PUBLIC BIKESHARING IN NORTH AMERICA: EARLY OPERATOR UNDERSTANDING AND EMERGING TRENDS

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ABSTRACT
Public bikesharing—the shared use of a bicycle fleet—is an innovative mobility strategy that has recently emerged in major North American cities. Bikesharing systems typically position bicycles throughout an urban environment, among a network of docking stations, for immediate access. Approximately five years ago, information technology (or IT)-based bikesharing services began to emerge in North America. Since 2007, 27 IT-based programs have been deployed–26 are operational and one is now defunct. Bikesharing growth potential in North America is examined on the basis of a survey of all 15 IT-based public bikesharing systems operating in the United States and all four programs operating in Canada, as of January 2012. These programs account for 172,070 users and 5,238 bicycles and 44,352 users and 6,235 bicycles in the United States and Canada, respectively. This paper reviews early operator understanding of North American public bikesharing and discusses emerging trends for prospective program start-ups.

KEY WORDS: Public bikesharing, North America, public transit, information technology, survey

WORD COUNT: 5,635 words, plus 3 tables and 4 figures

INTRODUCTION
Public bikesharing has emerged to offer a new form of mobility that is altering the shape of public transportation systems in North American cities. Bikesharing systems operate by providing publicly accessible shared-use bicycles within an urban environment. Much of the recent growth in bikesharing has involved information technology (or IT) in which users access bikes at kiosks that communicate directly with a central system that permits the release and return of a bicycle. Since 1965 bikesharing has operated in less advanced forms, expanding worldwide to over five continents: Europe, North America, South America, Asia, and Australia *(1)*. The recent evolution towards IT-based bikesharing has sparked a new era and rapid program proliferation.

Public bikesharing systems operate with bicycle docking stations that are typically unattended and concentrated in urban settings. Unlike most carsharing systems (short-term auto access), bicycles are accessible instantaneously, without reservation, and trips can be one-way (users can drop-off bicycles at any docking station with an available opening to securely lock the bicycle). For most systems, trips made in less than 30 minutes are free. Users can sign-up with bikesharing systems on an annual, monthly, daily, or per trip basis. Systems allow users to access bicycles by swiping a credit card, a membership card, and/or by mobile phone. When they finish using the bike, they can return it to any dock where there is room (including the same starting dock) and end their session.

Public bikesharing offers a number of environmental, social, and transportation-related benefits. It provides a quicker and zero emissions means to access public transportation or to make other short-distance trips between docking stations *(1-2)*. Potential bikesharing benefits include: 1) increased mobility; 2) economic benefits (including cost savings from modal shifts and increased tourism); 3) lower implementation and operational costs (in contrast to shuttle services); 4) reduced traffic congestion; 5) reduced fuel use; 6) increased public transit use; 7) increased health benefits; and 8) greater environmental awareness *(1)*.

Although before-and-after studies documenting public bikesharing benefits are limited, a few North American programs have conducted user surveys to record program impact. Table 1 presents a summary of trips, distance traveled, and estimated carbon dioxide (CO2) reductions from studies completed in the U.S. and Canada, including results from the authors' recent survey of four public bikesharing operators in North America. The emission-reduction estimates vary substantially across studies due to different assumptions about user behavior, trip distribution, and trip substitution. Key assumptions that influence CO2 reduction estimates pertain to public bikesharing trips that displace automobile trips. In addition to studies that have demonstrated reduced CO2 emissions and a modal shift toward bicycle use, evaluations indicate an increased public awareness of bikesharing as a viable transportation mode. Fifty-nine percent of Nice Ride Minnesota users said that they liked the "convenience factor" most about their program *(3)*. Denver B-cycle achieved a 30% increase in riders and a 97% increase in the number of rides taken in 2011 *(4)*. These studies coupled with anecdotal evidence suggest that public bikesharing programs have a positive impact on the public perception of bicycling as a viable transportation mode.

TABLE 1 Impacts of Public Bikesharing in North America

Canada	Year of Data	Trips per Year	Km per Year	CO_2 Reduction (kg per Year)	Change In Public Transit Usage	Change in Vehicle Ownership	Respondents Driving Less Often
BIXI Montreal	2011	7,300,000[5]			+16.2%[6]	-6.0%[6]	36.3%[6]
BIXI Toronto	2011				+11.0%[6]	-2.6%[6]	25.4%[6]
United States							
Boulder B-cycle	2011	18,500[7]		47,174[7]			
Capital Bikeshare (D.C.)	2011	1,249,454[6]				-4.6%[6]	0.45%[6]
Denver B-cycle	2011	202,731[8]	694,942[8]	280,339[8]			
New Balance Hubway (Boston)	2011	140,000[9]					
Madison B-cycle	2011	18,500[10]		46,805[10]			
Nice Ride Minnesota (Twin Cities)	2011	217,530[6]			+28.3%[6]	-4.5%[6]	52.4%[6]
San Antonio B-cycle	2011	22,709[11]		38,575[11]			

By addressing the storage, maintenance, and parking aspects of bicycle ownership, public bikesharing encourages cycling among users who may not otherwise use bicycles. Additionally, the availability of a large number of bicycles in multiple dense, nearby locations, frequently creates a "network-effect" further encouraging cycling and more specifically, the use of bikesharing for regular trips (e.g., commuting, errands).

This paper reviews early operator understanding of North American IT-based public bikesharing (2007-2012) and reviews emerging trends for prospective program start-ups. There are four sections to this paper: 1) methodology, 2) market dynamics, 3) operational overview, and 4) conclusion.

METHODOLOGICAL APPROACH

From May 2011 to June 2012, the authors completed stakeholder interviews on the state of public bikesharing in North America and conducted a total of 38 expert and operator interviews. Nineteen interviews were conducted with all IT-based public bikesharing programs operating in

the U.S. and Canada as of April 2012. An additional 14 interviews were conducted with a combination of city and regional transportation personnel, public transit operators, policymakers, community bike coordinators, and bicycle/bikesharing vendors. Finally, the authors completed five interviews with brokers, underwriters, and attorneys in the bikesharing insurance industry in June 2012. The purpose of these interviews were to twofold: 1) document the state of IT-based North American public bikesharing in 2012, and 2) highlight emerging trends for prospective start-ups. The scope of the study was focused on bikesharing programs accessible to the public and did not include college/university programs or those with a restricted user base. During the course of the study, the U.S. and Canadian dollars traded near parity, and are treated as equal through the following discussion.

NORTH AMERICAN BIKESHARING MARKET DYNAMICS

The first North American public bikesharing program launched as a free system in Portland, OR in 1994. Over the next five years, similar public bikesharing programs emerged, all of which were modeled after either white-bike systems, which are also known as free bike systems, or alternatively as coin-deposit systems, which require a refundable coin deposit to use a bicycle *(12)*. Bikesharing has evolved from these early systems (mid-1990s) to the deployment of IT-based bikesharing in the late-2000s *(12)*. In total, since 1994, there have been 40 program startups and eleven program closures in the U.S. and Canada (*1*, *6*). This evolution has been categorized into four key phases or generations, which are summarized in Figure 1. Since 2007, there have been 22 IT-based bikesharing program startups and one closure in the U.S., as well as four program launches in Canada. As of January 2012, 15 United States (U.S.) IT-based bikesharing systems accounted for 172,070 users and 5,238 bicycles, and the four Canadian programs accounted for another 44,352 users and 6,235 bicycles (summarized in Table 2). As of November 1, 2012, an additional six programs launched in the U.S. (for a total of 25 North American programs). The six additional program locations include: Houston B-cycle (TX); Spokies in Oklahoma City (OK); DecoBike Long Beach, NY; Kansas City B-Cycle (MO); Charlotte B-Cycle (NC); and Bike Nation Anaheim (CA).

First generation: "Free bikes" 	Bicycles are typically painted one color, left unlocked, and placed randomly throughout an area for free use. First-generation systems do not use docking ports. In some of the systems, the bikes are locked; users must get a key from a participating local business and may also need to leave a credit card deposit, but actual bike use is free. Many first-generation systems eventually ceased operations due to theft and bicycle vandalism, but some are still operating as community-based initiatives.
Second generation: "Coin-deposit systems" 	Bicycles have designated docking stations/parking locations where they are locked, borrowed, and returned. A deposit, generally not more than US$4, is required to unlock a bike. While coin-deposit systems helped reduce theft and vandalism, the problem was not eliminated, in part because of user anonymity. Many second-generation systems are still in operation.
Third generation: "IT-based systems" 	IT-based systems use electronic and wireless communications for bicycle pickup, drop-off, and tracking. User accountability has been improved through the use of credit or debit cards. Third-generation bikesharing includes docking stations, kiosks, or user interface technology for check-in and check-out, and advanced technology (e.g., magnetic-stripe cards, smartcards, smart keys). Although these systems are more expensive than first- or second-generation systems, information technology enables public bikesharing programs to track bicycles and access user information, improves system management, and deters bike theft. IT-based systems are responsible for public bikesharing's recent expansion in both locations and scale.
Fourth generation: "Demand-responsive / multi-modal systems" (*1*) 	Demand-responsive, multi-modal systems build upon the technology of third-generation systems by implementing enhanced features, such as flexible, clean docking stations or "dockless" bicycles; demand-responsive bicycle redistribution innovations to facilitate system rebalancing; value pricing to encourage self-rebalancing; multi-modal access; billing integration (e.g., sharing smartcards with public transit and carsharing); real-time transit integration and system data dashboards; and global positioning system (GPS) tracking. Fourth-generation bikesharing is an evolving concept that has yet to be fully deployed.

FIGURE 1 Overview of public bikesharing generations.

TABLE 2: IT-Based Public Bikesharing Programs in the U.S. and Canada (January 2012)

Organization	Location	Launch Year	Users	Bicycles	Stations
Canada					
BIXI Montreal	Montreal, QB	2009	40,000	5,120	411
BIXI Toronto	Toronto, ON	2011	4,200	1,000	80
Capital BIXI	Ottawa, ON	2011	150	100	10
Golden Community Bike Share	Golden, BC	2011	2	15	2
Canadian Total			44,352	6,235	503
United States					
Boulder B-cycle	Boulder, CO	2011	7,170	120	15
Broward B-cycle	Ft. Lauderdale, FL	2011	1,029	275	20
Capital Bikeshare	Washington, DC	2010	18,000	1,200	130
Chicago B-cycle	Chicago, IL	2010	10,000	100	7
DecoBike	Miami, FL	2011	2,100	850	85
Denver B-cycle	Denver, CO	2010	79,701	520	51
Des Moines B-cycle	Des Moines, IA	2010	1,298	18	4
Hawaii B-cycle	Kailua, HI	2011	475	12	2
Madison B-cycle	Madison, WI	2011	6,909	280	27
New Balance Hubway	Boston, MA	2011	3,500	600	61
Nice Ride Minnesota	Minneapolis/St. Paul, MN	2010	33,900	960	116
Omaha B-cycle	Omaha, NB	2011	426	35	5
San Antonio B-cycle	San Antonio, TX	2011	6,685	230	23
Spartanburg B-cycle	Spartanburg, SC	2011	877	14	2
Tulsa Townies *	Tulsa, OK	2007	N/A	24	3
United States Total			172,070	5,238	551

* Tulsa Townies does not offer a membership option to users.

† It is important to note that user populations are reported differently by organization (e.g., some include daily members, others do not).

Expansion of Existing IT-Based Public Bikesharing Systems

The growth of public bikesharing systems has occurred at different rates in different areas. For example, in the U.S., Tulsa Townies—the first and oldest operating third-generation bikesharing system in North America—has not increased the number of bicycles over the five years since their inception. Conversely DecoBike, which launched in 2011, has increased its bicycles by 70% from 500 to 850. As the proliferation of IT-based public bikesharing in North America is relatively new, the dynamics of system growth are not yet well understood. Nevertheless, a few early trends are emerging. Eight programs (42%) have increased their fleet size since launching by between 20% and 200%. In the near future, some larger programs are expected to launch. For instance, four programs are planned with fleets varying in size from 1,000 to 10,000 bicycles between Winter 2012 and Summer 2013 (Chicago, Los Angeles, New York City, and San Francisco). There are an additional 25 planned programs (23 in the U.S. and two in Canada),

which have anticipated launch dates prior to the end of 2013; collectively they plan to deploy a total of 23,341 bicycles. An additional nine cities in the U.S. and two in Canada are exploring public bikesharing, with launch dates after 2013.

BIKESHARING SYSTEM BUSINESS MODELS AND FUNDING

As bikesharing continues to grow, key understanding has emerged from industry experience thus far. Interviews with existing and planned operators uncovered five operational areas of consideration for future program start-ups: 1) business models; 2) funding; 3) station placement considerations; 4) accidents and insurance; and 5) bikesharing technologies.

Business Models

One of the first considerations for a prospective program is the type of business model to be applied. A number of public bikesharing business models have evolved with the advent of IT-based systems including: 1) non-profit, 2) privately owned and operated, 3) publicly owned and operated, 4) public owned/contractor operated, 5) street-furniture contract, 6) third-party operated, and 7) vendor operated (an emerging market). Due to variations in ownership, system administration, and operations, there can be overlap among these models. A description of each business model is provided in Table 3.

TABLE 3: Public Bikesharing Business Models

Business Model	Definition	Example
Non-Profit	• Goal of covering operational costs and expanding service • Start-up and operational funding typically are supported by grants, sponsorships, and loans	Denver B-cycle Denver, CO (Operational)
Privately Owned and Operated	• Owned and operated by a private entity • Operator provides all funding for equipment and operations • May have limited contractual agreement with public entities for rights-of-way	DecoBike Miami, FL (Operational)
Publicly Owned and Operated	• Owned and operated by a public agency or local government • Agency subsidizes bikesharing with system revenue	Golden Community Bike Share Golden, BC (Operational)
Publicly Owned/Contractor Operated	• Owned by a public agency or local government, responsible for funding and administering the system • Operations are contracted to a private operator	Capital Bikeshare Washinton, DC (Operational)
Advertising Model (Street Furniture Contract)	• Operator permitted to operate in a jurisdiction in exchange for advertising rights, generally with street furniture • System funded through advertising revenue	SmartBike D.C. Washington, DC (Defunct)
Third-Party Operated	• Operated in partnership with local businesses in exchange for a percentage of the profit • Hybrid operation scheme that can be paired with other business model	Chicago B-cycle Chicago, IL (Operational)
Vendor Operated	• Operated by the same company that designs and/or manufactures the system equipment (the vendor)	Bike Nation Anaheim Anaheim, CA (Proposed)

As of January 2012, 11 (58%) of the 19 IT-based public bikesharing programs in the U.S. and Canada were non-profit, four (21%) were privately owned and operated, three (16%) were publicly owned and contractor operated, and one (5%) was publicly owned and operated. No programs were managed as part of a street-furniture contract. As of January 2012, non-profit programs accounted for 82% of the membership and 66% of the bicycles deployed. Publicly owned and contractor operated programs accounted for 10% of the membership and 17% of the bicycles deployed. Privately owned and operated programs accounted for 8% of the membership and 17% of the fleets deployed. The one publicly owned and operated service, located in Canada, accounted for less than 1% of members and fleets deployed.

Of the six programs that have launched since our survey, five responded to questions relating to their business model. Forty percent were non-profit (n=2/5), 40% were publicly owned and contractor operated (n=2/5), and 20% were privately owned and operated (n=1/5). Of the 25 programs planned to launch by the end of 2013, 24 have identified a business model: five plan to launch as non-profits (21%), five as publicly owned and contractor operated (21%), seven as publicly owned and operated (29%), five as privately owned and operated (21%), and two as

vendor operated (8%). Two of these planned program launches (Buffalo Bikeshare in Buffalo, NY and City CarShare in San Francisco, CA) will be operated by a non-profit carsharing program. The increased diversity, and in particular, the increased privatization of initiatives is notable. With a few exceptions, public transportation is typically the domain of the public sector. Public bikesharing may be evolving to become another exception, where the private sector foresees value in the provision of transportation that reduces congestion, energy, and emissions. The establishment of this trend is unclear, at present. Nevertheless, the increasing diversity towards private sector funding presents the possibility that this transportation mode may be supportable with limited to no governmental support.

Funding

Related to increasing diversification of business models, public bikesharing systems have generated a considerable diversity in start-up and operational funding. Funding for existing public bikesharing has frequently been obtained through a combination of sources including: advertising; user fees; grants; loans; sponsorships; health-care/tobacco settlement funds; and governmental funds for capital costs, operational costs, or both. In many locations, public bikesharing startups have received some combination of local, state, and/or federal government funding. Operational costs are typically funded through a combination of user fees, advertising, and sponsorships. Advertising-based business models and funding have been common in European bikesharing systems, while North American systems have relied on sponsorships. The main difference between the systems is whether an advertising firm runs the program or the program sells advertising.

Fifty-eight percent (n=11/19) of U.S. and Canadian organizations reported receiving some form of startup and/or operational funding. Sixteen percent (n=3) did not receive startup and/or operational funding. Five operators did not provide data on funding sources. The authors classified funding portfolio diversity ranging from—less diverse (three funding sources), to moderate (four funding sources), to more diverse (five funding sources)—based on the number of funding sources per operator. Figure 2 illustrates the diversity of funding for the North American public bikesharing industry as of January 2012.

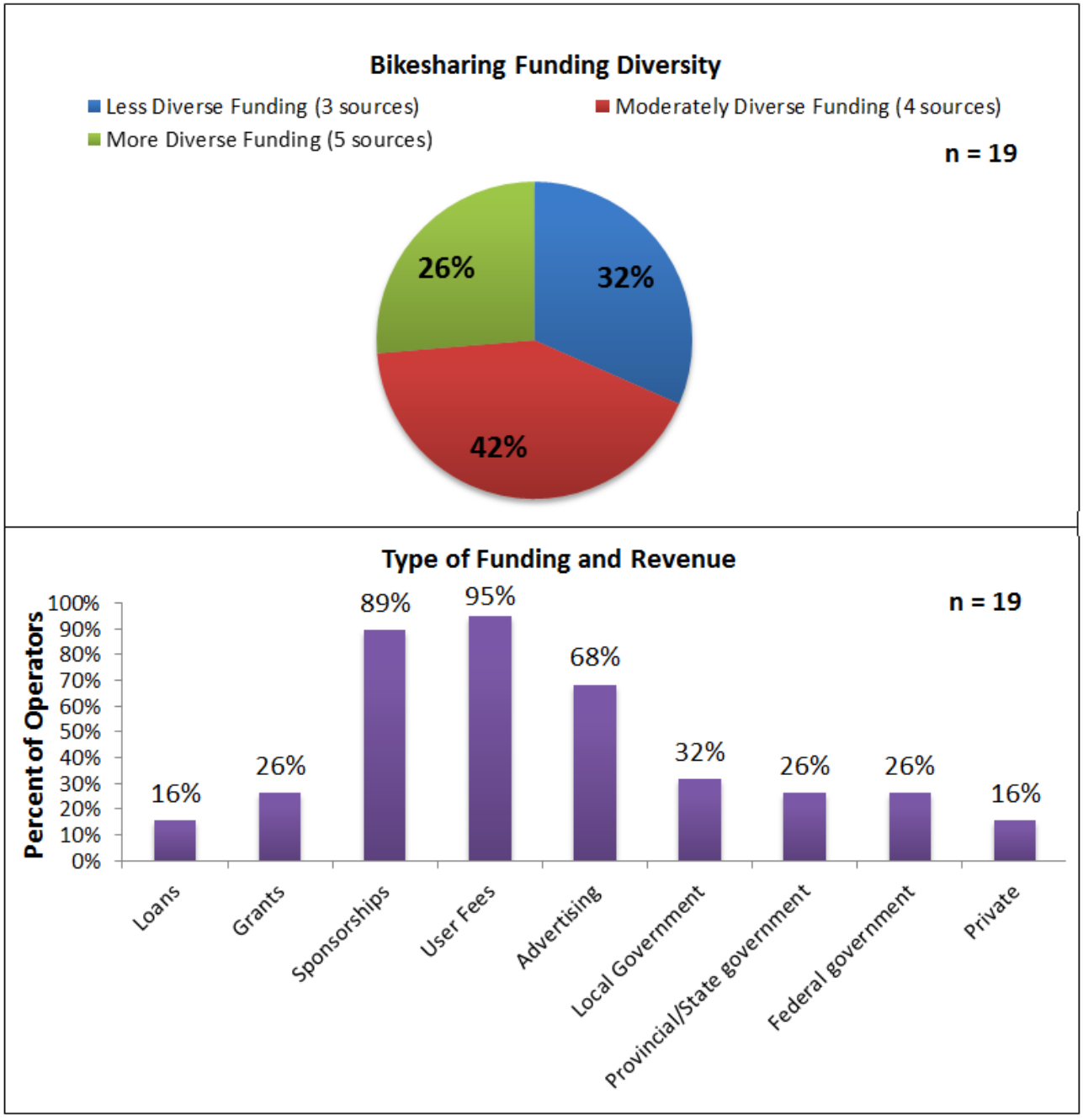

FIGURE 2 North American Public bikesharing funding.

With respect to user fees, in most systems, the first half hour of public bikesharing is free, and time charges increase in stepped amounts after that. Most users pay a flat annual or monthly fee and make trips of less than 30 minutes. Seventeen of the 19 IT-based North American public bikesharing operators (89%) offered three membership options: 1) a short-term membership (e.g., 24-hour to 7-day pass); 2) monthly or 30-day membership option; and 3) a season or annual memberships. In Fall 2012, a new membership option emerged in the Montreal BIXI system: the "occasional user," where a user has an account and a key fob but does not actively

maintain a subscription. Whenever the occasional user swipes their key fob in a dock, a 24-hour subscription is automatically purchased (Mitch Vars, unpublished data, October 2012). The cost for a 24-hour pass varies from US$0 to $10, averaging US$5.49. The cost of a 30-day membership varies from US$15 to $40, averaging US$31. The cost of an annual membership varies from US$30 to $95, averaging US$66.

PUBLIC BIKESHARING INSURANCE AND SAFETY

Both existing and planned operators have indicated significant concern over accident rates, as well as the cost and availability of insurance. Despite the existence of liability waivers, existing and planned operators have expressed concern that waivers do not protect operators from being sued by non-members (e.g., an accident involving a bikesharing user and a driver where the driver sues the operator). Such scenarios highlight the necessity for a wider variety of insurance coverage among new bikesharing programs. As such, accident rates and insurance have become a key consideration, particularly among prospective programs.

Accidents

Accident rates were relatively low among North American operators, averaging 1.36 accidents reported systemwide in 2011 (n=14/19). However, differences in data collection and study methodology frequently produce inconsistent results, often with limited samples, which make it difficult to compare bikesharing accident rates among operators. The operators interviewed tracked public bikesharing accidents in one of three ways: 1) total number of accidents, program-wide, annually; 2) the number of accidents per a number of rides; and 3) number accidents per distance of bikesharing usage. One operator reported an accident rate of approximately one incident for every 50,000 to 60,000 rides, and another noted one accident after approximately 100,000 miles (or 161,000 kilometers) of riding. In this study, operators with more than 1,000 bicycles reported an average of 4.33 accidents per year; those with between 250 and 1,000 bicycles averaged 0.6 accidents reported a year; and those with less than 250 bikes reported 0.3 accidents per year. In addition to collecting data about accident rates, the authors interviewed program operators about the nature of the accidents. Due to the relatively small number of accidents in North America, the authors were unable to discern patterns related to accident cause or severity.

Insurance

Not surprisingly, public bikesharing involves risk, and risk involves insurance. Insurance is a key institutional requirement when an organization is exposed to risk and liability, including public bikesharing. To better understand the current landscape of insurance in the bikesharing industry, the authors obtained insurance information from 15 of the 19 public bikesharing programs; three operators acknowledged carrying insurance but declined to provide additional details due to proprietary concerns. One operator neither responded nor confirmed carrying any type of insurance coverage. Operator surveys were supplemented with five expert interviews with brokers, underwriters, and attorneys with experience providing bikesharing insurance. Insurance varied considerably based upon the operator's business model because local governments, non-profits, and for-profits have different insurance requirements and may have existing policies that can be extended to cover bikesharing systems as well (e.g., local governments and public transit agencies). Seven types of common insurance policies were identified that could be applicable to bikesharing, as listed in Figure 3 (*13*). The four most common types of insurance coverage

carried by U.S. and Canadian bikesharing operators include: general liability coverage, workers' compensation, commercial auto, and inland marine coverage.

Types of Bikesharing Insurance
General Commercial Liability: Protects from public and product liability risks that may include bodily injury or property damage caused by direct or indirect actions of the insured. Liability insurance is designed to offer protection against third-party insurance claims (e.g., someone who suffers a loss either from using a bikesharing system or a loss of a non-user resulting from the use of a bikesharing bicycle). • ***Premiums and Coverage*** **-** Only nine of the 15 U.S. operators were able to provide details on their program's liability coverage. These programs maintained a general liability policy with coverage ranging from US$1M to $5M, with limits ranging from US$500,000 to $2M per an occurrence and deductibles ranging from US$1,000 to $10,000. Two operators reported paying an average cost of US$8,416; premiums ranging from US$5,000 to $11,832 annually for this coverage. As of May 2012, only two operators noted having a total of 16 successful liability claims. Fifteen of these claims belonged to one large operator with more than 1,000 bicycles. All 19 North American operators require users to sign a liability waiver prior to using the system.
Constructive Total Loss: Insurance covering repair costs for an item that is more than the current value of that item. It can also refer to an insurance claim that is settled for the entire property amount on the basis that the cost to repair or recover the damaged property exceeds its replacement cost or market value. Generally, the operators do not insure individual bicycles because repair or replacement costs would be less than the typical deductible. However, a few operators insure bicycles while they are parked at the kiosk ("kiosk loss") and in storage for seasonal programs.
Workers' Compensation: A form of insurance providing wage replacement and medical benefits to employees injured in the course of employment in exchange for mandatory relinquishment of the employee's right to sue his or her employer for the tort of negligence. • ***Premiums and Coverage*** **-** Five programs indicated carrying workers' compensation coverage, with coverage varying from US$100,000 per accident up to $500,000. Premiums for this coverage ranged from US$684 to $7,920 annually. As of May 2012, one of these five programs reported having one worker's compensation claim.
Commercial Automobile: Provides financial protection against physical damage and/or bodily injury resulting from traffic collisions and against liability that could also arise. In public bikesharing, this insurance is generally applied towards employees that rebalance bikes using trucks or other program vehicles, if applicable. • ***Premiums and Coverage*** **-** Four programs provided information on their commercial auto policies. Although these policies were largely dictated by state law, these programs maintained coverage including: US$500,000 per occurrence and US$3M per vehicle, with varying comprehensive and collision deductibles, averaging US$500 and $1,000, respectively. The annual premiums for these policies averaged US$4,000.
Professional Liability (Errors and Omissions): A form of liability insurance that helps protect professional advice and service-providing companies from bearing the full cost of defending against a negligence claim made by a user and damages awarded in such a civil lawsuit.
Inland Marine: Indemnifies loss to moving or movable property (e.g., shipment of bikes/kiosks after purchase). • ***Premiums and Coverage*** **-** Two programs indicated carrying inland marine coverage. Their insurance carried a maximum limit of US$1,000 per an item and up to US$500,000 per an occurrence. The average cost of this coverage was US$5,146 annually. In addition to inland marine coverage, one insurance broker indicated selling rigger's insurance (i.e., insurance for a contractor's liability arising from moving property and equipment that belongs to others, such as lifting bicycle kiosks with a crane), providing special coverage for the movement and station installation (e.g., when handled by cranes and other construction equipment).
Rigger's Liability: Insurance designed to protect the movement and relocation of kiosks by cranes.

FIGURE 3 Overview of North American Public Bikesharing Insurance

Generally commercial liability is the most common form of insurance. Unless a bikesharing program is self-insured by a sponsor or local government entity, most carry some form of liability coverage. Despite all North American programs requiring a liability waiver, many were required to carry liability insurance as a condition for placing kiosks on either public or private land. Most operators perceived liability insurance as a necessary protection against potential legal action, since liability waivers are only a protection for legal action from the users

(not the property owners or vehicles that may encounter bikesharing users). Other forms of insurance, such as constructive loss, worker's compensation, commercial automobile, professional liability, inland marine, or riggers liability, were carried by a subset of operators. These insurance forms covered more specific types of risks pertaining to operations.

In addition to insurance types, the experts indicated that there are three key factors that determine premiums: 1) geographic location, 2) limits and deductibles, and 3) system usage. Insurance premiums can be designed around: 1) percent of kiosk sales (e.g., percent of ridership revenue); 2) percent of gross revenue (e.g., percent of total revenue including ridership, sponsorships, advertising etc.); and 3) number of rides (e.g., premiums based on how often the bicycles are used). Percent of kiosk sales were indicated to be a sub-optimal method of structuring premiums because many operators include some amount of "free use." Gross revenue was the least preferred method because including advertising revenue, along with kiosk sales, does not result in more risk. Finally, structuring premiums based on number of rides was perceived to be the most fair and accurate method, as the number of rides can be correlated to the amount of use and program risk an operator confronts.

Helmet Usage

Helmet laws are generally perceived by public bikesharing experts and users as an obstacle to bikesharing use because of the inconvenience associated with carrying a helmet, lack of availability for last-minute trips, and the challenges associated with providing sterile shared-use helmets. As of April 2012, Golden Community Bike Share (Golden, BC) was the only North American program in which helmet use was required because British Columbia implemented a mandatory helmet law for all ages in 1996 (*14*). The organization offers complimentary helmets with each bike rental. Seven additional operators offer helmets, although use is not mandatory. Three of them sell helmets at a central location operated by the bikesharing provider (Chicago B-cycle, DecoBike, and San Antonio B-cycle), and two offer helmets for purchase when members join (Capital Bikeshare and New Balance Hubway). Additionally, two operators previously provided free helmets as part of membership (Denver B-cycle and Nice Ride Minnesota). Many operators offer helmets through partnerships with local bike stores and provide helmet purchase discounts. The author's 2011 North American user survey of four public bikesharing programs found that the majority of users never wear helmets (*6*). In Montreal 62% of survey respondents indicated never wearing a helmet while bikesharing compared to 50% in the Twin Cities, 45% in Toronto, and 43% in Washington, D.C (*6*). The survey also found that helmet use ranged between 20% and 38% while using bikesharing. In Vancouver, BC, three private companies are developing options for providing sterile shared helmets, including a helmet-rental sanitizing machine and disposable helmets (e.g., SandVault's HelmetStation) (*15*).

BIKESHARING TECHOLOGY AND SYSTEM DESIGN

Public Bikesharing Technologies

Another key consideration for prospective program start-ups is the type of technologies deployed within their system. Common components of public bikesharing systems include: bicycles, docking stations and kiosks, user interfaces for locating bicycles and availability, and systems for bicycle re-balancing and demand management.

Bicycles

As of April 2012, 10 (53%) of the North American IT-based operators use Trek bicycles, six (31%) use PBSC Urban Solutions bicycles, one (5%) uses the DecoBike Cruiser, and two (11%) use bicycles of other brands, such as Kona and Worksmith. DecoBike uses a custom-built bicycle exclusively for its system. Multi-speed bicycles are used by 17 (89%) of the operators, and fixed-speed bicycles are used by two operators (11%). In addition, 17 of 19 IT-based operators (89%) also use bicycles specifically built for their organization, while two (11%) employ bicycles purchased off-the-rack. Twelve (63%) operators equip their bikes with self-generating lights, while six others (32%) employ regular lights. One operator did not equip its bicycles with any lights to deter users from using the system at night. A total of 13 (68%) equip their bicycles with bells and baskets, and seven (37%) supply luggage racks. Ten operators provided per-bicycle cost estimates, ranging from US$750 to $7,000, with an average cost of US$1,800; other operators declined to provide cost estimates. Estimates vary substantially, in part, because operators frequently buy a group of bikes with each kiosk.

Many public bikesharing systems collect data to track the movement of their bicycles. The most common technology used is radio-frequency identification (RFID) tags. This technology, used by 18 of 19 operators (95%), identifies when and where a bicycle leaves and re-enters a docking station. It tracks the check-out and check-in of docking stations by location, bicycle, time, and user type, but it does not collect information on where the bicycle traveled in between. Seven of the 19 operators (37%), use both GPS and RFID technology, which augments check-in and check-out with trip data. In most systems, GPS technology is used to enable users to track their distance traveled, calories burned, and carbon offset, through the operator's website. One operator uses neither technology. Figure 4 illustrates the distribution of technology within public bikesharing systems in North America.

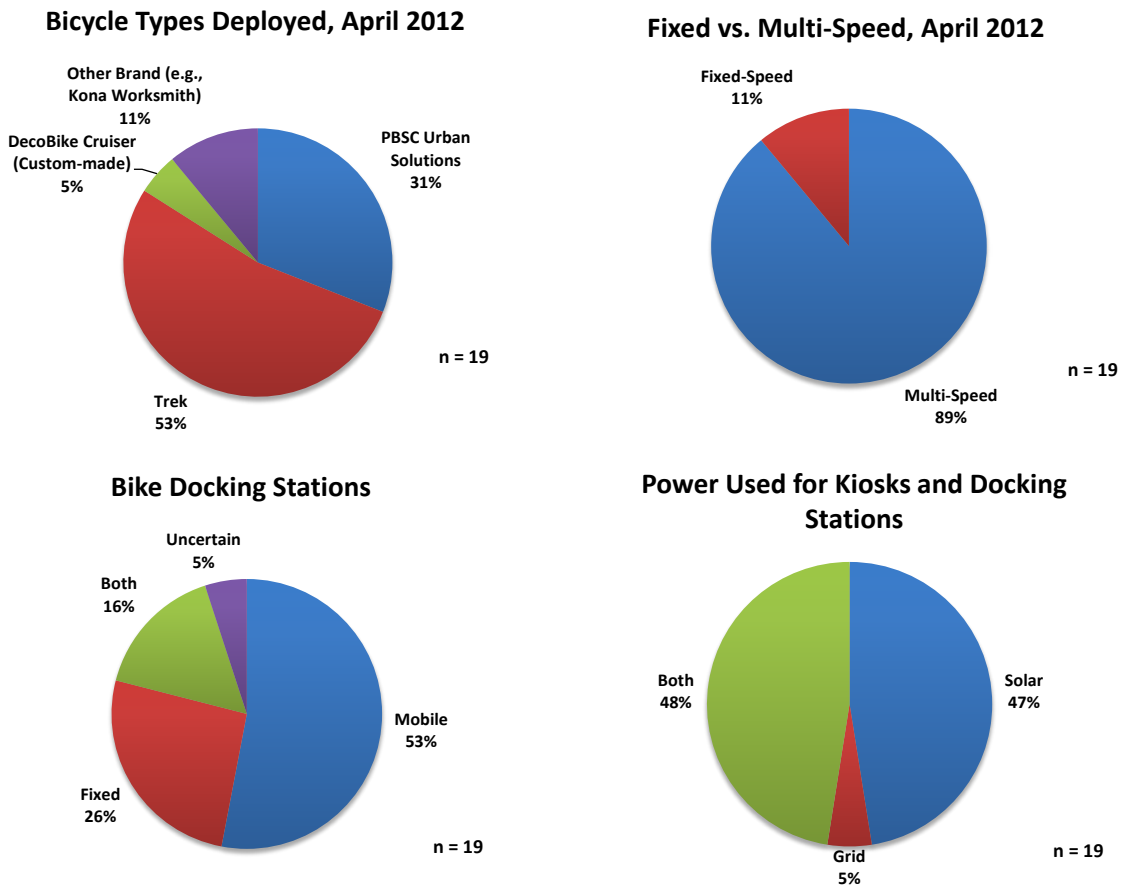

FIGURE 4 North American bicycle and docking stations trends.

Docking Stations and Kiosks

As of April 2012, three vendors provided kiosks and docking stations: PBSC Urban Solutions, B-cycle, and SandVault. Ten of 19 IT-based operators (53%) use B-cycle docks and kiosks, six (32%) use PBSC Urban Solutions/8D Technologies docks, and three (16%) use stations designed by SandVault. The number of ports at each docking station ranged from 7 to 130, averaging 20 per station. The majority employ re-locatable or "mobile" docking stations and incorporate solar kiosks (either exclusively or combined with grid power) into their systems. See Figure 4.

Vendors usually sell complete station systems that include bicycles, kiosks, map frames, customer keys, spare parts, supplies, and shipping (*16*). Only five operators provided data on docking station costs. The average was US$39,550 per station. Other studies have documented station costs ranging from US$26,064 to $58,000 (*17*). Station costs are difficult to compare across programs because many purchase stations that include bicycles in the package. According to one, the cost of a small station (four bicycles and seven docks) is US$26,064 or a cost of US$6,516 per a bicycle. A larger station (13 bicycles and 19 docks) costs up to US$52,275 (cost of US$2,751 per a bicycle) (*14*). Four operators provided cost estimates for relocating a mobile station, averaging US$4,000. Other studies have documented relocation costs ranging from US$1,000 to $1,500 (*16*). According to Toole Design, annual operating costs range from US$12,000 to $28,000 for a docking station with 11 to 19 docks (*17*).

User Interface

IT-based public bikesharing generally requires a user interface to check bicycles in and out. Preregistration can create usage barriers (e.g., time constraints and credit card use), but typically increases accountability and discourages theft. Eleven of 19 IT-based operators (58%) employ smartcards, six (32%) use smart keys, and two (10%) use access codes to retrieve bicycles in their systems. Four (24%) operators of the 17 that use either smart keys or smartcards also employ access codes to allow non-members to access the system. Thirteen of 19 operators (68%) indicated that a credit card was required for system use, and six reported that a credit card could be substituted for a debit card at their kiosks.

System Balancing and Demand Management

Operators employ a variety of methods to balance their systems, including physically moving bikes or offering incentives for users to move them to less-popular docking stations. Many operators strive to maintain a specific ratio of bikes to docking ports to minimize rebalancing. The average in North America is one bicycle to every 1.7 docking ports. Targeted bicycle-to-docking-port ratios are slightly higher in Canada (1:1.9) than in the U.S. (1:1.7). Publicly owned and contractor operated programs (e.g., Capital Bikeshare, BIXI Ottawa, and New Balance Hubway) tend to have the highest ratios, 1:1.8; non-profits have an average ratio of 1:1.7. Smaller programs (250 bicycles or less) reported rebalancing once or twice a season, whereas large programs need to rebalance continuously throughout the day. Ten out of 19 programs (53%) rebalance daily. Some strategies for system balancing include: use of computer systems to monitor system balance in real-time, use of bicycle depots for users to return bikes when stations are full, and locating docking stations closer together to lower rebalancing costs.

A few vendors have introduced the concept of dockless stations aimed at "dynamic self-rebalancing;" however, these systems had not been implemented as of November 2012. One vendor, Social Bicycles (SoBi), has a design in which its bicycles contain a solar-powered, GPS-enabled lockbox—eliminating the need for docking stations. User incentives and disincentives both encourage dynamic self-rebalancing (e.g., users who lock a bike outside of designated hub areas incur a fee, while those who return the bicycle to a high-demand location receive a credit). Dynamic pricing and dockless bikes may offer additional flexibility to bikesharing systems and could be used in conjunction with or in substitute of dock-based bikesharing systems. However, one possible drawback of dockless bikesharing is derived from the increased onus it places on the user to find usable bikes. Overcoming this challenge would require advanced guidance interfaces for users and possibly supporting rules pertaining to the visibility of "returned" bicycles to a dockless system.

Station Placement Considerations

Related to docking stations, a key consideration for prospective program start-ups is where to place stations, distance between kiosks, and how far stations must be placed from transit hubs to encourage multi-modal crossflow between public transit and bikesharing. Another consideration is whether to locate kiosks on public or private land. Five of 19 North American operators indicated that their stations were located entirely on public land (e.g., former on-street parking stalls, curbs, and other public rights-of-way), while another five were sited mostly on public land. Two reported that their stations were located on private land, and three stated that their docking ports were situated on both public and private lands (15 total of 19). The two operators with fleets of more than 1,000 bicycles relied more on public than private land in contrast to four of six with fleets ranging from 250 to 999 bicycles, which rely more on private land than on

public land. Similarly, six of the seven fleets with less than 250 bicycles also relied more on private land than public land.

Operators indicated, in almost all cases, that use of the land is free. In a few cases, sponsors pay operators to locate public bikesharing on their property. In one case, an operator had to pay to use a municipal property. Although operators generally do not pay for the use of land, there have been instances where they had to either move or install on-street furniture as part of their agreement.

Two operators (10%) indicated that the preferred linear distance between docking stations is between 90 and 275 meters. Ten operators (53%) reported that the preferred distance between stations is between 275 meters and 400 meters. Four (21%) indicated that the preferred distance is between 400 meters and 800 meters. One (5%) stated an optimum distance of 800 meters to 1,200 meters. Finally, two (11%) stated an optimum distance greater than 1,200 meters. In terms of distance from public transportation, three of nine respondents (33%) indicated that between 275 meters and 400 meters is the preferred maximum distance to locate docking stations from a public transit station to target transit riders. Three others indicated a maximum distance of 25 meters, and another three reported between 25 meters and 275 meters (nine reporting of 19). Determining optimal station placement can include the consideration of numerous factors and constraints, hence, the relatively wide distribution of spacing reported. This reflects both the diversity of operator environments, as well as the learning the industry is experiencing with respect to station-network design.

CONCLUSION

The advent of public bikesharing in North America is one of the latest developments in the continually evolving shared-use industry. With the incorporation of information technology into bikesharing, a new transportation mode has begun to emerge across the continent within pioneering cities and towns. While the basic mobility provided by bikesharing relies on the proven 100-year old operation of a bicycle, the instant access, distributed stations, improved travel speeds, and low cost have provided a new mechanism for people to travel in an emissions-free form. The accessibility of public bicycles in remote locations away from people's homes frees them from the necessity of supplying their own bicycle at the start of the day for tripmaking later in the day. The effects of this subtle change could be profound on mobility and emissions. Bikesharing provides easier accessibility to urban destinations farther away, reducing the need for driving or taxi use. The speed and accessibility of bikesharing may also increase activity and exercise, offering several public health benefits.

For public bikesharing to realize these benefits, it will need to become economically sustainable under a supportive business model that reflects the needs/goals of each program. Although bikesharing continues to gain popularity in the U.S. and Canada, the industry has not yet converged on a dominant business models or funding strategy. This convergence is not certain to happen in all areas. For example with carsharing, the industry ultimately settled on both non-profit and for-profit entities, but the classic neighborhood model, serving primarily residential customers, emerged as the primary customer base for industry leaders (at least today). With public bikesharing, there is even greater diversity of funding sources and business models, while the pricing structures and customer bases remain remarkably similar. Other industry challenges, including optimal station-placement; risk management and insurance; safety and technological management remain key issues. The early experiences of the industry will serve as important guidance for future operation and expansion of this seemingly transformative mode.

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