Bikesharing in Europe, the Americas, and Asia

Past, Present, and Future

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Growing concerns about global motorization and climate change have led to increasing interest in sustainable transportation alternatives such as bikesharing (the shared use of a bicycle fleet). Since 1965, bikesharing has grown across the globe on five continents: Europe, North America, South America, Asia, and Australia. Today, approximately 100 bikesharing programs are operating in an estimated 125 cities, with more than 139,300 bicycles. Bikesharing's evolution is categorized into three generations: (*a*) white bikes (or free bike systems), (*b*) coin-deposit systems, and (*c*) information technology-based systems. In this paper, a fourth generation is proposed: demand-responsive, multimodal systems. A range of existing bikesharing business models (e.g., advertising) and lessons learned are discussed, including (*a*) bicycle theft and vandalism, (*b*) bicycle redistribution, (*c*) information systems (e.g., real-time information), (*d*) insurance and liability concerns, and (*e*) prelaunch considerations. Although limited in number, several studies have documented bikesharing's social and environmental benefits, which include reduced auto use, increased bicycle use, and a growing awareness of bikesharing as a daily mobility option. Despite bikesharing's ongoing growth, obstacles and uncertainty remain: these include future demand, safety, sustainability of business models, limited cycling infrastructure, challenges to integrate with public transportation systems, technology costs, and user convenience (e.g., limited height adjustment on bicycles, lack of cargo space, and exposure to weather). More research is needed for a better understanding of bikesharing's effects, operations, and business models in light of its reported growth and benefits.

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 (*1*). 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 100 programs in approximately 125 cities worldwide with more than 139,300 bicycles on four continents and another 45 programs planned in 22 nations in 2010.

Despite rapid global motorization, worldwide bicycle use has generally increased during the past 30 years. Indeed, bicycling in Dutch, German, and Danish cities increased between 20% and 43% between 1975 and 1995 (*2*). 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 without the costs and responsibilities of bike ownership. Bikesharing is short-term bicycle access, which provides its users with an environmentally friendly form of public transportation. This flexible short-term use scheme targets daily mobility and allows users to access public bicycles at unattended bike stations. Bicycle reservations, pickup, and drop-off are self-service. Commonly concentrated in urban settings, bikesharing programs also 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 carsharing or short-term auto use) (*3*).

Besides individual user perks, bikesharing offers environmental-, social-, and transportation-related benefits. For instance, bikesharing provides a low-carbon solution to the "last mile" problem. The last mile refers to the short distance between home and public transit or transit stations and the workplace, which may be too far to walk. 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. Potential bikesharing benefits include (*a*) increased mobility options, (*b*) cost savings from modal shifts, (*c*) lower implementation and operational costs (e.g., in contrast to shuttle services), (*d*) reduced traffic congestion, (*e*) reduced fuel use, (*f*) increased use of public transit and alternative modes (e.g., rail, buses, taxis, carsharing, ridesharing), (*g*) increased health benefits, and (*h*) 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 also has expanded to college and work campuses throughout North America. Indeed, there are more than 65 college and university bikesharing programs operating throughout North America and another 10 programs planned in 2010. Examples of college and university programs worldwide include Cibi-UAM 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 paper, however, is on citywide systems that are open to residents and visitors, as opposed to closed systems that are accessible only to students and employees of a

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university or major employer. Furthermore, bike rental programs are not addressed, which also have expanded worldwide. Unlike bikesharing, bike rental traditionally targets users interested in leisure-oriented mobility and is most prevalent in areas with a high tourist concentration. Bike rental systems generally consist of a single or limited number of bike stations that are operated by a service attendant. A majority of bike rental programs also require users to return rented bicycles to the original bike station and are generally operated on an hourly pricing basis.

During the past 43 years, bikesharing's evolution has been categorized into three key phases (also known as bikesharing generations). 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 (*4*). In this paper, a fourth generation, called demand-responsive, multimodal systems, is proposed, which builds on the third.

This paper is organized into seven sections. First, a history of bikesharing in Europe, the Americas, and Asia is presented, focused on the first two generations. Next, current bikesharing activities (or IT-based systems) in Europe, the Americas, and Asia are discussed. Third, bikesharing business models and vendors are described. Next, the current understanding of the social and environmental benefits associated with bikesharing is summarized. Fifth, lessons learned are presented. Next, a fourth bikesharing generation is proposed with an eye toward future developments and innovation. Finally, the paper concludes with a summary and recommendations for future bikesharing research.

HISTORY OF BIKESHARING

In this section an overview of bikesharing's history is provided. Asia's and South America's experience with bikesharing does not begin until the third generation, IT-based systems. That is categorized as the present. Thus, Asia's and South America's experiences are not included in this section, which focuses on the first two generations of bikesharing in Europe and North America.

Bikesharing in Europe

Early European bikesharing systems were small scale, operated as nonprofits, and focused on social and environmental issues. In July 1965, the Provos—an organization that was heavily involved with environmental issues—released its White Bike Plan in Amsterdam, Netherlands (*5*). This plan was seen as the solution to traffic problems in Amsterdam's inner city. Fifty bicycles were painted white, left permanently unlocked, and placed throughout the inner city for the public to use freely. These bikes were often stolen or damaged. In addition, police officers confiscated all bicycles that were found unattended or unlocked, claiming that they invited theft (*5*). As such, the White Bike Plan failed soon after its launch.

White Bikes (or Free Bike Systems): First Bikesharing Generation

Despite earlier experiences, the bikesharing concept caught on and led to the first generation of bikesharing known as white bikes (or free bike systems) (*6*). In a free bikesharing system, the bicycle is the main program component. Other distinguishing characteristics of first-generation bikesharing were 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 in the United Kingdom in 1993, called Green Bike Scheme. Soon after Green Bike Scheme's launch, the almost 300 shared bicycles in Cambridge were stolen, resulting in program failure (*7*). However, the La Rochelle initiative, called vélos jaunes or yellow bikes, proved to be successful and continues to operate today. 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. Through the strong support of La Rochelle's urban community, vélos jaunes became the first successful bikesharing program in France.

Coin-Deposit Systems: Second Bikesharing 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 any previous system. In January 1995 Bycyken (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 (*8*). Bicycles were unlocked with a 20 DKK (Danish krone) coin deposit (US$3) that was refunded on bicycle return.

Bycyken of Copenhagen is famous not only because it continues to operate with more than 2,000 bicycles and 110 city bike racks today but also because it led to the second generation of bikesharing, known as coin-deposit systems. The main components of this generation are (*a*) distinguishable bicycles (usually by color and special design); (*b*) designated docking stations in which bikes can be locked, borrowed, and returned; and (*c*) small deposits to unlock the bikes.

Soon after the implementation of coin-deposit systems, the Copenhagen 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 these coin-deposit systems demonstrated that second-generation systems were more expensive to operate than early systems. Nonprofit groups were frequently created to administer the bikesharing programs. In many cases, local governments also provided bikesharing organizations with funding.

The incorporation of designated bicycle stations and the use of coin-deposit locks in second-generation systems created a much more reliable bikesharing system that was both dependable and more theft resistant. Although amounts vary by country, coin deposit fees are generally low (about 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 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" (*9*). 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 (*10*). This program, however, closed in 2001. Soon after, Yellow Bike evolved into Create-A-Commuter at the Community Cycling Center and focused on providing better cycling services. 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, and a group of high school students made up the majority of volunteers who maintained the bicycles. This system was eventually cancelled as a result of bike theft. The City of Boulder, however, has issued a Request for Information and is considering a new bikesharing program that would consist of 250 bicycles and 10 stations and receive half its funds from President Obama's stimulus plan (*11*).

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 used 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. In 1996 the Minnesota Office of Environmental Assistance provided the program with short-term funding. This program was eventually cancelled. At present, the city of Minneapolis has selected the Public Bike System Company, maker of Montreal's BIXI, to provide 1,000 bicycles and 80 stations by June 2010 (*12*).

The launch of St. Paul's Yellow Bikes was soon followed by multiple North American bikesharing systems that used the coin-deposit model. Programs included Olympia Bike Library in Olympia, Washington (1996); Yellow Bike in Austin, Texas (1997); Red Bikes in Madison, Wisconsin (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 in Decatur, Georgia (2002).

BIKESHARING: THE PRESENT

Since 1965 bikesharing activity has expanded to include four continents: Europe, Asia (including Australia), North America, and South America. Not surprisingly, Europe remains the leading hub for bikesharing growth, development, and success.

At present, there are approximately 101 bikesharing programs operating in an estimated 125 cities around the world, with more than 139,000 shared bicycles. As the leader in bikesharing activity today, Europe currently has 19 nations that support bikesharing. The Americas operate programs in Canada, Mexico, the United States, Brazil, and Chile. Asia, which represents the fastest growing bikesharing market, operates programs in China, South Korea, and Taiwan. Table 1 provides an overview of available bikesharing data worldwide.

TABLE 1 Worldwide Bikesharing Programs

Country	Programs	Bicycles	Stations
Austria	3	1,500	82
Belgium	1	1,000	100
Brazil	2	232	26
Canada	1	5,000	400
Chile	1	50	10
China	3	61,400	2,518
Czech Republic	3	51	16
Denmark	3	2,513	277
Finland	1	300	26
France	22	36,443	2,936
Germany[a]	3	6,069	128
India	1	100	6
Italy	16	3,392	361
Ireland	1	450	40
Luxembourg	2	370	40
Mexico	1	1,100	82
Monaco	1	10	2
Netherlands	1	—[b]	200
Norway	1	1,660	154
New Zealand	1	175	11
Poland	1	100	13
Romania	1	100	10
South Korea	1	430	20
Spain	21	11,080	842
Sweden	3	2,125	171
Switzerland	1	120	11
Taiwan	2	2,000	31
United Kingdom	2	1,410	809
United States	1	120	10
Total	101	139,300	9,332

NOTE: The authors count one program for each system that spans multiple cities in one country.
[a]Bikesharing in Germany has fixed stations and flex stations. In all, there are 128 fixed stations in Germany, and five cities employ flex stations for bikesharing. Flex stations are not designated; users can leave their bicycles at a major intersection and inform the program where the bicycle is locked.
[b]Number of bicycles could not be confirmed.

Following is a discussion of the evolution from second- to third-generation bikesharing and current bikesharing activities in Europe, the Americas, and Asia.

Evolution from Second- to Third-Generation Bikesharing

Although the first generation of bikesharing introduced an innovative mobility option, the notable failure of the 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 on this innovation, third-generation programs gained worldwide popularity by incorporating advanced technologies for bicycle reservations, pickup, drop-off, and information tracking. See

the list below for an overview of the generations of bikesharing. Although 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 is called here, fourth-generation systems.

Bikesharing Generations

- First generation: white bike (or free bike) systems
  - Component: bicycles
  - Characteristics
    1. Distinct bicycles (usually by color),
    2. Bicycles located haphazardly throughout an area,
    3. Bicycles unlocked, and
    4. No charge for use.
- Second generation: coin-deposit systems
  - Components
    1. Bicycles and
    2. Docking stations.
  - Characteristics
    1. Distinct bicycles (color or special design),
    2. Bicycles located at specific docking stations, and
    3. Bicycles with locks.
- Third generation: IT-based systems
  - Components
    1. Bicycles,
    2. Docking stations, and
    3. Kiosks or user interface technology.
  - Characteristics
    1. Bicycles are distinct (color, special design, or advertisements).
    2. Bicycles are located at specific docking stations.
    3. Bicycles have locks.
    4. Smart technology is used for bicycle check-in and checkout (mobile phones, mag-stripe cards, or smartcards).
    5. Theft deterrents (program specific; members are required to provide ID, bankcard, or mobile phone number to identify users) are used. 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 deposits.
    6. Programs are paid for as a membership service, typically free for the first specified time interval with gradually increasing costs enforced.
- Fourth generation: demand-responsive, multimodal systems
  - Components
    1. Bicycles,
    2. Docking stations,
    3. Kiosks–user interface, and
    4. Bicycle distribution system.
  - Characteristics
    1. Distinct bicycles,
    2. Programs may include electric bicycles,
    3. Specific docking stations that are more efficient (mobile, solar powered, etc.),
    4. Improved locking mechanism to deter bicycle theft,
    5. Touch screen kiosks–user interface,
    6. Bicycle redistribution system, and
    7. Linked to public transit smartcard.

The four main components of third-generation bikesharing programs are (*a*) distinguishable bicycles (either by color, special design, or advertisement); (*b*) docking stations; (*c*) kiosk or user interface technology for check-in and checkout; and (*d*) advanced technology (e.g., magnetic striped card, smartcards) (*13*). Third-generation bikesharing programs are distinct because the incorporation of information technology has allowed bikesharing programs to track bicycles and user information. The incorporation of third-generation information technology has helped to deter bike theft, which was a major concern of second-generation coin-deposit systems. The next sections summarize third-generation bikesharing in the three main regions of the world.

Europe

European experience provides a robust history of bikesharing planning, implementation, and operations. Furthermore, the more recent growth of third-generation bikesharing programs can be attributed to innovations tracing back to this understanding. Relative to other countries, third-generation bikesharing programs in Europe are large scale, operate through public–private partnerships, and feature advanced technologies.

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 3 h, SmartBike required users to complete a smartcard application. After 11 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 (*14*).

The program that popularized third-generation bikesharing is Velo'v in Lyon, France. JCDecaux launched Velo'v in 2005 with 1,500 bicycles. It operates with more than 3,000 bicycles in Lyon and Villeurbanne.

One early European bikesharing program—vélos jaunes, which launched in La Rochelle in 1974—continues to evolve, expand its geographic coverage, and adopt new technologies to support its growth. In 2006 the city extended the bikesharing system to include 120 bicycles available 24 h per day, 7 days per week at 12 different stations. In 2009 La Rochelle launched a second, fully automated system (i.e., bicycle pickup and drop-off are self-service via smartcard) called Yélo, with 26 stations, 110 bicycles, and smartcards that enable full integration with the public transportation network. Yélo plans to operate a total of 50 stations and 300 bicycles (*15*).

As of fall 2009 there were approximately 19 European nations operating bikesharing programs. These include Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, Ireland, Luxembourg, Monaco, the Netherlands, Norway, Poland, Romania, Spain, Sweden, Switzerland, and the United Kingdom. In addition, London partnered with BIXI and plans to launch its own bikesharing program with 6,000 bicycles and 400 stations by summer 2010.

The most widely known third-generation bikesharing system today is Vélib' in Paris. To date, Vélib' operates with 20,600 bicycles and has plans of expanding to 23,900 bicycles by the end of 2009 (*16, 17*). More than 2 million Parisians have access to 1,451 bicycle stations, which are available every 300 m, 24 h a day, and 7 days a week. Vélib' operates on a fee-based system, encouraging program users to use bicycles for short trips by offering the first 30 min of cycling free to users. After 30 min, increasing costs are scheduled. Users also have the option of purchasing a 1-day pass for €1 (US$1.42),

a 1-week pass for €5 (US$7.11), or a 1-year subscription for €29 (US$41.21).

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

The Americas

Although North American bikesharing experience is more limited, Washington, D.C.'s, SmartBike pilot program demonstrated that bikesharing is feasible. Launched in 2008, SmartBike marked the beginning of North America's experience with IT-based systems. To date, this program operates with 120 bicycles at 10 different bicycle stations. In January 2009 the president of Clear Channel Adshel reported that the program was serving 1,050 subscribers (*18*). Users are required to pay a US$40 annual subscription fee in contrast to paying a fee each time they access the service. At present, the program allows users to access bicycles for up to only 3 h at a time.

The largest IT-based system in North America is BIXI (BIcycle-TaXI) in Montreal, Quebec, Canada. Launched in May 2009, BIXI operates with 5,000 bicycles, 400 stations, and 11,000 program members (Gian-Carlo Crivello, unpublished data). BIXI's system has also been chosen as the provider for a planned bikesharing program in Boston, Massachusetts, which aims to launch with 2,500 bicycles and 290 stations by summer 2010. Technological advances in the BIXI program mark a shift toward the fourth-generation of bikesharing described below.

The implementation of bikesharing programs in North America is limited, and bikesharing activity in South America started only recently, in 2008. At present, Brazil and Chile are the only two nations with fully operating programs. Argentina and Colombia are in the process of planning their own bikesharing systems.

In 2008 Brazil launched two bikesharing programs—UseBike in São Paulo and Samba in Rio de Janeiro. UseBike operates with 202 bicycles and 23 bike stations. This program offers users 1 free hour and costs 2 Brazilian reais (US$0.85) for each additional hour.

Samba was launched with 80 bicycles and eight bike stations. It is in the process of expanding to neighboring cities and is expected to reach 500 bicycles with 50 bike stations by the end of 2009. To access bicycles, Samba requires mobile phone activation. Users are instructed to subscribe online, and then they can walk up to any of the eight bike stations, call the designated number from their mobile phone, enter a security code, dial the station and spot number, and the bicycle is unlocked. Following the launch of Samba in Brazil, Chile launched its own bikesharing program with 50 bicycles and 10 bike stations.

Asia

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 activity 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 operated with 130 bicycles at 12 locations. Bicycles were accessed by magnetic striped membership cards, which helped prevent theft. Because of Taito's high population density, program users felt that more bicycle locations were necessary (despite access to 12 rental locations in 1 square mile) (*19*).

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. The program has 430 bicycles and 20 terminals located at the city center. 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. The entire system operates on a build-operate-transfer basis that costs NT$90 million (US$2.58 million). Following the launch of Kaohsiung's program, the Taipei government partnered with Giant to launch the bikesharing system YouBike in 2009. This program is completely automated with an electronic management system that allows bicycles to be rented and returned to any location. There are 500 bicycles at 10 locations that provide 718 YouBike parking spaces in Taipei (*20*).

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. This system was the first IT-based system in Mainland China. With a population of 3.73 million, Hangzhou has a high population density, which makes it a promising bikesharing location. Hangzhou's system operates with 40,000 bicycles and 1,600 stations and is expected to expand to 50,000 bicycles and 2,000 stations by the end of 2009 (*21*). Increasing the number of bicycle stations to 2,000 means that tourists and residents will have access to a bicycle station every 200m. According to a survey by the Hangzhou Public Transport Corporation, bicycles are used six times per day on average, and no bicycles have been lost during the first year of implementation (*21*).

The Hangzhou Public Bicycle System has surpassed Vélib' as the largest bikesharing program in the world. Not surprisingly, it has sparked great interest in bikesharing in Mainland China. Indeed, Beijing, Tianjin, Hainan, and Suzhou launched pilot programs in 2008 and 2009.

Australia

In February 2010 the city of Melbourne, Australia, announced plans for its first bikesharing program. The city has selected BIXI as the provider and plans to launch with 1,000 bicycles and 52 stations by summer 2010.

BUSINESS MODELS AND VENDORS

The success of third-generation programs has made it the most prominent bikesharing model worldwide. Furthermore, third-generation successes have increased the number of bikesharing vendors, providers, service models, and technologies. Bikesharing providers, for instance, range from local governments to transport agencies, advertising companies, and for-profit and nonprofit groups (*22*). Bikesharing is funded through advertising, self-funding, user fees, municipalities, and public–private partnerships (*16*). Table 2 provides an overview of bikesharing business models and providers.

The most prominent funding sources for third-generation bikesharing are municipalities and advertising partnerships (i.e., advertising companies provide bikesharing services in exchange for the right to advertise on city street furniture and billboards). According

TABLE 2 Bikesharing Providers and Business Models

Provider	Standard Operating Model	Revenue Sources	Program Example
Advertising company	Provide bikesharing services in exchange for rights to advertise on city street furniture and billboards	Advertising funding from city street furniture, billboards, bikes, and bikesharing stations Member–nonmember usage fee	SmartBike (United States) Cyclocity (France)
Public transport agencies	Provide bikesharing services under the guidance of a public authority to enhance the public transportation system	Government subsidies Member–nonmember usage fee Ads on bikes and bikesharing stations	Hangzhou Public Bicycle (China) Call a Bike (Germany)
Local governments and 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	Municipality funding Member–nonmember usage fees Ads on bikes and bikesharing stations	City Bikes (Denmark) OV-fiets (Netherlands) Nubija (South Korea) YouBike (Taiwan) Shanghai public bicycle (China)
For profit	Provide profitable bikesharing services with minimal government involvement	Member–nonmember usage fee Ads on bikes and bikesharing stations	Nextbike (Germany)
Nonprofit	Provide bikesharing services under the support of public agencies or councils	Public–private partnership funding Member–nonmember usage fees Bank loans Local funding	BIXI (Canada) Hourbike (United Kingdom) Bicincittà (Italy) Wuhan public bicycle (China)

to Midgley local governments operate 27% of existing bikesharing systems. In addition, JCDecaux and Clear Channel—the two biggest outdoor advertising companies—operate 23% and 16% of worldwide bikesharing programs, respectively (*7*). Public agencies also are becoming an increasingly important provider of bikesharing programs. In China, for instance, public transport agencies operate the Hangzhou bikesharing system under local government guidance. Furthermore, nonprofit bikesharing programs, which typically require public support at the start-up stage, are likely to remain a prominent model for the foreseeable future.

At present, major bikesharing vendors include Clear Channel Adshel, BIXI, Veolia Transportation, Cemusa, JCDecaux, and B-Cycle (*16*). Of these, the major bikesharing systems are (*a*) SmartBike by Clear Channel Outdoor in the United States, (*b*) Bicincittà by Comunicare in Italy, and (*c*) Cyclocity by JCDecaux in France (*23*). 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 its first SmartBike program 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), QI Systems CycleStation (kiosks and smartcards), Sekura-Byk (bicycle racks and smartcard systems), and Urban Racks (bicycle racks) (*24*).

SOCIAL AND ENVIRONMENTAL EFFECTS

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

One effect 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 km per day. SmartBike calculates that a car covering this same distance would produce 37,000 kg of carbon dioxide (CO_2) emissions per day (*25*). With an average of 78,000 trips per day and approximately 20 min 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 emissions (*26*). As of October 2009, the Hangzhou Public Bicycle Program generated 172,000 trips per day. With an average trip lasting approximately 30 min, Hangzhou program users covered an estimated 1,032,000 km per day. In contrast, 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 greenhouse gas emission reductions.

The potential of bikesharing programs to reduce vehicle emissions is promising when one considers current data on modal shifts. For instance, in a recent survey of SmartBike (Washington, D.C.) members, researchers found that bikesharing drew nearly 16% of individuals who would otherwise have used personal vehicles for trip making (*27*). Velo'v in Lyon, France, reports that bicycle use replaced 7% of trips that would otherwise have been made by private vehicles (*28*). In Paris, 20% of Vélib' users also reported using personal vehicles less frequently (*29*).

The growth and evolution of bikesharing programs worldwide have 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 has evolved. A 2008 Vélib' survey, for instance, found that 89% of program users agreed that Vélib' made it easier to travel through Paris. According to SmartBike, nearly 79% of respondents reported that bikesharing use in Washington, D.C., 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 positively affected the perception of bicycling as a viable transportation mode.

Although very few studies evaluate behavioral shifts, available data suggest notable changes. For example, during the first year of Velo'v, the city of Lyon documented a 44% increase in bicycle riding

(*28*). Ninety-six percent were new users who had not previously bicycled in the Lyon city center. In addition, bicycle riding in Paris increased by 70% with the launch of Vélib'. Given the relatively limited impact data, more research is needed on the social and environmental benefits of bikesharing.

LESSONS LEARNED

The past 45 years of bikesharing planning, implementation, and operations have led to a range of lessons learned. Such developments have contributed to a growing body of bikesharing knowledge. Five key lessons learned are addressed: (*a*) bicycle theft and vandalism; (*b*) bicycle redistribution; (*c*) information systems; (*d*) insurance and liability considerations; and (*e*) prelaunch considerations. Table 3 provides a summary of the lessons learned.

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, a fourth bikesharing generation is proposed: demand-responsive, multimodal systems.

FOURTH-GENERATION BIKESHARING: DEMAND-RESPONSIVE, MULTIMODAL SYSTEMS

The advances and shortcomings of previous and existing bikesharing models have contributed to a growing body of knowledge about this shared public transportation mode. Such experiences are making way for an emerging fourth-generation bikesharing model or demand-responsive, multimodal systems. These systems build on the third generation and emphasize (*a*) flexible, clean docking stations;

TABLE 3 Bikesharing Lessons Learned

Situation	Discussion
Bicycle theft and vandalism	Early on, bikesharing programs learned that user anonymity created a system that was 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 bicycle theft and vandalism. Despite such innovations, a 2009 study of Vélib' reported that since its launch in 2007, 7,800 bicycles have disappeared, and another 11,600 bicycles have been vandalized (*30*). High rates of theft raise concerns because Vélib' bicycles are expensive. Indeed, it currently costs the program 400 euros (US$519) to replace bicycles. While existing technologies, such as Global Positioning Systems (GPS) and radio frequency identification tracking developments, have greatly decreased bicycle theft, such technology greatly increases implementation costs. Other methods that programs are now considering include a membership-based lending process (e.g., overnight) to reduce bicycle theft. In contrast to Vélib', Hangzhou's bikesharing system and BIXI in Montreal have experienced relatively low theft and vandalism rates. To curb theft and vandalism, Hangzhou's system employs inexpensive bikes (400 RMB). 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% of its budget to address theft. To date, less than 3% of that budget has been used (Gian-Carlo Crivello, unpublished data). Overall, emerging fourth-generation models should consider more robust bicycles that require less maintenance and include more effective locking mechanisms that 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 20 natural gas powered vehicles to transport bicycles from one station to another (*31*). 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 are also employing 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 section "Fourth-Generation Bikesharing: Demand-Responsive, Multi-Modal Systems") 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., individual program website or websites such as Google Maps), direct text messages to mobile phones, or by calling system hotlines. Such technologies should continue to be improved and 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 the question of insurance and liability. For instance, helmet use is not mandatory for most bikesharing programs, which may conflict with insurance liability laws. As of 2008, Vélib' reported three fatalities. In contrast, nextbike has encountered three accidents, while BIXI and Hangzhou have each encountered one (Mareike Rauchhaus, unpublished data). One exception, however, is the Hangzhou bikesharing system, which currently covers any injury that occurs through their bikesharing system (Xuejun Tao, unpublished data). At present, the main obstacle for insurance is high cost.
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, which can be relocated according to usage patterns. BIXI also has identified pre-launch marketing as a critical action for successful programs. Hourbike has noted pricing as key to establishing a successful business model. Furthermore, the implementation of incremental usage fees encourages bicycle users to plan short trips to avoid high fees.

(*b*) bicycle redistribution innovations; (*c*) smartcard integration with other transportation modes, such as public transit and carsharing; and (*d*) technological advances including Global Positioning System (GPS) tracking, touch screen kiosks, and electric bikes (*32*). See the bulleted list above for an overview of the four generations of bikesharing described in this paper.

BIXI, which launched in Canada in May 2009 and is operating with 5,000 bicycles and 11,000 members, marks the beginning of bikesharing's fourth generation (Gian-Carlo Crivello, unpublished data). One major innovation of BIXI's bicycle docking stations is that they are mobile, which allows stations to be removed and transferred to different locations. This innovation enables bicycle stations to be relocated according to usage patterns and user demands. Another improvement that BIXI's system might offer to future bikesharing programs is the use of solar-powered stations. Not surprisingly, solar-powered stations would further reduce emissions and the need to secure access to an energy grid to support operations (*33*). Fourth-generation bikesharing also may consider omitting docking stations and opt for flex stations in which users employ mobile phone technology and street furniture for bicycle pickup and drop-off, as do five cities in Germany.

Another area of improvement for fourth-generation systems is bicycle redistribution innovations. Vélib's use of specially designed vehicles for bicycle relocation represents a first step toward addressing that issue. However, using larger, designated vehicles for bicycle transport increases implementation costs and is not emission free, at present. In the future, bikesharing services will continue to deploy more efficient redistribution methods (e.g., automated technologies that facilitate demand-responsive bike relocation). Fourth-generation bikesharing models may also incentivize user-based redistribution (i.e., in which the rider performs bicycle redistribution) by using demand-based pricing in which users receive a price reduction or credit for docking 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 et al. (*3*), Shaheen and Cohen (*34*), and Millard-Ball et al. (*35*)] via smartcards, which support numerous transportation modes on a single card. In 2009 the Yélo bikesharing system was launched in La Rochelle, France. This system includes a smartcard, which is fully integrated with the public transportation system. That facilitates multimodal transportation linkages and user convenience, which could lead to greater reductions in auto ownership and usage, as more daily trips are supported by alternative modes. However, creating a program that coordinates various forms of transportation on a single card is challenging; it can be costly and often requires multiagency involvement.

Another area for improvement is bicycle security, which can be supported by ongoing technological advancement, such as the design and integration of GPS units into more robust bicycle frames that further enhance existing locking mechanisms, deter bike theft, and facilitate bike recovery. However, adding GPS units is 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 45 years ago. Since their inception, bikesharing systems have evolved to address geographic and technological demands. Bikesharing has expanded to include four continents—Europe, North America, South America, and Asia (including Australia). Bikesharing growth also has undergone three evolutionary stages including (*a*) first-generation white bikes (or free bike systems), which began in Amsterdam in 1965; (*b*) second-generation coin-deposit systems, which started in Copenhagen, Denmark, in 1995; and (*c*) third-generation IT-based systems, which emerged in the Rennes, France, city-based system in 1998.

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

Building on third-generation systems, a fourth is proposed: demand responsive, multimodal systems. This emerging bikesharing generation is characterized by (*a*) flexible, clean docking stations; (*b*) bicycle redistribution innovations; (*c*) smartcard integration with other transportation modes, such as public transportation and carsharing; and (*d*) technological advances including GPS tracking, touch screen kiosks, and electric bikes.

Although bikesharing systems are growing worldwide and many have demonstrated the potential to reduce greenhouse gases and fuel consumption by discouraging personal vehicle use for daily mobility, their future demand and long-term sustainability are uncertain. Many obstacles exist, such as limited and supportive infrastructure (i.e., docking stations, bike lanes), theft, high technology costs, funding considerations, and safety issues. More in-depth understanding and research on bikesharing are needed. That includes bikesharing's social and environmental benefits, a better understanding of the conditions in which it thrives (e.g., cities in which biking is less popular as a daily mode and residential and business storage is limited), business models, operational understanding, advanced technology applications, and the potential role of public policy in maintaining this mode and supporting its expansion.

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