation European and North American public bikesharing systems.

tions launched in 2012 (for a total of 29 in North America). Note: There have been two program closures (SmartBike, which was replaced by Capital Bikeshare, and Chicago B-Cycle) and two program suspensions (Golden Community Bike Share and DecoBike Long Beach). Between January and May 2013, five North American programs launched operations including: Bike Nation (Anaheim, CA); Citi Bike (New York City, NY); Fort Worth B-cycle (Fort Worth, TX); Greenville B-cycle (Greenville, SC); and SLC Bike Share (Salt Lake City, UT). As of May 2013, there were six programs with planned launch dates in the latter half of 2013 (all in the US). These program locations include: Chicago, IL; Columbus, OH; Long Beach, CA; San Diego, CA; San Francisco, CA; and Tampa, FL. There are an additional 33 locations exploring public bikesharing with unscheduled or non-publicly released launch timeframes (30 in the US and three in Canada), as of March 2013; collectively these locations plan to deploy an estimated 24,000 bicycles (Shaheen et al., forthcoming).

The curve suggests that the uptake of the systems lags European adoption by around 5–7 years. As the number of systems in North America grows, we suggest that there is potential for social media to spur further adoption, simultaneously increasing membership in existing systems and encouraging new program start-ups, indicating the adoption curve could move into a mainstream adoption phase.

4.2. Expansion of bicycle numbers

Another important element in the examination of public bikesharing system growth is the study of what happens within "adopter" cities. Are the systems maintained and do they grow? This is considered further in Fig. 3. This bar chart displays the bicycle numbers of the systems that took part in the surveys (Spring 2012, reflecting data as of January 1, 2012) and indicates if there have been any increases in these numbers since the systems opened. Fig. 3 displays in black the bicycle numbers for each system when they were opened. The gray bars indicate where the levels were as of January 1, 2012, and helps to distinguish where increases have occurred. Some notable points immediately emerge from this figure. Please note that the Paris system figures have been omitted to allow easier comparison of the many smaller programs on the chart.

The length of time that a system has been open does not appear to affect the level of increase in bicycle numbers. For example, in Europe, Oslo is one of the earliest third-generation systems, opening in 2001. In the 10 years that it has been operating, it has not had an increase in bicycle numbers, although they remain optimistic about a future increase of up to 1500 bicycles. On other hand, the Barclays Cycle Hire system in London, which launched in July 2010, has already increased its numbers from 5000 to 8000 bikes. Similarly, in North America, Tulsa Townies (Tulsa, OK), the first, third-generation program to launch (2007), has been operating for 5 years and has not had an increase in bicycle numbers. On the other hand, DecoBike (Miami, FL), which launched in 2011, has increased its number of bicycles from 500 to 850, representing a 70% increase.

There are varying levels of expansion among the systems since their opening. Notably, seven out of 25 systems that were examined have at least doubled the size of their systems. One such city is Paris; its size sets it apart from the other cities having more than doubled its bicycle numbers to 20,600 bikes since its opening. It is

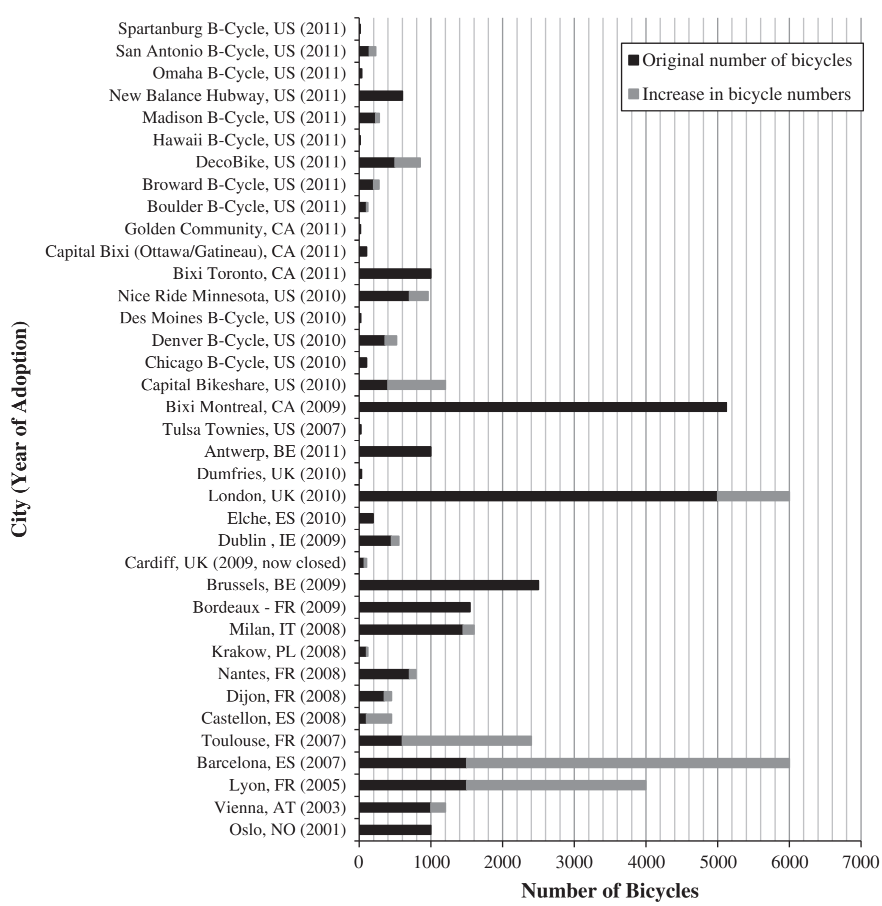

Fig. 3. Increases in the number of bicycles since opening.

interesting to note a number of other systems that have experienced a greater increase in bicycle numbers in proportion to their initial launch levels. Toulouse, Barcelona, and Lyon have all more than doubled their bike numbers in Europe.

The overall growth in bicycle numbers can also be illustrated further by considering the mean and median of the collective numbers. The mean number of bicycles at opening is 1531 in Europe and 509 in North America, while the median was 1000 in Europe and 140 in North America. In Europe, the mean figures are dominated by Paris and London, which opened their systems with 10,000 and 5000 bikes, respectively. The current bicycle numbers show an increase in the average size of a system, with the mean now 2864, while the median has remained at 1000 in Europe. Launch numbers likely reflect the business model deployed. Advertising models (advertising companies deploy bikesharing services in exchange for advertising space in the city) are more predominant in Europe. In contrast in North America, cities have not pursued the advertising model and have tended to deploy non-profit and government-owned/contractor operated models, which are backed by a combination of government funding and grants.

In North America, it is too early to comment definitively on public bikesharing system growth due to its more recent adoption. Nevertheless, a few trends appear to be emerging. Since launching, eight out of 19 North American programs have increased the size of their bike fleets. The fleet increases have been more modest compared to Europe, ranging from 20% to 200% per program, averaging 62% fleet growth among the eight North American programs increasing the number of bicycles after program deployment (measured from program launch date until January 1, 2012).

Until 2011, program launches in North America tended to be smaller scale in terms of fleet size deployed and post-launch increases in fleet size in contrast to their European counterparts. This suggests that the nature of the systems in Europe and North America may be different. As mentioned earlier, there are a number of major European cities that have initiated large systems, whereas in North America the growth pattern for adopting cities appears to be more incremental. This may relate to the financial model for system implementation, which in Europe, are in part or fully borne by the private sector operators or sponsors. There could also be a nature of more cautious experimentalism in North America, where cycling levels are typically lower. As public bikesharing becomes more mainstream in North America, we anticipate that this could change, evidenced by a number of large-scale planned programs including four North American programs set to launch with fleets varying in size from 700 to 7000 bicycles in 2013 (Chicago, Los Angeles, New York City, and San Francisco).

Overall, the data suggest that many of the systems are experiencing only modest expansion in the size of their bicycle numbers. Of the 19 European systems examined, seven had a growth of 10% or less. Similarly, in North America, of the 19 North American systems examined, 11 had a growth rate of 10% or less. This includes cities such as Boston, Dublin, Montreal, Milan, Nantes, and Vienna. Notably, Cardiff and Chicago (B-cycle system) have since been withdrawn and no longer operate. SmartBike DC was replaced by Capital Bikeshare in Washington DC. Golden, B.C. (due to municipal fiscal austerity measures) and DecoBike Long Beach (due to Storm Sandy) were temporarily suspended in late-2012.

4.3. Size of system and city size

In discussing system size and expansion, it is important to consider the underlying drivers of demand. One significant demand driver is population. It could be hypothesized that cities with large populations will have larger systems. Fig. 4 plots a range of cities based on a comparison between their population size and January 2012 bicycle numbers (excluding Paris and London due to their

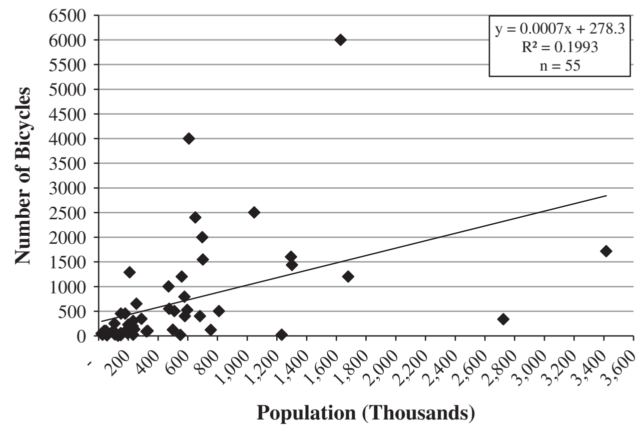

Fig. 4. Comparison of system size versus population size in Europe. Source of city size data: Eurostat (2010).

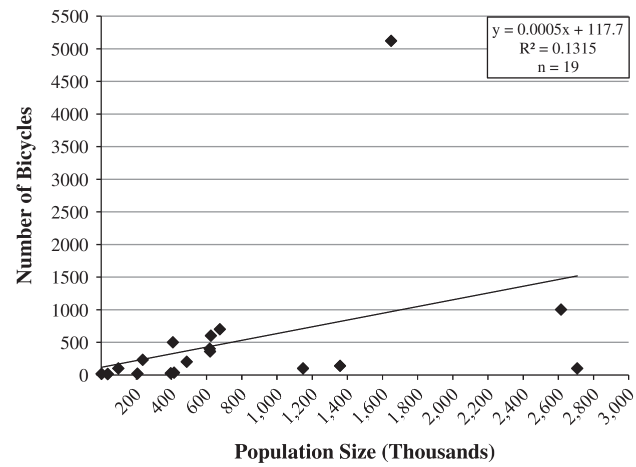

Fig. 5. Comparison of system size versus population size in North America. Source of city size data: U.S. Census (2010) and Can Stat (2011).

rather different characteristics). The figure confirms the expectation that the larger the population, the more bicycles a city can accommodate and support, although there is clearly variation among cities of similar size.

Fig. 5 plots US and Canadian cities in 2012, again comparing population size and current bicycle numbers. Comparing Fig. 5 with Fig. 4, North American cities tend to have smaller systems (measured by fleet size) in smaller cities with a lower density of bicycles per a thousand people than their European counterparts. This may, however, be in part due to North America being earlier in the diffusion process and business model, as mentioned earlier. The one outlier represents BIXI Montreal with 5120 bicycles, a significantly larger system than their North American counterparts, at the close of the 2012 season. (BIXI stands for BIcycle–TaXI). As mentioned earlier, four larger programs in major metropolitan cities are scheduled to launch in 2013. Please note there are 19 operators in Fig. 5, however, two data points overlay other data points.

4.4. Future planned growth

Fig. 6 shows the existing bicycle numbers against the predicted future numbers for each system where the survey respondent was able to provide an estimate. The systems with the larger initial bicycle numbers are the ones with the expectations to expand toward much greater levels in the future. This is likely to be related

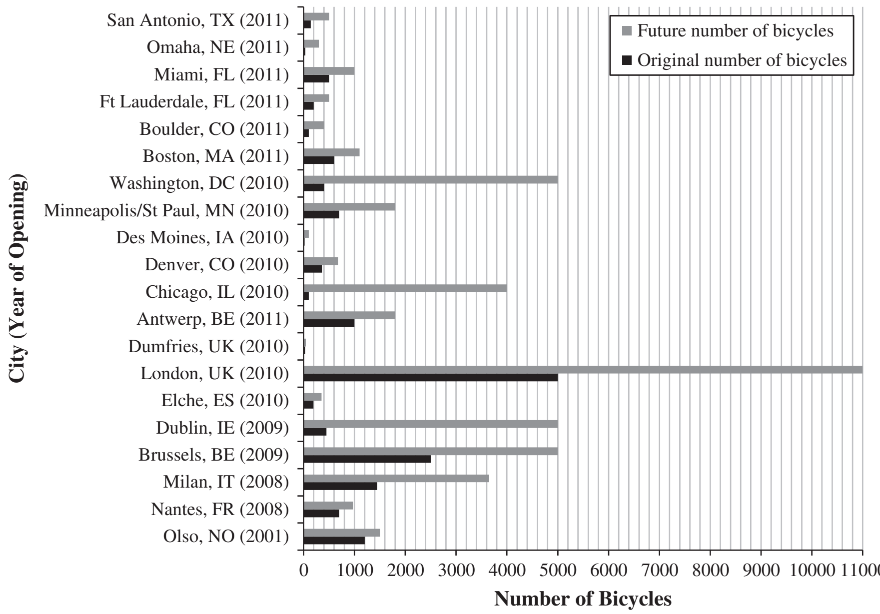

Fig. 6. Comparison of initial size of system against future system size.

to population and potential demand. However, there are examples of cities that start small and experience ambitious growth potential (e.g., Dublin and Washington DC). Systems such as Des Moines, Dumfries, Elche, Ft. Lauderdale, Nantes, and Oslo only anticipate relatively conservative increases in their numbers, and the factors behind this bear further investigation. It could be that these programs were only intended to serve a small population or niche or that their adoption has not been as significant as it had been previously anticipated. It is critical to look at these lessons to ensure that lessons learned can be garnered for other cities about the initial numbers of bikes and docking stations upon system start-up.

5. Understanding the diffusion patterns

The data in Section 4 show that there are clear differences between the systems adopted within Europe and between Europe and North America. It is anticipated that more large-scale systems will also be adopted in North America in 2013, further adding diversity to the mix. This requires attention to the process and reasons for adoption. In addition, it suggests the need for further information dissemination on key outcome variables that define successful system use, such as percent of utilization, cost/bike miles or kilometers, and user satisfaction. This will enable potential adopters to match the type of system and its configuration with their overall aims. This section explores three key aspects that appear to have been important in the diffusion process. First, operator models are discussed, as system operators have acted as diffusion agents due to the knowledge that they bring to facilitate and accelerate adoption. Next, learning processes are examined to understand what, beyond the operator's role has been important. Finally, this section considers some topics related to future system adoption.

5.1. Operator models

In Europe and North America, different operating models are emerging. Relative to other regions, third-generation public bikesharing programs in Europe tend to be large scale, operate through public–private partnerships and advertising models, and feature advanced technologies. According to Midgley (2009b) local governments operate 27% of existing public bikesharing systems. In Europe, it has become common for external operators, notably advertising firms to work alongside city authorities in the implementation of a bikesharing system. These operators have their own bike system models that they sell to the city. While they differ in their visual design, these models have many similarities with regards to system characteristics, such as electronic docking stations, robust bicycles, and smartcards or key fobs. These operators have created systems in a range of European countries with JCDecaux and Clear Channel being the most prevalent. In both of these cases, the advertising company provides bikesharing services in exchange for the right to advertise on city street furniture and billboards. JCDecaux operates 11 systems in four countries, and Clear Channel has slightly more with 13 systems in six countries (Midgley, 2009a). JCDecaux and Clear Channel – the two biggest outdoor advertising companies – operate 23% and 16% of worldwide bikesharing programs, respectively (Midgley, 2009b). In comparison, only one advertising-based bikesharing program launched in North America (SmartBike by Clear Channel in 2008) and ceased operations in January 2011. There were no advertising models operating in North America as of March 2013.

Companies such as JCDecaux and Clear Channel, who are both outdoor advertising agencies, have undertaken a degree of diversification to move into bike system provision, but their motivations could largely be attributed to the fact that they negotiate free advertising rights in the cities in return for the provision of the bikesharing systems. In London, Barclays has sponsored the Transport for London-owned system gaining publicity through the high presence of the bikes and docking stations. These companies have clearly played a role in the increased uptake of public bikesharing systems in Europe and have played a notable role in largely deferring the need for significant up-front investment from local governments.

In North America, different financial and operating models are emerging. In 2012, North American programs emphasized sponsorships to support program costs rather than advertising agencies as program funders and operators. Non-profit organizations (e.g., BIXI Montreal, Nice Ride Minnesota) were the predominant business model, followed by publicly-owned/contractor operated models (e.g., Capital Bikeshare, Capital BIXI), and next for-profit vendor operated models (e.g., DecoBike, Bike Nation, SoBi) (Shaheen et al., 2012a). For-profit vendors operate as businesses and do not require public support.

With sponsorships, public bikesharing operators often obtain start-up and operational support from a combination of corporate sponsors and station sponsors, as well as government. Public and private entities can sponsor either an entire bikesharing system or specific kiosk locations, generally in exchange for the sponsor's advertising on the bikesharing system. In a sponsorship model, sponsor-based advertising is often used to support bikesharing capital purchases rather than as a means to sell advertising as a business; again, the latter is a more common practice in European advertising models. Citibike (a program sponsored by Citibank and MasterCard and owned by the NYC Department of Transportation) launched in New York City in May 2013, with more than 6000 bicycles to start (Associated Press, 2013). Citibank paid $41 million USD to be the programs lead sponsor, followed by MasterCard, which contributed $6.5 million USD. Citibike highlights an emerging trend emphasizing sponsorships in contrast to advertising in North America and is a similar approach to the Barclays program in London.

It is important to note that in North American public bikesharing tends to be highly dependent on casual or short-term users (with passes ranging from 24 h to 7 days) for its revenues. Initial findings suggest that casual/short-term usage accounts between 85% and 90% of North American public bikesharing users; however, additional study is needed to determine how many of these short-term users are return customs (for example, how many people may have purchased multiple 24-h passes) (Shaheen et al., 2013).

Dockless bikesharing models, such as Call-a-Bike and Nextbike, are both quite large operators in Europe. Call-a-Bike has recently implemented two systems with docking stations in Germany, and Nextbike has also more recently created a system in Germany. In contrast, dockless bikesharing has not yet been implemented in public bikesharing North America. One company, SoBi has developed a dockless bicycle outfitted with a solar-powered GPS-enabled lockbox; this concept has recently been implemented in conjunction with AT&T and San Francisco International Airport as an employer-based system. Two other vendors, Zagster and viaCycle, in the US provide dockless bikesharing systems in both urban and campus settings, such as businesses, hotels, and college/universities. SoBi plans on launching North America's first dockless public bikesharing system in Tampa, Florida in the latter half of 2013.

In Europe, certain operators appear to dominate in different countries, suggesting some emerging regional trends. For example, the French company, JCDecaux, who operate under the brand of "Cyclocity," is responsible for a large number of systems within France. On the other hand, Clear Channel is responsible for the creation of all three of the systems that exist in Norway. In contrast, it is too early to determine if regionalism will develop in North America. While three BIXI-branded programs operate in Quebec and Ontario (Canada), BIXI has also established programs in Australia and the United Kingdom. Additionally, its partners Alta Bicycle Share and Public Bike System Company (PBSC) have been instrumental in establishing systems in the Washington DC, Massachusetts and Minnesota (US). Similarly, by the end of 2012, B-Cycle had established program locations in 11 US states, and DecoBike had launched programs in two states (with plans to expand to a third in 2013). Bike Nation launched in January 2013 in Anaheim, California with plans to expand into Los Angeles in Summer 2013. The prevalence of private-sector programs in both Europe and North America (both planned and operational) indicates that a major driver of the diffusion of public bikesharing is entrepreneurs, coupled with transportation planners and their "outreach" in expanding bikesharing.

5.2. Learning process

We also conducted follow-up interviews with respondents to the online surveys to gather more in-depth data regarding the adoption of the systems in European and US cities. Following the online surveys, four respondents in Europe were willing to participate in a telephone interview. These included: Antwerp in Belgium, Dublin in Ireland; and Cardiff[1] and Dumfries in the UK. Transportation planners in Minneapolis; Portland, OR; and San Francisco in the US were also interviewed. Additionally, all 19 existing North American programs (operational as of April 2012) and 14 public agency representatives where bikesharing was operational and planned were asked about public policy developments in their region (Shaheen et al., 2012a).

A key theme that emerged from the interviews was the role of policy entrepreneurs. Policy entrepreneurs can influence policy direction by identifying solutions to policy problems that can attract the attention of decision-makers (Mintrom, 1997). In this context, the bikesharing operators fulfill the role of policy entrepreneurs. The respondents noted the critical role of program operators in bringing expertise and knowledge to the adoption process in their cities and helping to influence their adoption decision. One example of this process in action comes from Dublin where JCDecaux proposed the provision of a public bikesharing system as part of a series of measures to secure advertising rights in the city.

Rogers (2003) argues that the existence of an innovation champion can have a significant effect on the successful adoption of an innovation by an organization. Of the cities interviewed, the presence of an innovation champion is evident in five of the cities – Antwerp, Dublin, Minneapolis, Portland, and San Francisco – and appears to have played an important role in the successful adoption of the public bikesharing systems. In Antwerp, the Deputy Mayor used his position to champion the innovation through the decision-making process and ultimately ensured its successful adoption. In Dublin, a city councilor was influential in helping to implement the policy in the face of significant opposition from those unconvinced of the system's potential. In San Francisco, a project manager at the Municipal Transportation Agency (SFMTA) was able to champion support for a public bikesharing pilot both within their agency and partnering with outside agencies, notably the Bay Area Air Quality Management District (BAAQMD). Similar partnerships between Nice Ride Minnesota and Minneapolis Public Works and bicycle supporters within the Portland Bureau of Transportation have been instrumental in supporting existing and planned public bikesharing efforts in their respective cities.

Evidence of the adopting cities learning from previous bikesharing system adoption also emerged from the interviews. The respondents from the cities of Cardiff and Antwerp were clear that they focused on the past successes and failures of bikesharing systems to understand how they could create a system with a greater chance of long-term success. North American operators also indicated using prior launches to encourage future program success. Some of the lessons learned incorporated by new programs from early North American bikesharing deployments include trying new strategies such as reverse rider rewards programs[2] and incorporating racks on trucks and vans to prevent bicycle damage (Shaheen et al., 2012a). Policy entrepreneurs again feature here, with respondents highlighting their ability to pass on their own previous experiences to the adopting cities.

The "last mile" concept, discussed earlier, features heavily in the interviewee responses, indicating how public bikesharing systems can make a contribution to fulfilling this need. Antwerp, Dub-

[1] Note that the Cardiff system has now been withdrawn.

[2] Where cyclists returned bikes to particular stations to avoid the need for the operator to redistribute bikes.

lin, Cardiff, and San Francisco, for instance, all saw their bikesharing systems as helping to integrate their transportation systems by providing users with a transport option to link their final destinations with the existing public transport infrastructure. For cities seeking to create a more integrated and sustainable transportation system, this is an attractive system feature.

5.3. Future developments

The dynamic nature of the market that we observed during this research process indicates that the system configurations and the implementation processes are still subject to a good deal of innovation. In the future, we envision that as public bikesharing continues to diffuse throughout Canada and the US and into Mexico, bikesharing will also continue to target employers, residential developments, colleges/universities, and hotels to gain market share.

As programs progress from third-generation to fourth-generation systems, future technological innovations will likely accentuate demand-responsive system redistribution to facilitate system rebalancing; value pricing to encourage self-rebalancing; multimodal access; billing and data integration with public transit and carsharing; and GPS tracking. Another likely innovation will be the deployment of "geo-fencing"; using GPS systems to keep bicycles within a geographic area and alerting bikesharing operators when bicycles leave an allowable vicinity (e.g., SoBi).

As public bikesharing becomes more mainstream, increased collaboration will likely occur in key areas of public policy. Governments, public transit authorities, and public and private entities can support bikesharing through endorsements, co-promotions, financial support, enabling provisions for kiosk advertising, encouraging bikesharing in development projects, becoming bikesharing customers, smartcard integration and issuing requests for proposals to bring and expand bikesharing in their region.

As bikesharing continues to expand, new program entrants, possible program mergers, continued technological innovation, and policy developments will continue to characterize it in the coming years. Additionally, public bikesharing will likely receive more attention as a sustainable transportation alternative as a result of rising fuel prices, public health concerns, smart-growth initiatives, and climate-change considerations.

6. Conclusions

This paper has explored the spread of public bikesharing systems employing insights from diffusion theory. The research approach has underlined the importance of gaining a detailed understanding of the nature of the innovation that is being studied and of the processes that underpin its adoption. Only identifying where bikesharing schemes are and how big they are can mask the emerging differences in system configurations, business models, and the different adoption pathways that cities might take (e.g., from incremental expansion to big bang). Although public bikesharing is similar in its operational components in Europe and North America, it is too early to establish key differences, outside of business model variances. An interesting future avenue for research will be to compare use, system management metrics, and impacts (e.g., economic, safety, infrastructure, health, cycling, modal shift, vehicle ownership).

Entrepreneurs in both the private and public sector have been important to the spread of public bikesharing systems and the accelerated deployment in Europe and North America. This suggests strong support for policy transfer as a social process, at least where the systems appear to offer relatively few formal institutional barriers. The business model and long-term sustainability of bikesharing systems is also important. While bikesharing will help to reduce congestion and emissions and improve public health, the public sector has played a more limited role financially in Europe overall. This has not been the case in many North American bikesharing start-ups to date, but this appears to be changing with the emergence of the Citibike system in New York City, as well as private sector approaches like DecoBike, Bike Nation, and SoBi.

While it is not possible to conclusively identify Lyon or Paris as the source of widespread system expansion throughout the globe, there does appear to have been credibility afforded to public bikesharing due to its widespread adoption in these two cities in particular. Over time, other cities become "go to" beacons or exemplars for advice on a more local basis (e.g., London for the UK; Montreal in Canada; and DC, Denver, and the Twin Cities, MN in the US). Interestingly, the earliest adopters are not necessarily the major sources of information dissemination. This may reflect the need for such adopters to learn from the initial innovations and to improve and tweak the systems to make them work effectively or it could reflect the understanding gained from operators through more "local," deeper, and broader practitioner networks.

Finally, this paper demonstrates how quickly some policy innovations can spread – even when public sector cooperation is central to adoption. Since public bikesharing is associated with many social and environmental benefits and is not a particularly contentious policy, its diffusion rate has been swift in contrast to other innovations. Congestion pricing or major public transit projects, for instance, tend to face many more adoption barriers. This suggests that the challenges associated with expensive or controversial policies, as well as the local politics tied to their introduction, remain key obstacles to the more rapid spread of other sustainable transportation policy innovations.

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