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Bikesharing across the Globe

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Concerns about global climate change, energy security, and unstable fuel prices have caused many decision makers and policy experts worldwide to closely examine the need for more sustainable transportation strategies. Sustainable strategies include clean fuels, vehicle technologies, transportation demand management, and integrated land use and transportation strategies (Shaheen and Lipman 2007). Bikesharing—the shared use of a bicycle fleet—is one mobility strategy that could help address many of these concerns. In recent years, interest in this evolving concept has spread across the globe. At present, there are an estimated 135 programs in approximately 160 cities around the world with more than 236,000 bicycles on four continents and over 35 more planned in 16 nations in 2011.

Despite rapid global motorization, worldwide bicycle use has generally increased over the past thirty years. Indeed, as shown in chapter 2, bicycling in Dutch, German, and Danish cities increased between 20 to 43 percent between 1975 and 1995 (Pucher and Buehler 2008). In fact, bicycle trips in Berlin alone quadrupled between 1970 and 2001 (Pucher, Dill, and Handy 2010). Although cycling growth and trends vary worldwide, bikesharing offers a transportation alternative to increase bicycle use by integrating cycling into the transportation system and making it more convenient and attractive to users.

The principle of bikesharing is simple. Individuals use bicycles on an "as-needed" basis. Bikesharing is short-term bicycle access, which provides its users with a sustainable and environmentally friendly form of public transportation. This flexible short-term usage scheme targets daily mobility and allows users to access public bicycles at unattended bike stations. Bicycle reservations, pickup, and dropoff are self-service. Commonly concentrated in urban settings, bikesharing programs provide multiple bike station locations that enable users to pick up and return bicycles to different stations. Bikesharing programs typically cover bicycle purchase and maintenance costs as well as storage and parking responsibilities (similar to car sharing or short-term auto use) (Shaheen, Cohen, and Chung 2009).

By addressing the various aspects of bicycle ownership, bikesharing programs encourage cycling by providing hassle- and maintenance-free bicycle access. Individuals who may not otherwise use bicycles (i.e., tourists or individuals who do not own a bicycle or have access to bicycle storage) are able to enjoy cycling benefits without the respon- sibility of ownership. Access to multiple bikesharing locations makes short distance travel within participating cities more convenient. Furthermore, making a large number of bicycles available for use at various locations may increase the number of individuals who use cycling to meet their daily mobility needs. A stronger bicycle presence can contribute to an overall acceptance of bicycle use for trips that are not solely recreational but also more practical (i.e., commuting to work, running errands). A stronger bicycle presence may also foster a safer cycling environment. As discussed in chapter 7, having more cyclists on the road improves motorist behavior because drivers become more aware of cyclists and are less likely to collide with them (Jacobsen 2003).

Besides individual user perks, bikesharing also offers environmental, social, and transportation-related benefits. For instance, bikesharing provides a low-carbon solution to the "first mile/last mile" problem (i.e., the issue of connecting the short distance between home and public transit and/or transit stations and the workplace). Thus, bikesharing has the potential to play an important role in bridging the gap in existing transportation networks, as well as encouraging individuals to use multiple transportation modes. Bikesharing benefits can include (1) increased mobility options, (2) cost savings from modal shifts, (3) lower implementation and operational costs (e.g., in contrast to shuttle services), (4) reduced traffic congestion, (5) reduced fuel use, (6) increased use of public transit and alternative modes (e.g., rail, buses, taxis, car sharing, ride sharing), (7) increased health benefits, and (8) greater environmental awareness. The ultimate goal of bikesharing is to expand and integrate cycling into transportation systems so that it can more readily become a daily transportation mode.

In recent years, bikesharing has also expanded to college and work campuses throughout North America. Indeed, there are approximately seventy college/university bikesharing programs operating throughout North America, with another eight planned in 2011. Examples of college/university programs worldwide include CibiUAM at the Universidad Autonoma de Madrid (UAM) in Spain and Velocampus Leeds at the University of Leeds in the United Kingdom. The focus of this chapter, however, is on public systems that are open to residents and visitors, as opposed to closed systems that are accessible only to students and employees of a university or major employer. Furthermore, the authors do not address bike rental programs, which traditionally target users interested in leisure-oriented mobility and are most prevalent in areas with a high tourist concentration. In general, bike rental systems consist of a single or limited number of bike stations that are operated by a service attendant and require users to return rented bicycles to the original bike station.

Over the last forty-six years, bikesharing's evolution has been categorized into three key phases (also known as bikesharing generations) (DeMaio 2003). These include the first generation, called "white bikes" (or "free bikes"); the second generation: coin-deposit systems; and the third generation or information technology (IT)–based systems (Gradinger 2007). In this paper, the authors propose a fourth generation, *demand-responsive, multimodal systems*, which builds upon the third.

This chapter is organized into five sections. First, the authors present a history of first- and second-generation bikesharing systems in Europe and North America. Next, third-generation (or IT-based systems) activities are discussed in Europe, the Americas, and Asia. Third, bikesharing business models, impacts, and lessons learned from third-generation systems are discussed. Next, a fourth bikesharing generation is proposed with an eye toward future developments and innovation. Finally, the authors conclude with a summary and recommendations for future bikesharing research.

Bikesharing: The First and Second Generations in Europe and North America

In this section, the authors provide an overview of first- and second-generation bikeesharing in Europe and North America. Asia and South America's experience with bikesharing does not begin until the third generation, IT-based systems, which is addressed later in this chapter.

Bikesharing in Europe

Early European bikesharing systems were small-scale, operated as non-profits, and focused on social and environmental issues. In July 1965, the Provos—an organization involved with anarchist politics, the youth movement, and environmental issues—released their white bike plan in Amsterdam (Home 1991). Fifty bicycles were painted white, left permanently unlocked, and placed throughout the inner city for the public to use freely. However, these bikes were often stolen or damaged. Thus, the white bike plan failed soon after its launch.

White Bike (or Free Bikes): First Generation

Despite Amsterdam's experience, the bikesharing concept caught on and became the first generation of bikesharing known as white bikes (or free bike systems) (DeMaio 2009). In a free bike system, the bicycle is the main program component. Other distinguishing characteristics offirst-generation bikesharing include that bicycles were usually painted one bright color, unlocked, and placed haphazardly throughout an area for free use.

Other cities that implemented a free bike system were La Rochelle, France, in 1974 and Cambridge, England, in 1993. The free bike system in Cambridge, called "Green Bike Schemes," launched with almost 300 shared bicycles that were eventually stolen, resulting in program failure (Midgley 2009b). However, the La Rochelle initiative, called "Vélos Jaunes" or "Yellow Bikes," proved to be successful.

La Rochelle's Mayor, Michel Crépeau, created Vélos Jaunes. Similar to Amsterdam's White Bike plan, Vélos Jaunes was launched as an environmentally progressive measure and became the first successful bikesharing program in France.

Coin-Deposit Systems: Second Generation

Problems with Free Bike Systems (namely bike theft) led the city government and the City Bike Foundation of Copenhagen, Denmark, to launch a bikesharing service that was different from previous systems. This initiative led to the second generation of bikesharing, known as coin-deposit systems. The main components of this generation are (1) distinguishable bicycles (usually by color and special design); (2) designated docking stations in which bikes can be locked, borrowed, and returned; and (3) small deposits to unlock the bikes.

In May 1995, "Bycyklen" (City Bike) was launched as the first large-scale urban bikesharing program in Europe. This initiative included 1,100 specially designed bicycles that were locked and placed throughout downtown Copenhagen at designated city bike racks (New Mobility Agenda 2008). Bicycles were unlocked with a 20 Danish krone coin deposit (US$3) that was refunded upon bicycle return. Today, Bycyklen of Copenhagen is famous because it continues to operate with more than 2,000 bicycles and 110 city bike racks, and it led to the second generation of bikesharing.

Copenhagen's coin-deposit model led to a series of European bikesharing programs including: "Bycykler" in Sandnes, Norway (1996); "City Bikes" in Helsinki, Finland (2000); and "Bycykel" in Arhus, Denmark (2005). The experience of the coin-deposit systems demonstrated that second-generation systems were more expensive to operate than earlier systems. Nonprofit groups were frequently created to administer the bikesharing programs. In many cases, local governments also provided bikesharing funding.

Incorporating designated bicycle stations and coin-deposit locks into second-generation systems created a much more reliable bikesharing system. Although amounts vary by country, coin deposit fees are generally low (around US$4). Also, these systems do not issue a time limit for bicycle use, which means that bikes are often used for long time periods or not returned at all. The major problem with coin-deposit systems is bicycle theft, which can be attributed to customer anonymity. Although bikesharing began as a way to reduce motor vehicle use, Bonnette (2007, 20) indicates that "both the first and second generation [bikesharing schemes] provided welcome opportunities to cycle but did not provide adequate enough support nor reliable service to alter motorized transportation choices and influence people to make significant changes." The shortcomings of second-generation systems later gave rise to the third generation of bikesharing.

Bikesharing in North America

Although the history of bikesharing in North America is shorter than in Europe, North America has transitioned through three bikesharing generations. In 1994, the United Community Action Network (a small nonprofit that works on environmental and livability issues) launched the first North American bikesharing program in Portland, Oregon, called: "Yellow Bike." Sixty bicycles were left unlocked at Pioneer Square in Portland and were available for anyone to use (O'Keefe and Keating 2008). This program closed in 2001, however. Soon after, Yellow Bike evolved into "Create-A-Commuter" at the Community Cycling Center. Since 2007, the City of Portland has tried to create a new bikesharing program.

Soon after Yellow Bike's introduction, Boulder, Colorado, launched the "Green Bike Program" in 1995. The City Transportation Management department ran this program. At the time, 130 bicycles were provided for free use. This system eventually ended due to bike theft.

Coin-Deposit Systems: Second Generation

In 1996, the twin cities of Minneapolis and St. Paul launched the "Yellow Bike Project." Created by a local health club's law firm, it was the first coin-deposit system (or second-generation system) in North America. This program employed 150 bicycles that were placed at designated locations. To use this program, users made a one-time, refundable US$10 deposit, signed a waiver, and received a Yellow Bike Card that facilitated bike use. This program was eventually canceled.

St. Paul's Yellow Bike Project was soon followed by multiple North American bikesharing systems that employed the coin-deposit model. Programs included "Olympia Bike Library" in Olympia, Washington (1996); "Yellow Bike" in Austin, Texas (1997); "Red Bikes" in Madison, Wisconsin (which launched as a free bikesharing system in 1995 and evolved into a coin-deposit model a few years later); "Freewheels" in Princeton, New Jersey (1998); and "Decatur Yellow Bikes" (DYB) in Decatur, Georgia (2002).

Third Bikesharing Generation: Europe, The Americas, and Asia

Since its inception in 1965, bikesharing activity has expanded to include five continents: Europe, Asia, Australia, North America, and South America. At present, Europe is the leading hub for bikesharing growth, development, and success.

As of March 2011, there were approximately 135 bikesharing programs operating in an estimated 160 cities around the world, with more than 236,000 shared bicycles. Eighteen European nations currently support bikesharing. The Americas operate programs in Canada, Mexico, the United States, Argentina, Brazil, and Chile. Asia, which represents the fastest growing bikesharing market, operates programs in China, South Korea, and Taiwan. Table 9.1 provides an overview of available bikesharing data worldwide. Researchers compiled the data for this table via expert interviews, phone calls, and emails with bikesharing system operators worldwide.

Evolution from Second- to Third-Generation Bikesharing

The first generation of bikesharing introduced an innovative mobility option, but the notable failure of this approach demonstrated the need for a new model that deterred theft and incentivized bicycle return. Second-generation bikesharing programs introduced a more viable alternative by integrating the use of coin-deposit locks. Building upon this innovation, third-generation programs gained worldwide popularity by incorporating advanced technologies for bicycle reservations, pickup, dropoff, and information tracking. Though a significant number of bikesharing programs currently operate as third-generation models, existing and developing bikesharing programs are exploring or exhibiting the potential for continuous improvements in what the authors call "fourth-generation" systems. See table 9.2 for an overview of the bikesharing generations.

The four main components of third-generation bikesharing programs are (1) distinguishable bicycles (color, special design, and/or advertisement); (2) docking stations (e.g., flex or fixed stations); (3) kiosk or user interface technology for checking bikes in or out; and (4) advanced technology (e.g., mobile phone, magnetic strip card, smartcards) (City-Ryde n.d.). See figure 9.1 for an overview of third-generation bikesharing

Table 9.1
Worldwide bikesharing programs

Country	Programs	Bicycles	Stations
Argentina	1	560	15
Australia	2	2,600	200
Austria	3	1,500	82
Belgium	1	2,500	180
Brazil	2	452	43
Canada	1	6,100	490
Chile	1	150	15
China	19	123,172	4,422
Czech Republic	1	30	16
Denmark	3	2,650	187
France	29	36,830	3,141
Germany	5	13,330	811
Ireland	1	550	44
Italy	19	3,763	362
Japan	1	150	15
London	1	6,000	400
Luxembourg	2	400	64
Mexico	1	1,200	90
Monaco	1	10	2
Norway	1	1,660	154
Poland	1	155	13
Romania	1	300	3
Slovenia	1	300	31
Spain	25	14,048	1,142
South Korea	2	2,031	185
Sweden	2	1,500	110
Switzerland	1	600	45
Taiwan	2	5,000	61
United States	4	3,122	313
United Kingdom	2	6,091	420
Total	**136**	**236,754**	**13,056**

Notes: The authors count one program for each system that spans multiple cities in one country. Bikesharing in Germany has fixed stations and flex stations. In total, there are approximately sixty-two fixed stations in Germany. Seven cities also use flex stations as bikesharing stations.

Table 9.2
Bikesharing generations

First generation: White bikes (or free bikes) systems
• Components
◦ Bicycles
• Characteristics
◦ Distinct bicycles (usually by color)
◦ Located haphazardly throughout an area
◦ Bicycles unlocked
◦ Free of charge
Second generation: Coin-deposit system
• Components
◦ Bicycle
◦ Docking stations
• Characteristics
◦ Distinct bicycles
◦ Located at specific docking stations
◦ Bicycles have locks
Third generation: IT-based system
• Components
◦ Bicycles
◦ Docking stations
◦ Kiosks or user interface technology
• Characteristics
◦ Distinct bicycles (color, special design, or advertisements)
◦ Located at specific docking stations
◦ Bicycles have locks
◦ Smart technology is used for bicycle checkin/checkout (mobile phones, mag-stripe cards, or smartcards)
◦ Theft deterrents (program specific; members are required to provide ID, bankcard, or mobile phone number to identify users). Failure to return bicycle incurs charges to recover bicycle cost and may also include high punitive costs. Nonmembers are generally required to pay a large deposit to ensure bike return, under risk of losing their deposit.
◦ Programs paid for as a membership service, typically free for the first specific time interval with gradually increasing costs enforced.

Figure 9.1
Three main components of third-generation bikesharing systems, as shown here in Paris, France. *Credit:* Tristan Nitot (flickr.com/photos/nitot/).

components. Information technology makes third-generation bikesharing programs distinct by enabling programs to track bicycles and user information, which has helped to deter bike theft. The next sections summarize third-generation bikesharing in the three main regions of the world.

European Overview

European experience provides a robust history of bikesharing planning, implementation, and operations. More recent growth of third-generation bikesharing programs can be attributed to innovations tracing back to this understanding.

In 1998, the first citywide IT-based system appeared when Clear Channel, a large outdoor advertising company, launched its first "SmartBike" program in Rennes, France. To access free bicycles for up to three hours, SmartBike required users to complete a smartcard application. After eleven years of service, the Rennes system, more commonly known as "Vélo à la Carte," came to an end in May 2009. This program has been replaced by "LE vélo STAR," which operates with 900 bicycles and 81 stations.

The program that later popularized third-generation bikesharing is "Velo'v" in Lyon, France. Launched by JCDecaux in 2005, Velo'v now operates with more than 4,000 bicycles in Lyon and Villeurbanne.

In 1974, the city of La Rochelle launched Vélos Jaunes. By 2006, the program included 120 bicycles and 12 stations. In 2009, La Rochelle replaced Vélos Jaunes with a second, fully automated system (i.e., bicycle pickup and dropoff is via self-service with a smartcard) called "Yélo." Yélo, which currently operates with 350 bicycles and 50 stations, employs smartcards that enable full integration with the public transportation network.

In 2010, London also launched the "Barclays Cycle Hire" system (with BIXI as the service provider). At present, users have access to 6,000 bicycles at 400 bike stations.

Today, the most widely known third-generation bikesharing system is "Vélib'" in Paris, France. To date, Vélib' operates with 20,600 bicycles and 1,451 bicycle stations available every 300 meters. Vélib' operates on a fee-based system in which the first thirty or forty-five minutes of cycling is free to users (depending on user subscription).

Between 2007 and 2008, Vélib' reported that 20 million trips were made through their program. Averaging 78,000 trips per day, Vélib's usage rates require that the program operate as efficiently as possible to maintain and distribute the bicycles.

As of March 2011, there were eighteen European nations operating bikesharing programs: Austria, Belgium, the Czech Republic, Denmark, France, Germany, Italy, Ireland, London, Luxembourg, Monaco, Norway, Poland, Romania, Spain, Sweden, Switzerland, and the United Kingdom.

Americas Overview

Although North American bikesharing experience is more limited, Washington DC's "SmartBike" pilot program demonstrated that bikesharing is feasible. Launched in 2008 with 120 bicycles and 10 stations, SmartBike marked the beginning of North America's experience with IT-based systems. By January 2009, the program reported 1,050 subscribers. As highlighted in chapter 13, in 2010, SmartBike DC came to an end and "Capital Bikeshare" was launched. Capital Bikeshare operates in Arlington County, Virginia, and Washington, DC, with 1,100 bicycles and 114 stations. At present, it is the largest bikesharing program in the United States.

The largest IT-based system in North America is "BIXI" in Canada. BIXI stands for BIcycle-TaXI. BIXI first launched in May 2009 in Montreal and operates with 5,000 bicycles and 400 stations. Following the cancellation of their second-generation bikesharing program—the Yellow Bike Project—the city of Minneapolis launched "Nice Ride" Minnesota in June 2010, with BIXI as the service provider. This system currently operates with 700 bicycles and 73 stations.

In May 2011, BIXI launched in Toronto and currently operates with 1,000 bicycles and 80 stations. The program also expanded into the Ottawa-Gatineau area and operates with 100 bicycles and 10 stations. It is important to note that technological advances in the BIXI program mark a shift toward the fourth-generation of bikesharing described shortly.

In 2010, Mexico City launched "EcoBici," which currently operates with 1,200 bicycles and 90 docking stations. Prior to Ecobici's launch, city officials agreed to build 186 miles of bike lanes by 2012 to encourage cycling.

Bikesharing activity in South America started in 2008. At present, Argentina, Brazil, and Chile are the only nations with fully operating programs. Colombia is in the process of planning its own bikesharing system.

In 2008, Brazil launched two bikesharing programs—"UseBike" in São Paulo and "Samba" in Rio de Janeiro. Following Samba's launch in Brazil, Chile started a bikesharing program, which currently operates with 180 bicycles and 18 stations.

Asian Overview

Asia's bikesharing history is limited to third-generation, IT-based systems. Despite its more limited experience, Asia is the fastest growing market for bikesharing today. The first bikesharing program to launch in Asia was "TownBike" in Singapore in 1999 (known as "Smart Bike" from 1999 to 2004). This program ended in 2007.

The second bikesharing program in Asia was the "Taito Bicycle Sharing Experiment," which operated in Taito, Japan, from November 2002 to January 2003. It was the first bikesharing pilot in Japan and was funded by the national government's Social Experiment grants. The program employs 130 bicycles at twelve locations. Users accessed bicycles by magnetic striped membership cards, which helped prevent theft.

At present, bikesharing programs are operating in South Korea, Taiwan, and mainland China. South Korea's city government launched its first bikesharing program, "Nubija," in Chongwan in 2008. It now operates with more than 3,500 bicycles and 160 stations. Similar to other programs, Nubija does not charge users a fee for the first hour of use.

"C-Bike" in Kaohsiung City launched in 2009 as the first bikesharing program in Taiwan. At present, this program offers 4,500 bicycles and 50 bike stations. Following Kaohsiung's program, the Taipei government partnered with Giant to launch their bikesharing system, "YouBike," in 2009. This program is completely automated and offers 500 bicycles at ten locations.

The largest and most famous bikesharing program in Asia is the "Public Bicycle" system in Hangzhou, China, which was launched by the Hangzhou Public Transport Corporation in 2008 (see figure 9.2). This system was the first IT-based system in mainland China. With a population of 4.24 million people (in the urban area), Hangzhou's high population density makes it a promising bikesharing location. Today, Hangzhou's system operates with 60,600 bicycles and more than 2,400 bike stations. According to a survey by the Hangzhou Public Transport Corporation, bicycles are used six times per day on average, and no bicycles were lost during its first year of implementation (Hangzhou Public Transport Corporation, n.d.).

The Hangzhou Public Bicycle System has surpassed Vélib as the largest bikesharing program in the world. It has sparked great interest in bikesharing in mainland China. Indeed, Chinese cities with bikesharing programs include Shanghai, Wuhan, Guangzhou, Nanjing, Dujiangyan, Foshan, Haiko, Shenzhen, Qingzhou, Suzhou, Yantai, Wuxi, Yinchuan, Jiangyin, Zhoushan, Tongliang, Nanchang, and Chizhou.

In May 2010, the city of Melbourne, Australia, launched its first bikesharing program, known as "Melbourne Bike Share" (with BIXI as the service provider). It currently operates with 600 bicycles and 50 docking stations, and users must abide by mandatory cycle

Figure 9.2
Hangzhou, China, has the world's largest public bikesharing system, with more than 60,000 bikes. *Credit:* Hua Zhang.

helmet-wearing laws. Many bikesharing commentators speculate that these mandatory helmet laws have hindered the success of Melbourne's program, as helmet laws tend to deter casual cyclists.

Business Models, Impacts, and Lessons Learned from Third-Generation Bikesharing Systems

The success of third-generation programs has made it the most prominent bikesharing model worldwide. Furthermore, its successes have increased bikesharing markets to include a growing number of bikesharing vendors, providers, service models, and technologies.

Business Models and Vendors

Bikesharing providers range from local governments to transportation agencies, advertising companies, for-profit groups, and nonprofit groups (DeMaio 2009). Bikesharing is funded through advertising, self-funding, user fees, municipalities, and public-private partnerships (CityRyde

Table 9.3
Bikesharing providers and business models

Provider	Standard operating model	Program example
Advertising company	Provide bikesharing services in exchange for rights to advertise on city street furniture and billboards	• SmartBike (US) • Cyclocity (France)
Public transportation agencies	Provide bikesharing services under the guidance of a public authority to enhance the public transportation system	• Hangzhou Public Bicycle (China) • Call a Bike (Germany)
Local governments/ public authority	Directly design and operate a bikesharing program for the well-being of cities or a local government purchases bikesharing services that are provided by others	• City Bikes (Denmark) • Nubija (South Korea) • YouBike (Taiwan) • Shanghai Public Bicycle (China)
For-profit	Provide profitable bikesharing services with minimal government involvement	• Nextbike (Germany)
Nonprofit	Provide bikesharing services under the support of public agencies or councils	• BIXI (Canada) • Hourbike (UK) • Wuhan Public Bicycle (China)

2009). Table 9.3 provides an overview of bikesharing business models and providers.

The most prominent funding sources for third-generation bikesharing are municipalities and advertising partnerships (in which advertising companies provide bikesharing services in exchange for advertising rights on city street furniture and billboards). In Barcelona, Bicing funds bikesharing through advertising, but it also uses revenue from parking fees (i.e., parking meters) to cover the costs. According to Midgley (2009b), local governments operate 27 percent of European bikesharing systems. In addition, JCDecaux and Clear Channel—the two biggest outdoor advertising companies—operate 23 percent and 16 percent of bikesharing programs, respectively. Public agencies also are becoming an increasingly important provider of bikesharing programs. As mentioned earlier, a public transportation agency operates the Hangzhou bikesharing system under local government guidance. Furthermore, nonprofit bikesharing programs, which typically require public support at the startup stage, are likely to remain a prominent model for the foreseeable future.

At present, major bikesharing vendors include JCDecaux, Clear Channel Adshel, BIXI, Véolia Transportation, Cemusa, and B-Cycle (CityRyde 2009). Examples of other providers include Nextbike, OYBike, B-igloo, and Domoblue. Several major bikesharing systems include: BIXI by the Public Bike System Company (PBSC) in the United States, Bicincittà by Comunicare in Italy, and Cyclocity by JCDecaux in France (Midgley 2009a). Furthermore, increasing use of advanced technologies in third-generation bikesharing has led to a growing market for technology vendors. IT-based systems became popular after the largest outdoor advertising company, Clear Channel, launched SmartBike in Rennes, France. Other companies that provide automated IT-based systems include: Biceberg (underground bicycle parking); BIXI Public Bike System (bicycles and bike station); Ebikeshare (bicycles and bike station); LeisureTec Bike Station (bicycle stations); Q I Systems CycleStation (kiosks and smartcards); Sekura-Byk (bicycle racks and smart card systems); and Urban Racks (bicycle racks) (International Bicycle Fund, n.d.).

Social and Environmental Impacts

At present, research on the environmental and social benefits of bikesharing, particularly before-and-after behavioral trends, is limited. However, many bikesharing programs have conducted user-based surveys that document program experience.

One impact of bikesharing is its potential to provide emission-free transportation. SmartBike, for instance, estimates that more than 50,000 SmartBike trips cover a total of 200,000 kilometers (km) per day throughout Europe, and USA SmartBike calculates that a car covering this same distance would produce 37,000 kilograms of carbon dioxide (CO_2) emissions per day (SmartBike 2008). With an average of 78,000 trips per day and approximately 20 minutes per trip, Vélib' users cover an estimated 312,000 km per day. A car covering this same distance would have produced approximately 57,720 kg of CO_2 per day. As of August 2009, BIXI users covered an estimated 3,612,799 km, which translates into 909,053 kg of reduced greenhouse gas (GHG) emissions. As of October 2009, the Hangzhou Public Bicycle Program generated 172,000 trips per day. With an average trip lasting approximately thirty minutes, Hangzhou program users covered an estimated 1,032,000 km per day. An automobile covering this same distance would produce 190,920 kg of emissions. If successful, these data suggest that increased bikesharing activity has the potential to yield notable GHG emission reductions. However, emission reductions are difficult to estimate. Factors such as bicycle redistribution systems and previous user behavior (i.e., not all bikesharing users were previously automobile users) may reduce emission reduction estimates.

Nevertheless, the potential of bikesharing programs to reduce vehicle emissions is promising when one considers current data on modal shifts. For instance, after the 2007 launch of Bicing in Barcelona, the city's bicycle modal share rose from 0.75 percent in 2005 to 1.76 percent in 2007 (Romero 2008). Following the 2007 launch of Vélib', the bicycle mode share in Paris increased from about 1 percent in 2001 to 2.5 percent in 2007 (Nadal 2007). Furthermore, a recent survey of SmartBike (Washington, DC; now Capital Bikeshare) members found that bikesharing attracted nearly 16 percent of individuals who would otherwise have used personal vehicles for trip making (District of Columbia Department of Transportation 2009). Velo'v in Lyon, France, reports that bicycle use replaced 7 percent of trips that would otherwise have been made by private vehicles (Bührmann 2007). In Paris, 20 percent of Vélib' users also reported using personal vehicles less frequently (The Vélib' Letter 2008).

Although few studies evaluate behavioral shifts, available data suggest notable changes. For example, during the first year of Velo'v, Lyon documented a 44 percent increase in bicycle riding (Bührmann 2007). Ninety-six percent were new users who had not previously bicycled in the Lyon city center. In addition, bicycle riding in Paris also increased by 70 percent with the launch of Vélib'.

The growth and evolution of bikesharing programs worldwide has led to increased public awareness of bikesharing and its potential social, environmental, financial, and health-based benefits. Along with increased bikesharing awareness, public perception of bicycling as a transportation mode also has evolved. A 2008 Vélib' survey, for instance, found that 89 percent of program users agreed that Vélib' made it easier to travel through Paris. According to SmartBike, nearly 79 percent of respondents reported that bikesharing use in Washington, DC, was faster or more convenient than other options. In Montreal, the initial public reaction to BIXI was skeptical. However, the heavy presence of BIXI bicycles has led Montreal residents to embrace the new system. In general, cities that have implemented successful bikesharing programs appear to have improved the image of bicycling as a viable transportation mode. Given the early and limited impact data, more research is needed on the social and environmental benefits of bikesharing.

Lessons Learned

The last forty-five years of bikesharing planning, implementation, and operations have led to a range of lessons learned. In this section, we address six key lessons learned: (1) bicycle theft and vandalism, (2) bicycle redistribution, (3) information systems, (4) insurance and liability considerations, (5) role of supportive infrastructure and partnerships (e.g., bike-transit connection), and (6) prelaunch considerations.

Bicycle Theft and Vandalism

Early bikesharing programs learned that user anonymity created a system prone to bicycle theft. Third-generation bikesharing introduced electronic smartcards to access bicycles from their racks. Smartcards record user identification information as well as bike usage (e.g., time, duration, location, kilometers). This improvement solved previous issues of user anonymity and facilitated bicycle tracking, which reduced bike theft and vandalism. Despite such innovations, a 2009 study of Vélib' reported that since its launch in 2007, 7,800 bicycles had disappeared and another 11,600 bicycles had been vandalized. High rates of theft raise concerns because Vélib' bicycles are expensive. Indeed, it currently costs the program €400 (US$519) to replace each bicycle. Although existing technologies such as global positioning systems (GPS) and radio frequency identification tracking developments can greatly decrease bicycle theft, such technology increases implementation costs. In contrast to Vélib', Hangzhou's bikesharing system and BIXI in Montreal have experienced low theft and vandalism rates. To curb theft and vandalism, Hangzhou's system employs inexpensive bikes (400 RMB, or US$60). A high density of bicycles—free for the first hour—makes cycling more convenient, which can decrease the need to steal a bicycle. To curb the impact of vandalism, BIXI allocates 8 to 9 percent of their budget to address theft. By the end of 2009, less than 3 percent of BIXI's budget to address vandalism and theft had been used (Crivello 2009). Overall, emerging fourth-generation models should consider more robust bicycles that include more effective locking mechanisms to further deter theft.

Bicycle Redistribution

Vélib's experience highlights the need for bicycle redistribution (i.e., bicycles must be redistributed to key demand locations frequently after use). To manage its 20,600 bicycles, Vélib' uses twenty natural-gas-powered vehicles to transport bikes from one station to another. As bikesharing programs grow and cover larger areas, emerging systems must find ways to address redistribution issues that have been raised in Vélib's experience. For instance, BIXI and Hangzhou also employ trucks to redistribute bicycles. In addition, BIXI is redesigning redistribution trucks to include on-board computers that can provide drivers with real-time information on bicycle stations to facilitate a speedier and more efficient response to bicycle shortages and station overcrowding. As cities launch larger programs, it is important that emerging fourth-generation systems (described in the following section) incorporate technological improvements for bicycle redistribution.

Information Systems

One of the most revolutionary changes introduced by third-generation bikesharing programs is the use of real-time information systems. Today, the majority of third-generation programs provide users with real-time information on station parking and bicycle availability through the Internet (e.g., an individual program website or websites such as Google Maps) by directing text messages to mobile phones or phone-based hotlines. Such technologies should continue to be improved and be included in current and future bikesharing programs to facilitate a more efficient and user-friendly system.

Insurance and Liability Considerations

The growth of bikesharing programs also has raised questions regarding insurance and liability. For instance, helmet use is not mandatory for most bikesharing programs, which may conflict with insurance liability laws. As of 2007, Vélib' reported an estimated six fatalities. In contrast, Nextbike has encountered three accidents (user injuries), and BIXI and Hangzhou each had one accident in 2009. The authors are aware of two programs that currently provide insurance for users: Hangzhou and Bicing. In the case of Hangzhou bikesharing, the service covers any injury that occurs due to bikesharing use (Tao 2009). Bicing provides public liability insurance, which includes all damage or harm resulting from the service (such as equipment and users) to a third party. This policy also covers harm to users. At present, the main obstacle to insurance coverage is high cost.

Role of Supportive Infrastructure and Partnerships

Overall, a comprehensive city bikesharing strategy—from cycling infrastructure to public transit connections—is needed to encourage bikesharing growth. Cities that have successfully implemented bikesharing programs have also expanded their cycling infrastructure. For instance, bike lanes in the city of La Rochelle grew from 130 km in 2003 to 150 km in 2005 (Midgley 2009a). Bike lanes in Paris expanded from 122 km in 1998 to 399 km in 2007 (Pucher, Dill, and Handy 2010). The city of Barcelona had less than 10 km of bike lanes in 1990, which increased to 155 km of bike paths by 2008 (Romero 2008). In Germany, cycling networks increased from 12,911 km in 1976 to 31,236 km in 1996 (Pucher and Buehler 2008).

Bikesharing partnerships are also crucial to encouraging bikesharing growth. Typical partnerships are established between bikesharing programs and public transit. For instance, bike parking is often made available at metro and subway stations, near bus stops, train stations, and other forms of public transportation. "Call a Bike" in Germany not only places bicycles at rail stations, but also offers financial incentives to users with a Bahn rail card. Partnerships also include the use of linked smartcards that allow users to access various transportation modes with a single linked transit card. This approach encourages multimodal connections to complete a trip. However, a fully integrated linked transit card is hard to establish because it requires various public transportation departments to sync their schedules, establish connecting facilities, and create a single pricing scheme.

A comprehensive bikesharing strategy (i.e., safety campaigns, linked transit options, cycling policies) is crucial in promoting bikesharing's current and future growth.

Prelaunch Considerations

Bikesharing programs around the world agree that successful systems are those that address the specific needs of their users and market segments prior to and after deployment. Programs such as BIXI have found that bicycle availability is not easy to predict. BIXI addresses this issue by employing mobile bicycle stations that can be relocated according to usage patterns. BIXI also has identified prelaunch marketing as a critical action for success. "Hourbike" (in the United Kingdom) has noted pricing as key to establishing a profitable business model. Furthermore, the implementation of incremental usage fees encourages bicycle users to plan short trips to avoid high fees.

The city of Paris implemented other prelaunch strategies that have encouraged bikesharing success. For example, prior to Vélib's launch, the city's mayor lowered vehicle speed limits, built more bike paths, and changed street directions by creating more one-way streets. These modifications helped reduce private vehicle traffic by 20 percent.

Spain established a national funding program known as the Spanish Institute for Energy Diversification and Saving (IDEA). As part of this effort, various Spanish cities received funding and support for bikesharing. In Germany, the department of transportation also established a national funding program to promote bikesharing efforts. In 2009, fifteen funding awards were granted for bikesharing programs.

To address other prelaunch concerns—including bicycle flow, number of docking stations needed, and bicycle redistribution practices—mathematical tools and models have now been created (see Shu et al. 2010). Such tools allow cities to evaluate various bikesharing scenarios to assess program viability before launch and during operation.

As third-generation bikesharing markets continue to expand worldwide, current models of implementation, operations, and technology provide key insights for future systems. In the next section, the authors propose a fourth bikesharing generation: "demand-responsive, multimodal systems."

The Future

Advances and shortcomings of previous and existing bikesharing models have contributed to a growing body of knowledge of this shared mode. Such experiences are making way for an emerging fourth-generation bikesharing model or demand-responsive, multimodal systems. These systems build upon the third generation and emphasize (1) flexible, clean docking stations (or no docking stations, e.g., German railways); (2) bicycle redistribution innovations; (3) smartcard integration with other transportation modes, such as public transit and car sharing; and (4) technological advances (e.g., GPS tracking, touchscreen kiosks, solar power, electric bikes). The main components of fourth-generation bikesharing are the bicycle, docking station, kiosk/user interface, bicycle distribution system, and linked public transit smartcard.

BIXI in Canada marks the beginning of bikesharing's fourth generation. One of BIXI's major innovations includes mobile bicycle docking stations, which allow stations to be transferred to different locations according to usage patterns and user demands. Another improvement that BIXI might offer is the use of solar-powered stations, which would further reduce emissions and the need to secure access to an energy grid to support operations.

Fourth-generation systems also might consider omitting fixed docking stations and opting for flex stations in which users employ mobile phone technology and street furniture for bicycle pickup and dropoff. With such a system, users receive a code on their mobile phone to unlock bicycles. Users leave bicycles at major intersections and inform the program where the bicycle is locked. This approach allows bicycles to be available throughout an entire city and minimizes the amount of infrastructure needed to operate a program.

Call a Bike in Germany operates a hybrid system in which flex and fixed stations are used. Between March and May 2010, the city of Berlin launched a pilot program that consisted of fixed and flex stations within a defined parking area. The city of New York is set to launch a "Social Bicycles" program (SOBI) whereby users will be able to call or use a smartphone application to locate a bicycle. If successful, reducing the need for bicycle docking stations may allow bikesharing to be more accessible in cities around the world, as it would dramatically decrease the cost of starting and operating a program. However, flex stations can pose program difficulties, such as difficulty locating bicycles because they are not confined to defined stations.

Another area of improvement for fourth-generation systems is bicycle redistribution innovations (DeMaio 2009). Vélib's use of specially designed vehicles for bicycle relocation represents a first step toward addressing this issue. However, employing larger, designated vehicles for bicycle transportation increases implementation costs and is not an emission-free solution. In the future, bikesharing services will continue to deploy more efficient redistribution methods (e.g., automated technologies that facilitate demand-responsive bike relocation). Bikesharing models may also incentivize user-based redistribution (i.e., the rider performs bicycle redistribution) by employing demand-based pricing in which members receive a price reduction or credit for parking bicycles at empty docking locations.

A third feature of fourth-generation systems is the seamless integration of bikesharing with public transportation and other alternative modes, such as taxis and carsharing (for more information on carsharing, see Shaheen, Cohen, and Chung 2009; Shaheen and Cohen 2007; Millard-Ball et al. 2005) via smartcards, which support numerous transportation modes on a single card. Launched in 2009 in La Rochelle, France, Yélo uses a smartcard that is fully integrated with the public transportation system. In 2010, the city of Guangzhou, China, launched the "Guangzhou Public Bike Initiative." This system is also fully integrated with the city's bus rapid transit (BRT) and metro stations (Shaheen et al. 2011). However, creating a program that coordinates various forms of transportation on a single card is challenging and costly, as it requires multiple agency involvement.

Another area for improvement is bicycle security, which can be addressed by ongoing technological advancements. For instance, GPS integration could deter bike theft and facilitate bike recovery. However, GPS units are costly and can potentially increase financial losses if bikes with built-in GPS are vandalized or stolen. Finally, to target a larger scope of bikesharing users, fourth-generation systems may be more likely to incorporate electric bicycles, which enable longer-distance trips; encourage cycling on steeper hills and slopes; and lessen physical exertion requirements, particularly when users are commuting or making work trips in business attire.

Conclusion

Bikesharing emerged in Europe as a transportation mode forty-six years ago. Since its inception, bikesharing systems have evolved to address geographic and technological demands. Bikesharing has expanded to include five continents: Europe, North America, South America, Asia, and Australia. Bikesharing growth has undergone three evolutionary stages including: first-generation white bikes (or free bike systems), second-generation coin-deposit systems, and third-generation IT-based systems. Building upon third-generation systems, the authors also propose an emerging fourth-generation system: demand responsive, multimodal systems.

Notable growth in third-generation bikesharing programs has led to a diversity of business models ranging from advertising to nonprofits. Despite limited research on the social and environmental benefits of bikesharing, recent surveys document (1) reduced auto use, (2) behavioral shifts toward increased bicycle use for daily mobility, and (3) a growing perception of the bicycle as a convenient transportation mode.

Other important benefits include GHG emission reduction and individual and citywide cost savings. Operating and maintaining personal automobiles includes fuel costs, insurance and registration fees, and maintenance-related expenses. In contrast, bikesharing programs cover bicycle purchase, maintenance, and storage or parking expenses. For cities, it is less costly to implement bicycle infrastructure than vehicle infrastructure. However, programs such as Vélib' have demonstrated that bicycle theft and vandalism can offset bikesharing cost savings.

Other benefits include positive health effects due to bicycle use (Pucher and Dijkstra 2003; Pucher and Buehler 2010). However, health benefits are often overlooked due to safety concerns. At present, cities with higher numbers of motorists experience increased cycling accidents. Bikesharing programs can help reduce traffic congestion and vehicle fuel use. However, obstacles such as limited trip length, lack of cargo space, exposure to weather conditions, and user issues (i.e., limited height adjustment on bicycles) reduce the number of potential bikesharing users.

As bikesharing continues to expand, lessons from previous and current bikesharing programs have led to a greater understanding of implementation and operational procedures. Indeed, this understanding has facilitated the success of bikesharing programs in cities with varying needs and characteristics. For instance, bikesharing has proven successful in Hangzhou—a city with a developed cycling culture and high levels of cycling prior to bikesharing introduction. Conversely, Mexico City—a city with historically low levels of cycling—has also launched a successful program.

Bikesharing has addressed a range of goals. For instance, bikesharing was launched to address high emission levels in China and traffic congestion in Mexico City. In Montreal, it was deployed to complement existing transportation options. Despite city size or cycling levels, the introduction of various bikesharing technologies, business models, and varying operational costs means that developed and developing cities have more options to launch a program that addresses issues and needs specific to their city. However, more in-depth understanding and research on bikesharing are needed, including bikesharing's social and environmental benefits; a better understanding of the environments in which it works best (e.g., cities in which biking is not already popular as a daily mode, where private storage is limited, and the potential in developing countries); sustainable business models; operations; advanced technology applications (i.e., the potential of electric bicycles); and the role of public policies in supporting its ongoing growth.

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