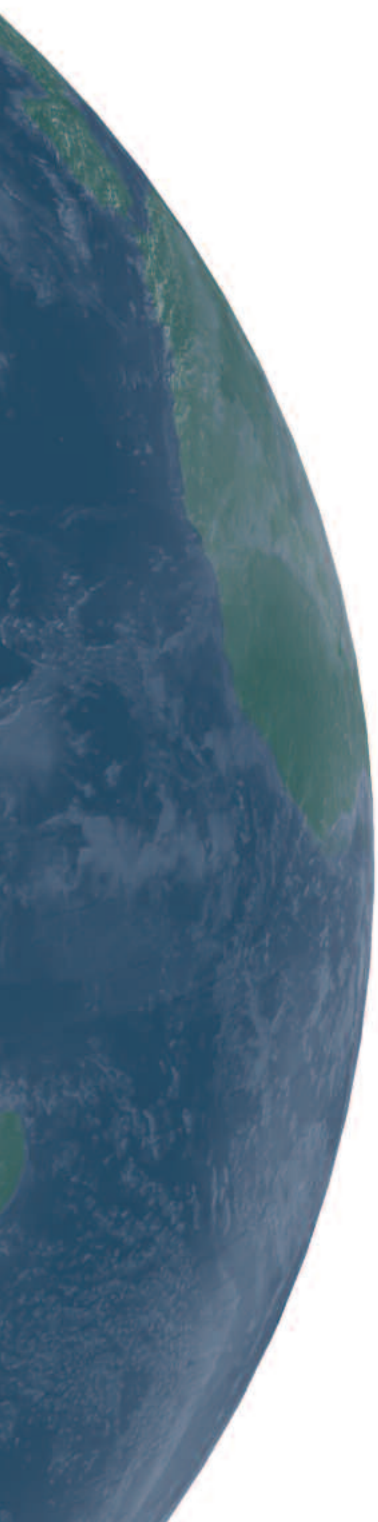


QUANTIFIED TRAVELER

Travel Feedback Meets the Cloud to Change Behavior

RAJA SENGUPTA AND JOAN L. WALKER

Halting climate change will require a concerted effort to reduce emissions from on-road vehicles. While significant progress has been made to improve vehicle efficiency and reduce CO_2 emissions, surface transportation accounted for half the increase in US greenhouse gas (GHG) emissions over the past two decades. Today, surface transportation accounts for 24 percent of all US emissions.

Automobile improvements alone will not be sufficient to meet federal and state emissions targets; policy makers also need to identify solutions that reduce the demand for car travel. Information technology offers a promising breakthrough on this front.

While many people are aware of the environmental damage caused by GHGs, that knowledge has not resulted in substantially less car travel. If travelers knew more about the impacts of their travel decisions, they might change their trip modes, routes, or departure times. And if they could compare their trips to those of their peers or the national standard, they might change their travel habits even more. To test this idea, we built and evaluated an information technology called Quantified Traveler. QT is meant to encourage travelers to be more mindful of their travel decisions and encourage drivers to walk, bike, ride transit, or forego a trip altogether. ➢

Raja Sengupta is Professor in the Department of Civil and Environmental Engineering at the University of California, Berkeley (rajasengupta@berkeley.edu). Joan L. Walker is Associate Professor in the Department of Civil and Environmental Engineering and the Center for Global Metropolitan Studies at the University of California, Berkeley (joanwalker@berkeley.edu).

If travelers knew more about the impacts of their travel decisions, they might change their trip modes, routes, or departure times.

To test the effects of QT, we recruited 135 subjects from UC Berkeley to track their travel habits using our phone app. QT then processed the data into travel diaries (lists of trips with times, locations, routes, and modes) while producing a personalized “travel impact footprint” (Figure 1). This provided users with web-based access to their travel time, travel cost, calories expended, and CO_2 produced. The footprint also compared each user’s data with three peer groups: the SF Bay area, the US average, and fellow Berkeley students (Figure 2). We then evaluated the participants over two weeks to learn whether access to this information led to a measurable increase in environmental sensitivity and a corresponding reduction in driving.

We paid participants $20 to sign up, install the app, and take an entry and exit survey. Each subject streamed travel data during the first week of the experiment. We used the data to develop personalized profiles that became the baseline footprint for each person. In the second week, participants gained access to the QT website. Most said they enjoyed the site and appreciated the information provided. All 135 subjects kept the QT App active during the two week study and looked at their personal QT web profile an average of 4.1 times during the second week. Analysis of the before-and-after survey responses suggests that QT represents a promising tool to shift people toward more sustainable attitudes and travel behavior.

Our sample group consisted of UC Berkeley affiliates, most of whom were undergraduate students. Their responses to our pre-test survey suggested they

- had little knowledge of the impact of their individual travel habits,
- held mixed views on the environment,
- were open to using sustainable travel modes,
- valued the potential health benefits, and
- had friends and family who support sustainable modes.

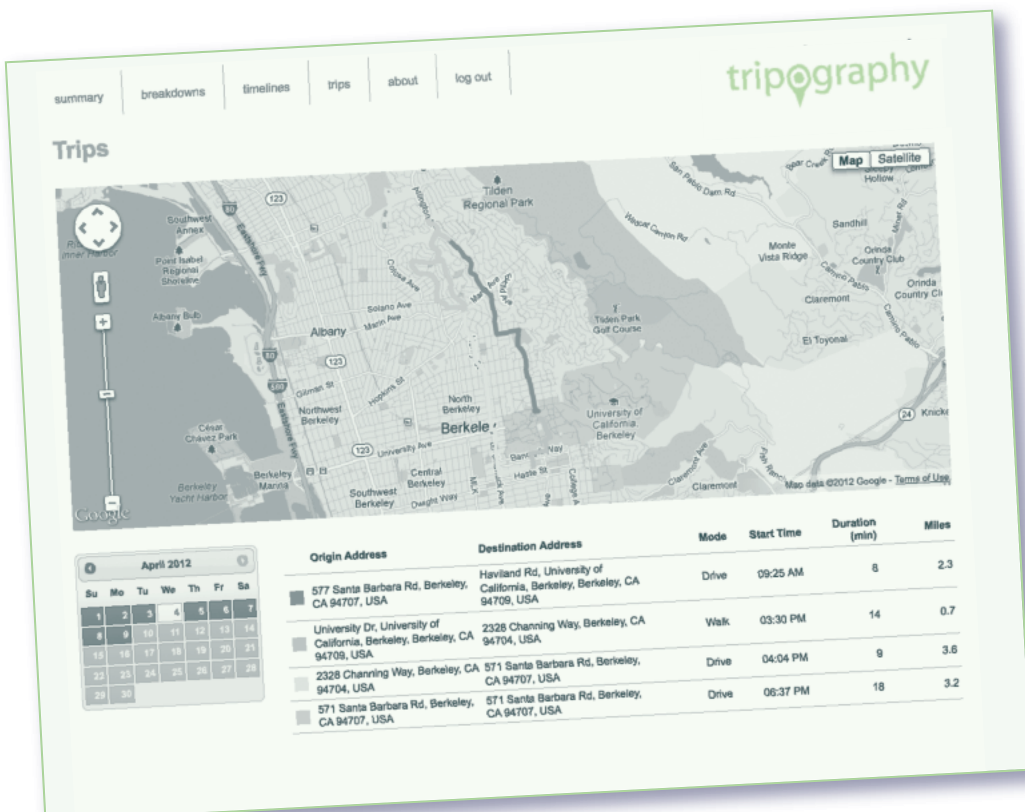


FIGURE 1

Example of Quantified Traveler Diary

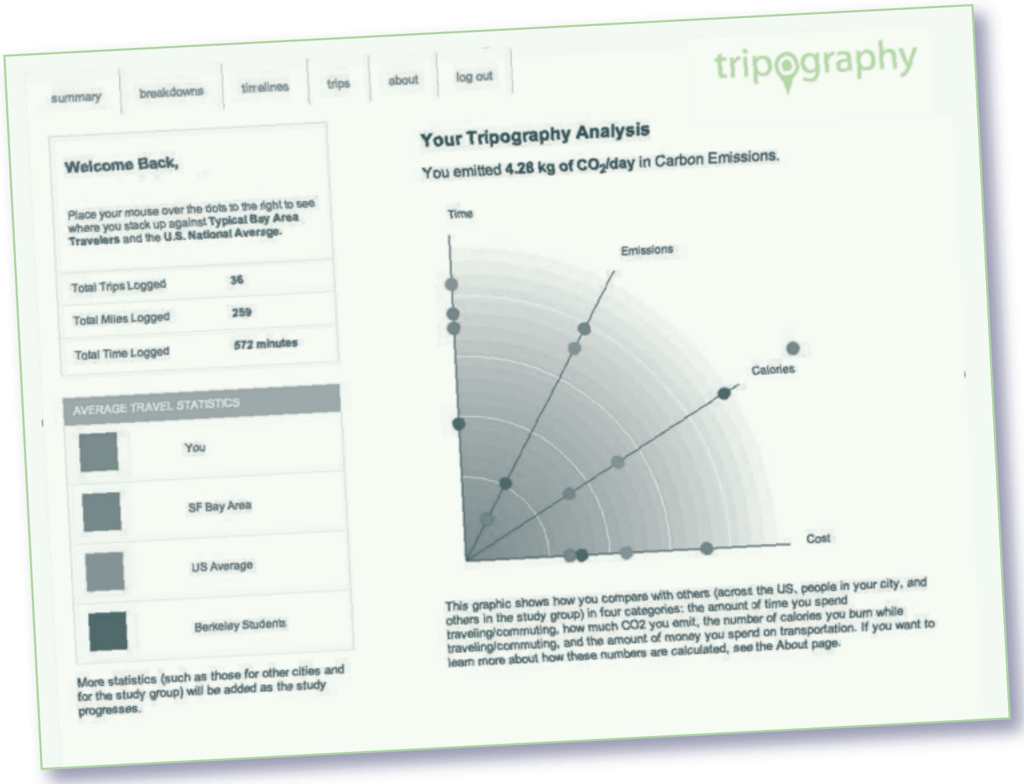


FIGURE 2

Personalized Travel Footprint with Peer Comparisons

Nevertheless, our subjects also acknowledged constraints on their ability to alter their travel modes, and most stated they had no intention of changing their travel behavior.

How then did the QT experiment affect their travel behavior? We explored whether receiving QT information affected travel patterns, and developed a model to identify statistically significant drivers of behavioral change. In the pre- and post-test surveys, we asked our subjects about a wide range of topics, including their

- awareness of the resources they expend in their travel,
- attitudes toward travel and its environmental and health impacts,
- beliefs regarding how their friends, family, and society view travel issues,
- belief in their ability to change their travel behavior, and
- interest in setting goals to change their travel behavior.

In the post-survey responses, we observed significant shifts across a range of behavioral categories suggesting that information from QT made their behavior more sustainable. The most significant shifts in responses were related to questions regarding the calories and CO_2 they expended from their travel—unsurprising results since the data in these two categories were the primary focus of the QT feedback system. QT had less impact on social norms, goal setting, and perceived ability to change their travel behavior. There were, however, small-scale shifts in these categories. In the post-survey, respondents disagreed more with the statement, “many constraints and limitations keep me from changing my transportation behavior.” They also agreed more with the statement, “I can get exercise when traveling.” These responses suggest that QT can generate more sustainable travel habits. ➢

Several responses to the questions targeting attitudes toward sustainable transport changed as well. For example, in post-survey responses, more people agreed with the policy to raise the price of gas to reduce congestion and pollution. People also shifted their feelings on sustainable behavior. After QT, more people felt it was important to engage in sustainable travel behavior and felt guilty for not using sustainable modes. Even though the individuals in our sample generally held "pro-health" views from the start, we observed an increase in the belief that sustainable transportation modes are beneficial to one's health.

Responses to two questions, however, demonstrated shifts toward less sustainable beliefs. Subjects were less likely to agree with the statements:

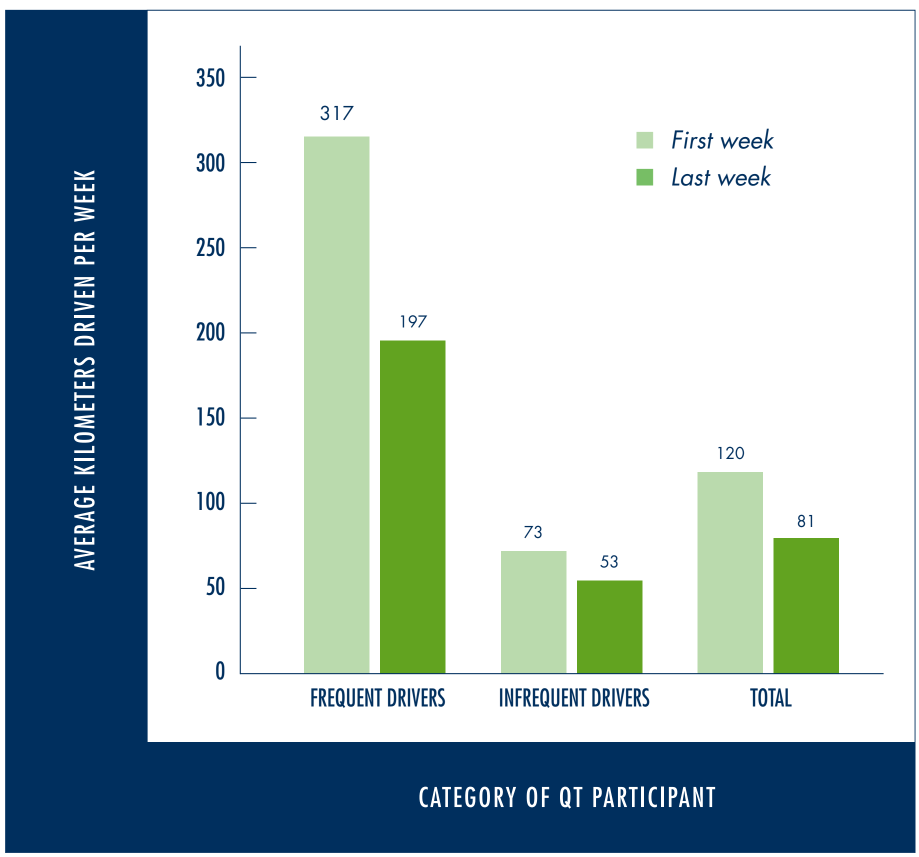
- "Greenhouse gases cause environmental problems such as global warming."
- "Everybody together should reduce the amount of fuel burned by their transportation behavior."

The reasoning behind these responses is unclear. It could be a reaction to the clearly environmentalist orientation of the experiment. Another explanation could be that pre-survey responses were very positively pro-environment, offering little room for improvement.

We also saw positive shifts in respondents' stated intentions to drive less and bike and walk more. Intentions and actions, however, are two different things. Smartphone tracking

FIGURE 3

Changes in Driving Behavior



allowed us to measure actual travel mode shifts between the two weeks, and we observed a statistically significant decrease in the average distance driven—39 kilometers (24 miles) or 33 percent less driving than the first week (Figure 3). While we did not observe a statistically significant increase in non-vehicle kilometers traveled, we did observe shifts in walking and biking based on driving frequency. Frequent drivers—those who reported in the pre-survey that they drove two or more days per week—shifted to walking and biking more than infrequent drivers. Frequent drivers drove on average 120 fewer kilometers (75 fewer miles) during the second week of the experiment than they drove during the first week, representing a reduction of 38 percent. Infrequent drivers drove 20 fewer kilometers (12 fewer miles) during the second week, for a reduction of 27 percent. Neither group significantly changed their distance traveled by transit, although frequent drivers walked on average 5 km more during the second week, for an increase of 42 percent over the first week.

We developed a behavioral model to assess whether the reductions in driving related to psychological changes measured by the entry and exit surveys. The model showed heightened awareness of CO_2 and calories expended when travelers changed attitudes and norms. The QT design of comparing one's own resource expenditures with those of one's peers seemed to play a significant role in changing attitudes toward more sustainable travel. We found that a positive change in attitude toward environmentally friendly transportation was strongly associated with less driving in the second survey week. In addition, those who more frequently signed in to the QT website significantly increased their walking and biking distances.

A Different ITS

Intelligent Transportation Systems (ITS), like QT, integrate information technology with transportation. While much of ITS aims to make better use of the existing transportation infrastructure, QT represents an emerging effort to develop information services designed to encourage behavioral changes. Real-time traffic information can impact route and departure time choice, but these services have little impact on mode choice. Mode choice is rooted in lifestyle choices that are psychologically complex and harder to change. Several programs effectively use information to influence mode and trip choice, such as the Travel Feedback Programs in Japan, Personalized Travel Planning in England, and Travel Blending in Australia. Such programs, however, often rely on person-to-person dialog and intervention instead of a Google Map-style automated information system. QT's automated style targets mode and trip decision-making by showing real-time results of travelers' actions and how those results compare to their peers' behavior. This form of ITS mimics certain psychological approaches to behavior change used by counselors and society in general.

Can automated travel feedback replace the human-to-human component used in other travel counseling programs? Travel feedback programs with in-person counselors have a record of success. If a computational surrogate could behave similarly to a counselor, travel feedback programs could be deployed at larger scales. We know people persuade people. Can computational systems persuade people? Our QT evaluation suggests they can. ◆

This article is adapted from "Quantified Traveler: Travel Feedback Meets the Cloud to Change Behavior," originally published in the *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations.* Note: the Quantified Traveler website is no longer active.

FURTHER READING

Jerald Jariyasunant, Maya Abou-Zeid, Andre Carrel, Venkatesan Ekambaram, David Gaker, Raja Sengupta, and Joan L. Walker. 2013. "Quantified Traveler: Travel Feedback Meets the Cloud to Change Behavior," *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, 19(2): 109–124. http://dx.doi.org/10.1080/15472450.2013.856714

Jalel Sager, Joshua S. Apte, Derek M. Lemoine, and Daniel M. Kammen. 2011. "Reduce Growth Rate of Light-Duty Vehicle Travel to Meet 2050 Global Climate Goal," *Environmental Research Letters*, 6(2): 024018. http://iopscience.iop.org/article/10.1088/1748-9326/6/2/024018

Melanie Swan. 2013. "The Quantified Self: Fundamental Disruption in Big Data Science and Biological Discovery," *Big Data*, 1(2): 85–99. http://dx.doi.org/10.1089/big.2012.0002

Ayako Taniguchi, Haruna Suzuki, and Satoshi Fujii. 2007. "Mobility Management in Japan: Its Development and Meta-Analysis of Travel Feedback Programs," *Transportation Research Record*, 2021: 100–109. http://dx.doi.org/10.3141/2021-12

Unraveling the Modal Impacts of Bikesharing

SUSAN SHAHEEN AND ELLIOT MARTIN

Public bikesharing has emerged as one of the latest transportation innovations, transforming North American cities and providing people with more transportation options. Much attention has focused on how new bikesharing programs fit in with the largely auto-oriented transportation culture. But there is another fascinating question: how do bikesharing programs influence the travel patterns of their members with respect to travel by rail, bus, and on foot? Our earlier study of several North American cities found the following:

- *In large, dense cities,* where public transit provides a robust network of lines and services, bikesharing may offer quicker, cheaper, and more direct connections for short distances normally traveled by walking or public transit. Though bikesharing competes with traditional public transit services, it also eases transit congestion during peak hours.
- *In suburbs and small- to medium-sized cities,* where public transit can be sparse, bikesharing complements transit and provides better access to and from existing lines. In these places, bikesharing serves as an important first- and last-mile connector and increases public transit use.

Despite notable differences in how bikesharing programs affect different cities, they consistently enhance urban mobility and reduce automobile use. To better understand these enhancements, we delve further into the demographics of bikeshare members and provide a detailed analysis of how bikesharing affects other types of travel.

Susan Shaheen is Co-Director of the Transportation Sustainability Research Center (TSRC) and Adjunct Professor in the Department of Civil and Environmental Engineering at the University of California, Berkeley (sshaheen@berkeley.edu). Elliot Martin is Assistant Research Engineer at the Transportation Sustainability Research Center (TSRC) at the University of California, Berkeley (elliot@berkeley.edu).

Bikesharing Background

Bikeshare systems allow users to access bicycles on an as-needed basis from a network of stations typically concentrated in urban areas. Bikesharing stations are usually unattended and accessible at all hours, providing an on-demand mobility option. Most bikeshare operators are responsible for bicycle maintenance, storage, and parking costs. Bikesharing patrons join the system for an annual fee or rent a bike on a trip-by-trip basis. At the conclusion of their rental, riders return the bike to any docking station, which allows for both one-way and roundtrip travel. One-way travel has, in particular, unlocked new travel options that result in modal shifts among bikeshare users. For example, a person might bikeshare in the morning to get to work and then take the bus home.

Bikesharing has the potential to bridge gaps in existing transportation networks as well as encourage people to use multiple transportation modes. Bikeshare systems offer numerous benefits:

- reduced transportation costs, traffic congestion, and fuel use;
- increased mobility and use of alternative travel modes (e.g., rail, bus, taxi, carsharing, ridesharing);
- economic development;
- health benefits; and
- greater environmental awareness.

Although before-and-after studies documenting public bikesharing benefits are limited, several programs have conducted member surveys and collected bicycle data to record program effects. Early program data suggest that bikesharing can result in emission reductions and modal shifts. For example, in Boston, Hubway data showed a carbon offset of 285 tons after two years of bikesharing operation.

Bikesharing has the potential to bridge gaps in existing transportation networks as well as encourage people to use multiple transportation modes.

A Tale of Four Cities

Beginning in November 2011, we administered an online survey to members of bikesharing programs in Montreal, Toronto, Washington, DC, and Minneapolis-Saint Paul. About 15 percent of members responded to our survey, for a total of 10,661 responses (6,486 in the US and 4,175 in Canada). The survey asked how respondents shifted modes as a result of bikesharing. Table 1 summarizes the results. We also collected respondent demographics, including home and work locations. ➢

TABLE 1

Changes in Vehicle Ownership and Driving Behavior among Bikesharers

CITY	PERCENTAGE CHANGE IN VEHICLE OWNERSHIP	PERCENTAGE OF BIKESHARERS WHO DRIVE LESS OFTEN
Montreal	-3.6%	36%
Toronto	-2.0%	25%
Washington, DC	-2.1%	41%
Minneapolis-Saint Paul	-1.9%	52%

We geocoded intersection data to calculate the distance between home and work locations in Minneapolis-Saint Paul and Washington, DC. We used this information together with survey responses to evaluate whether commute distance was associated with a shift to or from alternative forms of transportation. Our study indicated both a modal shift toward bicycle use and a heightened public awareness of bikesharing as a practical transportation mode, corroborating findings from previous bikesharing evaluations.

Demographic Findings

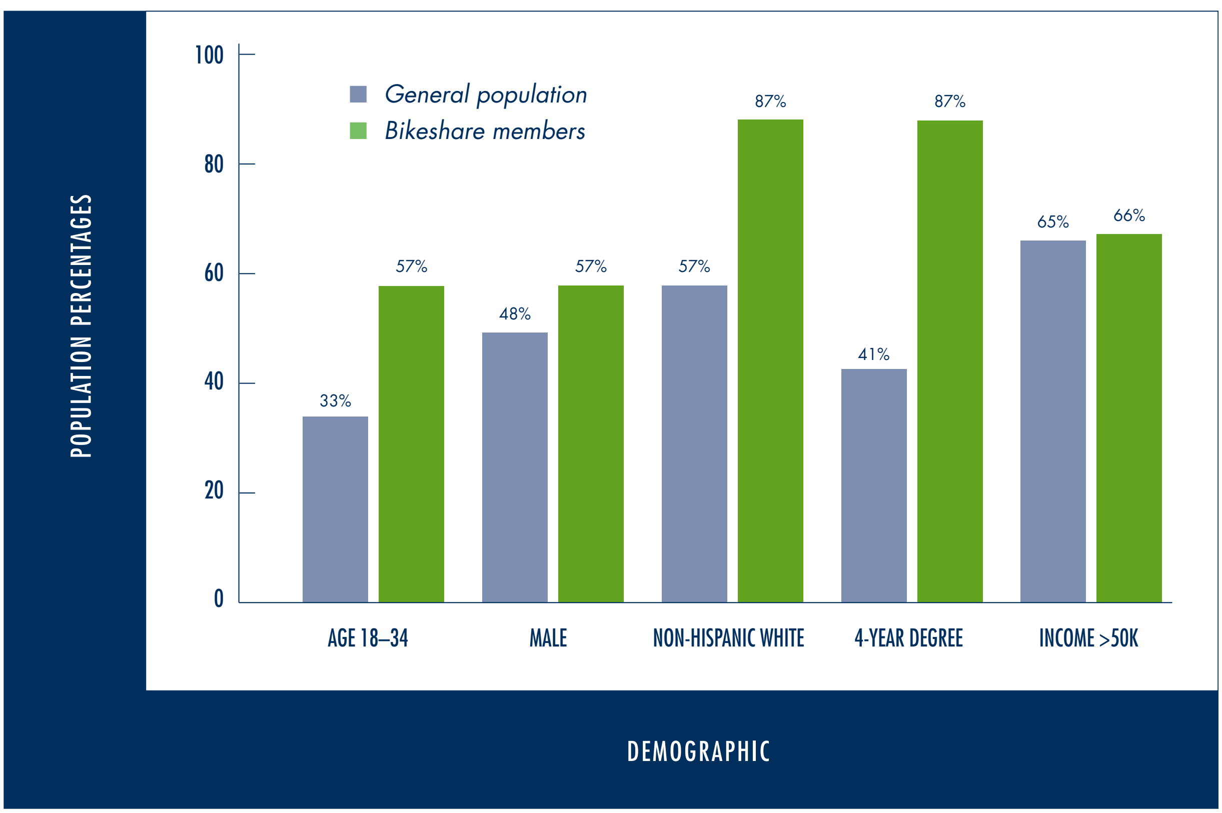
Within the four cities, bikeshare members were younger, disproportionately male, more likely to be non-Hispanic white, and significantly more educated than the general population (Figure 1). This may reflect the initial placement of bikesharing stations within downtown cores with high levels of white-collar employment. It may also reflect characteristics of early adopters, such as access to credit/debit cards, which are typically required for system use.

Modal Shifts

The survey responses suggest that bikesharing, especially its ease of one-way travel, results in different travel behavior than traditional cycling. Bikeshare members in Montreal, Toronto, and Washington, DC shifted away from cars, buses, and rail. In Minneapolis-Saint Paul, bikesharers shifted away from buses but toward rail: five times more bikesharers increased their rail travel than decreased it. And in contrast to members in the other cities, more bikesharers in Minneapolis-Saint Paul increased their number of walking trips (38 percent) than decreased them (23 percent). Figure 2 shows the ➢

FIGURE 1

Demographic Attributes of Bikeshare Members



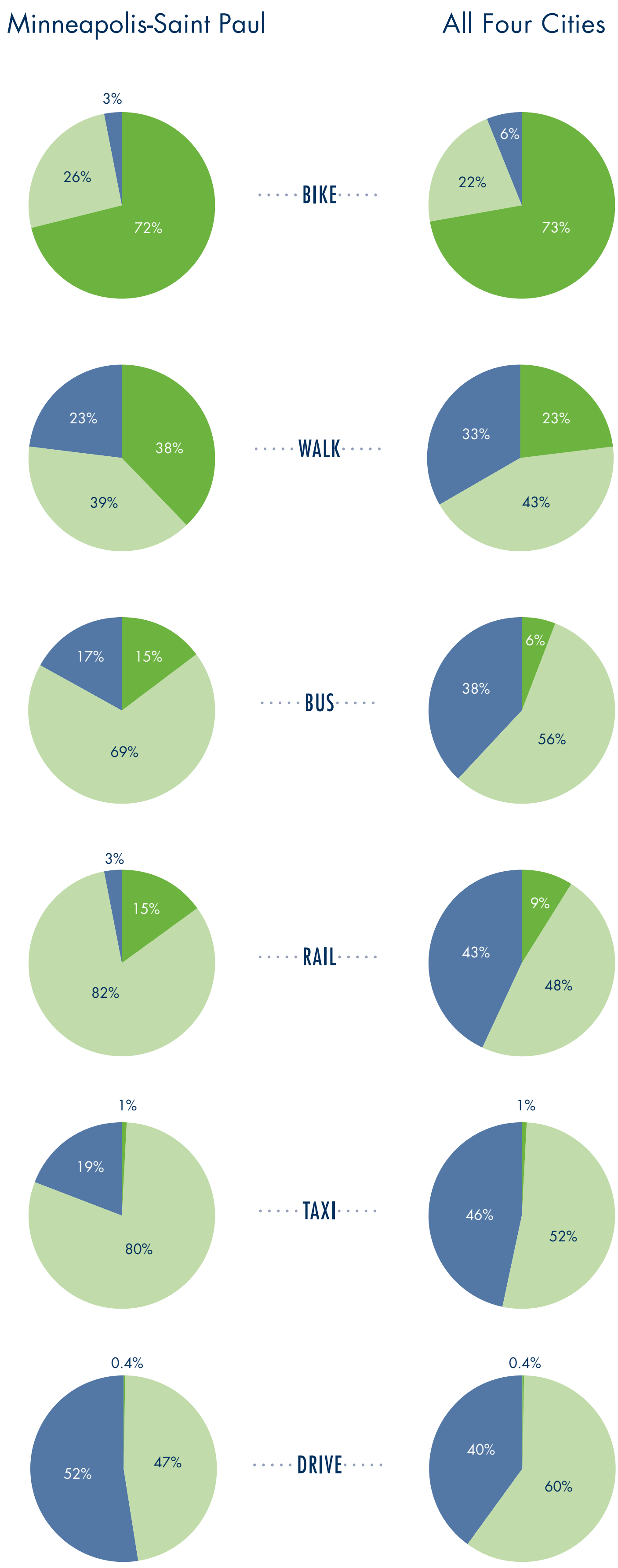


FIGURE 2

Modal Shifts Resulting from Bikesharing

responses from Minneapolis-Saint Paul and the combined responses across all surveyed cities, which more reflect the mode shifts in the larger bikeshare systems.

The differences in modal shift between Minneapolis-Saint Paul and the other three cities may stem from factors such as city size, population density, and the extent of the public transit system. Perhaps the greatest distinction with respect to rail shifts is related to the relatively small size of the Minneapolis-Saint Paul rail transit system. Although Minneapolis-Saint Paul opened a new light rail line in June 2014, the Blue Line was the only light rail transit in the region at the time of our survey. In contrast, rail systems in Montreal, Toronto, and Washington, DC are more extensive.

Shifts in Rail: Washington, DC vs Minneapolis-Saint Paul

We employed a geospatial analysis to more deeply assess the differences in modal shift between Washington, DC and Minneapolis-Saint Paul. We developed comparative maps of modal shift in both cities for rail and bus aggregated and grouped by zip code. Figures 3 and 4 illustrate the geographic distribution of modal shifts to and from rail among bikesharers in Washington, DC and Minneapolis-Saint Paul. The maps present pie charts for each zip code with segments to illustrate increased, constant, or decreased rail use. The number overlaid in each pie chart is the number of respondents in that zip code.

FIGURE 3

Modal Shifts to and from Rail in Washington, DC

FIGURE 4

Modal Shifts to and from Rail in Minneapolis-Saint Paul

DC bikesharers are concentrated downtown, where bikeshare stations are abundant and the rail network is most congested. Shifts away from rail were highest around this area, suggesting that bikesharing may substitute for shorter trips previously taken on rail.

Reduced demand for rail transit among bikesharers, particularly in the city center, may benefit public transit operators during rush hours in large transit-intensive cities like Washington, DC. By adding transportation alternatives, bikesharing opens up additional capacity on congested bus and rail lines in the urban core. Indeed, one reason Capital Bikeshare was launched in Washington, DC was to relieve congestion on the subway system. Additionally, bikeshare systems in cities with developed rail systems can save people time by providing more direct routes between their destinations, as well as providing health benefits and cost savings.

In contrast to DC, the Minneapolis-Saint Paul bikesharers demonstrate a uniquely positive net shift toward rail. Figure 4 shows that the shift toward rail occurs both in the downtown core and in the suburbs. The simplest explanation may be the layout and extent of the rail network at the time of the survey. Minneapolis had a single, linear rail line compared to DC Metro's multiple, interconnecting lines. In this linear system, bicycles did not offer any time savings over short rail trips that require transfers because transfers between rail lines did not exist at the time of the survey. ➢

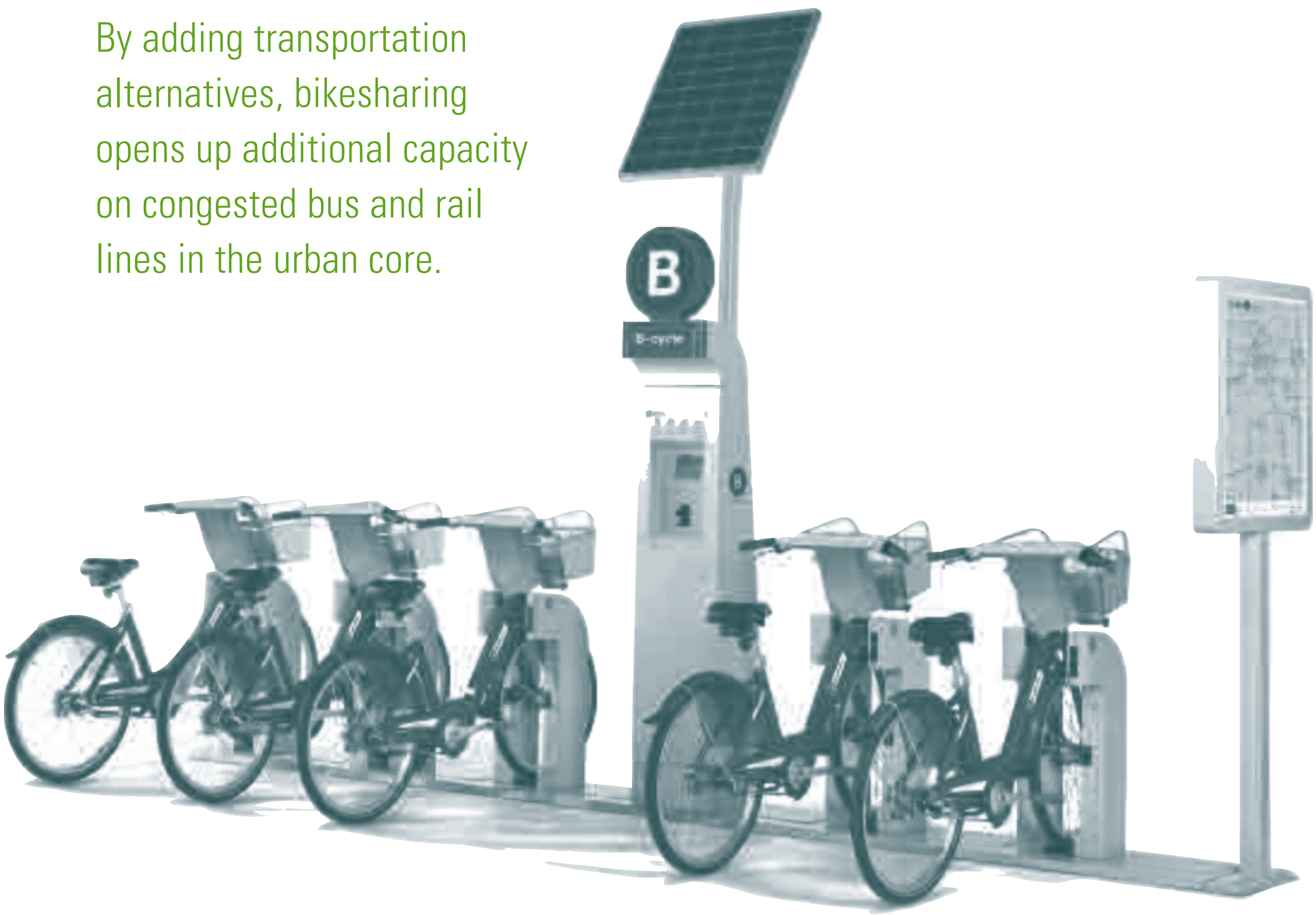
Bikesharing's primary effect in Minneapolis-Saint Paul was to increase access to and from the lone rail line. The increased rail usage indicates that bikesharing provides an important first- and last-mile connection for users with origins or destinations beyond walking distance from rail stations. Consequently, in smaller, less transit-rich cities, bikeshare can provide a low-cost alternative to public transit expansion.

Riding the Bus

Bus ridership in Washington, DC shifted in the same way as rail ridership shown in Figure 3. Few respondents in the urban core of DC indicated increasing their bus use as a result of bikesharing. The respondents who did report increased bus use were primarily near the edges of the region.

In Minneapolis-Saint Paul, respondents were almost equally likely to increase their bus use (15 percent) as decrease it (17 percent). Like rail, the shift toward bus was distributed within the urban core as well as the suburban periphery. In contrast to DC, this may suggest that bikesharing in the downtowns of cities like Minneapolis-Saint Paul serves a more balanced role in both complementing and substituting for bus travel.

By adding transportation alternatives, bikesharing opens up additional capacity on congested bus and rail lines in the urban core.



Effects on Walking

The results for walking are somewhat different. More bikesharers increased rather than decreased their walking in Minneapolis-Saint Paul, whereas the opposite occurred in DC. But in both cities, the shares of those who increased and decreased walking are more balanced relative to shifts in other modes. That is, 17 percent of DC bikesharing members walked more while 31 percent walked less. For Minneapolis-Saint Paul, 38 percent walked more and 23 percent walked less. The broader conclusion from this is that bikesharing often complements walking in certain cities but is likely to be situation-specific. Some members in the suburbs may bikeshare instead of walking to/from public transit. Downtown users may walk more to the actual bikesharing stations but then use public transit less. These and other modal shifts invite further study across a wider variety of urban and suburban environments.

Conclusion

Bikesharing has grown rapidly in North America and has provided an innovative mobility option that can both substitute for and complement public transportation. In areas with more robust or congested transit networks, bikesharing may offer quicker, cheaper, and more direct travel over short distances that have traditionally been taken on foot or public transit. In areas with smaller public transit systems, bikesharing serves a greater role as a first- and last-mile connector. These promising findings show that bikesharing has notable potential to enhance urban mobility and reduce automobile use in a wide variety of North American cities. ◆

This article is adapted from "Evaluating Public Transit Modal Shift Dynamics in Response to Bikesharing: A Tale of Two U.S. Cities," originally published in the *Journal of Transport Geography*.

Further Reading

Elliot Martin and Susan Shaheen. 2014. "Evaluating Public Transit Modal Shift Dynamics in Response to Bikesharing: A Tale of Two Cities," *Journal of Transportation Geography*, 41: 315–324.
http://dx.doi.org/10.1016/j.jtrangeo.2014.06.026

Nice Ride Minnesota. 2010. Nice Ride Subscriber Survey Summary Report.
http://projectadvisoryteam.files.wordpress.com/2011/01/nice-ride-subscriber-survey-summary-report-nov_1_2010-nice-ride-fall-subscriber-survey.pdf

Susan Shaheen, Stacey Guzman, and Hua Zhang. 2010. "Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future," *Transportation Research Record*, 2143: 159–167.
http://trrjournalonline.trb.org/doi/abs/10.3141/2143-20

Susan Shaheen, Elliot Martin, Nelson Chan, Adam Cohen, and Mike Pogodzinski. 2014. "Public Bikesharing in North America during a Period of Rapid Expansion: Understanding Business Models, Industry Trends, and User Impacts," Mineta Transportation Institute Report 12-29.
http://transweb.sjsu.edu/project/1131.html

Susan Shaheen, Elliot Martin, and Adam Cohen. 2013. "Public Bikesharing and Modal Shift Behavior: A Comparative Study of Early Bikesharing Systems in North America," *International Journal of Transportation*, 1(1): 35–53.
http://dx.doi.org/10.14257/ijt.2013.1.1.03