



Region 2
UNIVERSITY TRANSPORTATION RESEARCH CENTER

FINAL REPORT

**Analysis of Bicycling Trends and Policies in Large North American Cities:
Lessons for New York**

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16. Abstract <p>This research report reviews trends in cycling levels, safety, and policies in large North American cities over the past two decades. We analyze aggregate national data as well as city-specific case study data for nine large cities (Chicago, Minneapolis, Montréal, New York, Portland, San Francisco, Toronto, Vancouver, and Washington). The number of bike commuters in the USA rose by 64% from 1990 to 2009, and the bike share of commuters rose from 0.4% to 0.6%. Over the shorter period from 1996 to 2006, the number of bike commuters in Canada rose by 42%, and the bike share of commuters rose from 1.1% to 1.3%. From 1988 to 2008, cycling fatalities fell by 66% in Canada and by 21% in the USA; serious injuries fell by 40% in Canada and by 31% in the USA. Cycling rates have risen much faster in the nine case study cities than in their countries as a whole, at least doubling in all the cities since 1990. The case study cities have implemented a wide range of infrastructure and programs to promote cycling and increase cycling safety: expanded and improved bike lanes and paths, traffic calming, parking, bike-transit integration, bike sharing, training programs, and promotional events. We describe the specific accomplishments of the nine case study cities, focusing on each city's innovations and lessons for other cities trying to increase cycling.</p> <p>Although cycling has almost doubled in New York City since 1990, it lags far behind the other case study cities in almost every respect. It has the lowest bike share of commuters, the highest cyclist fatality and injury rate, and the lowest rate of cycling by women, children, and seniors. New York has built the most bikeways of any North American city since 2000 and has been especially innovative in its use of cycle tracks, buffered bike lanes, bike traffic signals, bike boxes, and sharrowed streets. Yet New York has almost completely failed in the important areas of bike-transit integration and cyclist rights and falls far short on bike parking and cycling training. Moreover, the refusal of New York's police to protect bike lanes from blockage by motor vehicles has compromised cyclist safety. New York has much to learn from the other case study cities, which have implemented a far more comprehensive, integrated package of mutually reinforcing policies to promote cycling.</p>					
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Executive Summary

This research report reviews trends in cycling levels, safety, and policies in large North American cities over the past two decades. We analyze aggregate national data as well as city-specific case study data for nine large cities (Chicago, Minneapolis, Montréal, New York, Portland, San Francisco, Toronto, Vancouver, and Washington). The number of bike commuters in the USA rose by 64% from 1990 to 2009, and the bike share of commuters rose from 0.4% to 0.6%. Over the shorter period from 1996 to 2006, the number of bike commuters in Canada rose by 42%, and the bike share of commuters rose from 1.1% to 1.3%. From 1988 to 2008, cycling fatalities fell by 66% in Canada and by 21% in the USA; serious injuries fell by 40% in Canada and by 31% in the USA. Cycling rates have risen much faster in the nine case study cities than in their countries as a whole, at least doubling in all the cities since 1990. The case study cities have implemented a wide range of infrastructure and programs to promote cycling and increase cycling safety: expanded and improved bike lanes and paths, traffic calming, parking, bike-transit integration, bike sharing, training programs, and promotional events. We describe the specific accomplishments of the nine case study cities, focusing on each city's innovations and lessons for other cities trying to increase cycling.

All nine of the case study cities have been implementing innovative measures to increase cycling, but each city has a somewhat different mix and focus. Portland does almost everything, but it is most notable for its bike boulevards, dense bikeway network, innovative bike corrals, large number of cycling events, and lively bike culture. Minneapolis has an extensive system of off-street bike paths, the most bike parking per capita of any city, and offers an impressive adaptation of cycling to cold, snowy winters. Vancouver has been a model of traffic calming, bike boulevards, and bike-transit integration. San Francisco has been at the vanguard of bike culture in the USA for two decades, leading the way in bike advocacy and cyclist rights as well as bike-transit integration. Montréal has North America's largest and oldest network of cycle tracks as well as the largest bike sharing system. Washington has the first bike sharing program in the USA, excellent bike-transit integration (including a bike station), and an extensive mixed-use trail network that extends into the entire region. Toronto stands out for its bike parking and pioneering role in bike training and community outreach with the bicycling ambassador program. Chicago has led the way in bike-transit integration, bike parking, community outreach, and enforcement of cyclist rights.

New York is a special case. Not only is New York by far the largest of the case study cities, but it has the most mixed record on cycling policies and accomplishments. Although cycling has almost doubled in New York City since 1990, it lags far behind the other case study cities in almost every respect. It has the lowest bike share of commuters, the highest cyclist fatality and injury rate, and the lowest rate of cycling by women, children, and seniors. New York has built the most bikeways since 2000 and has been especially innovative in its use of cycle tracks, buffered bike lanes, bike traffic signals, bike boxes, and sharrowed streets. Yet New York has almost completely failed in the important areas of bike-transit integration and cyclist rights and falls far short on bike parking and cycling training. Moreover, the refusal of New York's police to protect bike lanes from blockage by motor vehicles has compromised cyclist safety. New York has much to learn from the other case study cities, which have implemented a far more comprehensive, integrated package of mutually reinforcing policies to promote cycling.

New York and Chicago had the same bike mode share in 1990 (0.3%), but by 2009 Chicago's rate was twice as high as New York's (1.2% vs. 0.6%). The much slower growth in

cycling in New York is instructive. It emphasizes the need to implement a coordinated package of complementary policies. That was also the main conclusion of a recent international review of the entire range of infrastructure, programs, and policies to increase cycling. The review found that individual measures, such as the extensive bikeways built in New York since 2000, help promote cycling, but that they have limited impact unless supported by many other kinds of programs and policies. Portland is the American city that comes closest to implementing a truly comprehensive, well-integrated, long-term package of infrastructure, programs, and policies to promote cycling. Portland's success is evident in the numbers, with a 6-fold increase in cycling levels since 1990, compared to a doubling in New York.

The comparative case studies offer a few other possible lessons. Climate does not appear to be a serious obstacle to increasing cycling, as shown by Portland and Vancouver, with their rainy climates, and Minneapolis and Montréal, with their long and very cold winters. Similarly, even hilly cities like San Francisco can generate high cycling levels with the right infrastructure and policies in place. Very large cities appear to present special challenges to cycling: high density of traffic, long trip distances, and the sometimes harrowing experience of cycling in heavy traffic with high levels of noise and air pollution. Those factors might help explain the relatively low bike mode shares in both New York (0.6%) and Chicago (1.2%). The two largest cities in Europe, London (1.6%) and Paris (2.5%), also have relatively low bike mode shares in spite of many policies to encourage cycling.

In addition to the case study analysis, this report summarizes the results of our multivariate analysis of the impacts of bike lanes and bike paths on cycling levels in the 100 largest U.S. cities. The multivariate analysis was based on data collected specifically for this project on the length of bike lanes and paths in each city for the year 2008. Pearson's correlation, bivariate quartile analysis, and three different types of regressions were used to measure the differential impacts of bike paths and lanes, as well as other explanatory and control variables. Ordinary Least Squares, Two Stage Least Squares, and Binary Logit Proportions regressions confirm that cities with a greater supply of bike paths and lanes have significantly higher cycling levels—even when controlling for land-use, climate, socioeconomic factors, cycling safety, and geography. Standard tests indicate that the models are a good fit, with R^2 ranging between 0.57 and 0.67. Computed coefficients have the expected signs for almost all variables in the various regression models. Estimated elasticities indicate that both off-street paths and on-street lanes have a similar positive association with cycling commute levels in U.S. cities ($\epsilon \sim +0.25$). Our results validate earlier findings on the importance of separate facilities and provide additional information about potentially different impacts of paths vs. lanes.

Cycling has certainly been on the rise in most parts of the USA and Canada. The boom in cycling, however, has been limited to a few dozen cities which have implemented a wide range of programs to aggressively promote cycling, such as the nine case study cities portrayed in this report. Even in those cities, cycling growth has been highly concentrated in the central cities, and especially in gentrifying neighborhoods near the CBD and university districts, while cycling remains at very low levels in most suburbs. Moreover, cycling levels vary greatly by region. The western states/provinces of the USA and Canada have, by far, the highest cycling rates, while most states in the American South, from Texas all the way to North Carolina, have extremely low levels of cycling.

Over the past decade, there has been a large increase in funding for cycling and in the range and magnitude of pro-bike policies to promote cycling. That suggests that cycling is less of a fringe mode than it was considered even a decade ago. Indeed, cycling is becoming a

mainstream mode in a few cities. Portland's 2008 survey found that 18% of its residents used bikes as their primary or secondary mode for the work trip. That is comparable to cycling mode shares in northern Europe. The success of Portland is important because it shows that even car-dependent American cities can greatly increase cycling by implementing the right package of infrastructure, programs, and policies.

1. Introduction

The US Department of Transportation (1994, 2004) has set a goal of increasing the percentage of trips by bicycle while improving safety. The rationale for promoting cycling is that it would shift some trips from the car, thus reducing roadway congestion, parking problems, air pollution, noise, and energy use. Moreover, both the US Department of Transportation and the Centers for Disease Prevention and Control advocate active transport such as bicycling for physical activity that would help combat the worsening obesity epidemic.

Many states and cities across the USA have adopted similar goals and have begun ambitious programs to improve cycling infrastructure. New York City (2007) has adopted a Bike Master Plan that would vastly expand cycling facilities and bike parking while implementing cycling training, traffic safety, and promotional programs. New York has already added 345 miles of bike paths and lanes in the past ten years and plans an additional 463 miles of bike paths and lanes in the coming ten years. From 2001 to 2009, New York installed over 6,000 new bike racks. Official city plans call for a network of 1,800 miles of bike lanes and greenway paths by 2030.

Cycling in New York has increased considerably in recent years. Annual cordon counts conducted by the City of New York (2010a) at a wide range of locations indicate that cycling levels increased by 155% between 2000 and 2008. Nevertheless, cycling accounted for only 0.6% of work trips in 2009, compared to much higher bike mode shares for many other large cities: 5.8% in Portland, 3.9% in Minneapolis, 3.0% in San Francisco, 2.2% in Washington, DC, and 1.2% in Chicago (USDOT, 2010a). Thus, New York appears to be on the right path but has a long way to go, and could benefit from the experiences of more successful cities.

Our main approach is to do in-depth case studies of cycling in New York City; Portland, OR; Minneapolis, MN; San Francisco, CA; Chicago, IL; and Washington, DC. We enhance the analysis of American cities by adding three case studies of large Canadian cities: Vancouver, BC; Toronto, ON; and Montreal, QC. Only case study analysis can capture the overall range of policies, programs, and specific measures employed by each city to promote cycling. Only a few aspects of cycling programs can be quantified, such as miles of bike lanes and paths and numbers of bike racks. Using a newly collected dataset, we conducted a multivariate statistical analysis of the determinants of cycling levels in the 100 largest American cities and all 50 states as well as the District of Columbia.

The main purpose of both the case study and multivariate analysis is to determine which approaches are most effective in terms of raising cycling levels while improving safety. It is not possible to isolate out the independent impacts of each policy, program, and measure on cycling levels and safety rates, since these work in combination with each other. Indeed, it is precisely the symbiotic, interrelated impact of policy coordination that may best explain why some cities are more successful than others. That is one aspect we examined with particular interest in the American case study analysis, since it is what we also found in our analysis of European and Canadian cities.

Our report suggests ways in which the cycling policies and programs for New York City could be improved. Overall, New York's current policy of vastly expanding the bike lane and path network seems appropriate. But it should be accompanied by many other complementary measures, such as those found in more successful cities in Europe, Canada, and the USA.

2. National trends in cycling levels and trip purpose

As shown in Table 1, there has been considerable growth in cycling over the past few decades. The National Personal Transportation Surveys (NPTS) of 1977 to 1995 and the National Household Travel Surveys (NHTS) of 2001 and 2009 are the only sources of information on travel for all trip purposes in the USA. These surveys indicate that the total number of bike trips in the USA more than tripled between 1977 and 2009, while the bike share of total trips almost doubled, rising from 0.6% to 1.0%. The U.S. Census Bureau also surveys travel but only for the trip to work. It reports a roughly constant level of daily bike commuters over the period 1980 to 2000 and a slight fall in the bike share of work commuters, from 0.5% to 0.4%. There appears to have been a turnaround since 2000, however, as the U.S. Census Bureau's American Community Survey reports almost twice as many daily bike commuters in 2009 as in 2000 and an increase in bike mode share to 0.6% (Table 1).

Cycling has increased in Canada as well, but only work commutation data from the Canadian Census are available for tracking trends, and only since 1996. They reveal a 42% increase in the number of daily bike commuters between 1996 and 2006 and slow but steady growth in bike share of work commuters, from 1.1% to 1.3% (Table 1). That is more than twice as high as the 0.6% bike mode share for work commuters in the USA. Canada does not have a national travel survey with information on non-work trips, so it is not possible to compare cycling levels in the two countries for all trip purposes.

The 2001 and 2009 NHTS surveys for the USA report on travel behavior for a wide range of trip purposes and reveal some interesting trends. As shown in Table 2, there has been a considerable increase in utilitarian cycling, growing from 43% of all bike trips in 2001 to 54% of bike trips in 2009. For example, the share of bike trips made for the journey to work rose from 8% to 12%, and the share made for shopping rose from 8% to 10%. Bike trips to and from public transport stops rose from only 1% in 2001 to 3% in 2009. In spite of their declining share of all bike trips, social and recreational trips continue to have a higher bike mode share than other trip purposes: 1.3% compared to 0.6% for work commutation, for example.

Table 1.
Trends in cycling levels in Canada and the USA, 1977-2009.

	United States				Canada	
	Annual Bike Trips (millions)	Bike Share of Trips (%)	Daily Bike Commuters (thousands)	Bike Share of Workers (%)	Daily Bike Commuters (thousands)	Bike Share of Workers (%)
1977	1,272	0.6	-	-	-	-
1980	-	-	468	0.5	-	-
1983	1,792	0.8	-	-	-	-
1990	1,750	0.7	467	0.4	-	-
1995	3,141	0.9	-	-	-	-
1996	-	-	-	-	137	1.1
2000	-	-	488	0.4	-	-
2001	3,314	0.9	-	-	163	1.2
2006	-	-	-	-	196	1.3
2008	-	-	786	0.5	-	-
2009	4,070	1.0	766	0.6	-	-

Sources: (ORNL, 2005; Statistics Canada, 1996-2010; USDOT, 2010b)

Table 2.

Trends in cycling by trip purpose in the USA, 2001-2009.

Trip Purpose	Bike Share of All Trips		Share of All Bike Trips	
	2001	2009	2001	2009
Commute or Work Related	0.4	0.7	8%	12%
Shopping	0.3	0.5	8%	10%
Personal Business	0.3	0.4	7%	8%
School/Church/Doctor	0.5	0.7	6%	6%
Visit Friends	1.5	2.3	15%	16%
Recreational/Vacation	2.4	2.4	57%	46%
Transit Access/Egress	0.3	0.8	1%	3%

Sources: (ORNL, 2005; USDOT, 2010b)

3. Socioeconomic characteristics of cyclists

As documented in an earlier article, cycling in northern Europe is common across a broad range of social groups (Pucher and Buehler, 2008). For example, Dutch, German, and Danish women cycle as often as men, and rates of cycling fall only slightly with age. The situation is quite different in North America.

3.1. Gender

As shown in Table 3, most of the growth in cycling in the USA over the preceding decade has been among men. From 2001 to 2009, the percent of all bike trips in the USA made by women fell from 28% to 23%. The bike mode share for women for all trip purposes remained at 0.5% from 2001 to 2009, while bike mode share for men rose from 1.2% to 1.7% over the same period. The gender of cyclists in the USA and Canada can only be compared for the work trip, but the available Census data show a higher percentage of women bike commuters in Canada (29% vs. 24%). It is notable that the female share of cyclists has been rising in Canada (from 26% in 1996 to 29% in 2006), while it has been falling in the USA (Statistics Canada, 1996-2010). The gender difference might be due to the much greater cycling safety in Canada compared to the USA, as discussed later in this report. Several studies show that women are more sensitive to cycling dangers than men (Baker, 2009; Emond et al., 2009; Garrard et al., 2008; Geddes, 2009; Pucher et al., 2010a).

3.2. Age distribution

From 1995 to 2009 almost all the growth in cycling in the USA has been in the age groups 25-64, with little change in cycling levels among those under 25 years old, and a slight increase in cycling by seniors (ORNL, 2005; USDOT, 2010b). Consequently, the age group 25-64 almost doubled its share of all bike trips, from 23% in 1995 to 42% in 2009. In contrast, the share of all bike trips made by persons younger than 25 fell from 75% in 1995 to 53% in 2009. Table 3 only shows trends since 2001, but it confirms that trends from 1995 to 2001 have continued through 2009.

Table 3.

Trends in cycling by socioeconomic and demographic characteristics in the USA, 2001-2009.

	Bike Share of All Trips		Share of All Bike Trips	
	2001	2009	2001	2009
<i>Gender</i>				
Male	1.2	1.7	67%	77%
Female	0.5	0.5	33%	23%
<i>Age Group</i>				
5 to 15 years	3.3	3.3	56%	42%
16 to 24 years	0.6	0.9	8%	11%
25 to 39 years	0.5	0.8	21%	23%
40 to 64 years	0.4	0.7	10%	19%
65 and older	0.4	0.5	4%	5%
<i>Automobiles Owned in Household</i>				
No car	1.6	2.0	7%	10%
One car	0.7	1.3	17%	27%
Two cars	0.9	1.0	47%	40%
Three and more cars	0.7	0.8	29%	23%
<i>Household Income</i>				
Lowest Quartile	0.8	1.3	25%	31%
Second Quartile	0.8	0.8	25%	21%
Third Quartile	0.9	1.1	22%	25%
Highest Quartile	0.8	1.1	28%	23%
<i>Ethnicity</i>				
White	0.9	1.0	83%	79%
African American	0.5	0.7	8%	10%
Hispanic	0.6	0.8	6%	8%
Asian	0.5	0.8	2%	3%

Sources: (ORNL, 2005; USDOT, 2010b)

3.3. *Income, car ownership, and ethnicity*

In 2001 there was almost no difference in bike mode shares among the four income quartiles (Table 3). By comparison, the 2009 NHTS indicates a somewhat higher bike mode share in the lowest income quartile (1.3%) than in the top two income quartiles (1.1%). Although cycling rates do not vary much by income, it seems likely that low-income persons cycle mainly for work trips and other utilitarian purposes, while high-income persons may cycle more for recreation and exercise (Heinen et al., 2010; Krizek et al., 2009; Smart, 2010).

Cycling rates decline sharply with increased car ownership (Table 3). In both 2001 and 2009, bike mode share was more than twice as high for households without cars as for households with three or more cars. Bike mode share grew the most among households with no

cars or only one car. Such households also increased their share of all bike trips from 24% in 2001 to 37% in 2009. Thus, car ownership appears to have become a stronger determinant of cycling rates over the past decade.

As shown in Table 3, non-Hispanic whites have the highest bike mode share among ethnic groups, but cycling rates are rising fastest among African Americans, Hispanics, and Asian Americans. Those three groups also account for an increasing share of total bike trips, rising from 16% in 2001 to 21% in 2009. Clearly, however, cycling is still dominated by non-Hispanic whites, who make 79% of all bike trips in the USA but account for only 66% of the population (USDOD, 2010a).

Comparable breakdowns of cycling rates by age, income, car ownership, and ethnicity were not possible for Canada due to the unavailability of data. Even if the Canadian Census permitted such breakdowns, they would be skewed because only work commutation is surveyed.

4. National trends in cycling safety

In both the USA and Canada, cycling has become safer. Over the 20-year period from 1988 to 2008, the total number of cyclist fatalities fell by 21% in the USA and by 66% in Canada, but with considerable fluctuations from year to year in both countries (Figure 1). It is noteworthy that the percentage decline in fatalities was three times larger in Canada. Yet trends in serious cycling injuries have been similar in the two countries. From 1988 to 2008, there was a 31% decline in serious injuries in the USA, with a slow but fairly steady decline until a sharp rise in 2008. Over the slightly shorter period from 1988 to 2007, there was a 40% decline in serious injuries in Canada, roughly paralleling the trend in the USA except for 2008. In short, Figure 1 suggests a greater improvement in cycling safety in Canada than in USA, although these fatality and injury totals do not control for rates of exposure.

Cycling levels have grown considerably in both countries. Thus, on a per trip basis, cycling safety has improved far more than suggested by Figure 1. For the USA, fatalities per 10 million bike trips (all trip purposes) fell by 65% between 1977 and 2009, from 5.1 to 1.8 fatalities per 10 million trips. Relative to work trips only, fatalities per 10,000 bike commuters in the USA fell from 21 in 1980 to 14 in 2000 and 9 in 2008, with an overall decrease of 57% since 1980. In Canada, fatalities per 10,000 bike commuters fell from 4 in 1996 to 3 in 2006, only a third the fatality rate in the USA.

In short, cycling has become safer in both countries, but it is much safer in Canada than in the USA, at least relative to the only available exposure measure that can be compared between the two countries. As noted earlier, greater safety might help explain the higher percentage of women cyclists in Canada.



Fig. 1. Trends in Cyclist Fatalities and Injuries in the USA and Canada, 1988-2008 (as percent relative to 1988).
 Sources: (Transport Canada, 2010; USDOT, 2010a)

4.1 Growth in federal funding of cycling facilities

Over the past decade there has been impressive expansion in programs and policies to promote cycling, especially in the USA, where the federal government has taken the lead in providing increased funding and programmatic support (Clarke, 2003; Cradock et al., 2009; Handy et al., 2009; PBIC and FHWA, 2010; USDOT, 2004). Due to space limitations, we cannot examine in detail each of the federal programs, but they reflect the federal government's growing interest in encouraging active travel. Rising federal funding is probably the best indicator of support. Figure 2 shows average federal funding levels for walking and cycling in each of the major periods of transport legislation, with amounts expressed in constant 2009 dollars to control for inflation. It is not possible to separate out funding for cycling alone because official federal statistics only report on combined spending for walking and cycling. With each of the last three major federal transportation acts, funding for walking and cycling has increased considerably. From 1988 to 1990, in the three years just prior to the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA), average annual federal funding was only about \$5 million per year, and then rose to about \$150 million per year with ISTEA from 1992 to 1998. Funding increased to an average of \$360 million per year from 1999 to 2005 under the Transportation Equity Act for the 21st Century (TEA21), and then to almost \$1 billion a year from 2006 to 2009 under the Safe, Accountable, Flexible, Efficient, Transportation Equity Act (SAFETEA-LU), including the added stimulus funds during the recession. Even excluding the \$405 million in temporary stimulus spending, it is clear that federal funding for walking and cycling infrastructure and programs has increased dramatically over the past two decades. That infusion of federal funding for pedestrian and cycling infrastructure and programs has unquestionably encouraged local and state governments to construct new and improved cycling facilities.

There are no national data on the total extent of cycling facilities in the USA, but the Rails-to-Trails Conservancy (Rails to Trails Conservancy, 2010b) reports that the total length of bike trails grew from 2,044 miles in 1990 to 11,029 in 2000 and 15,964 in 2010. That represents a nearly 8-fold increase in the trail network over the two decades since passage of ISTEA. Those mileages only include rail trails and thus exclude most mixed use paths and bike paths in urban areas, but they are suggestive of the rapid expansion of cycling facilities thanks to ISTEA, TEA21 and SAFETEA-LU.

In contrast to the USA, there is no regular federal funding for cycling facilities in Canada, so financing depends almost entirely on provincial and local funds. There are no national statistics for cycling facilities and funding in Canada.

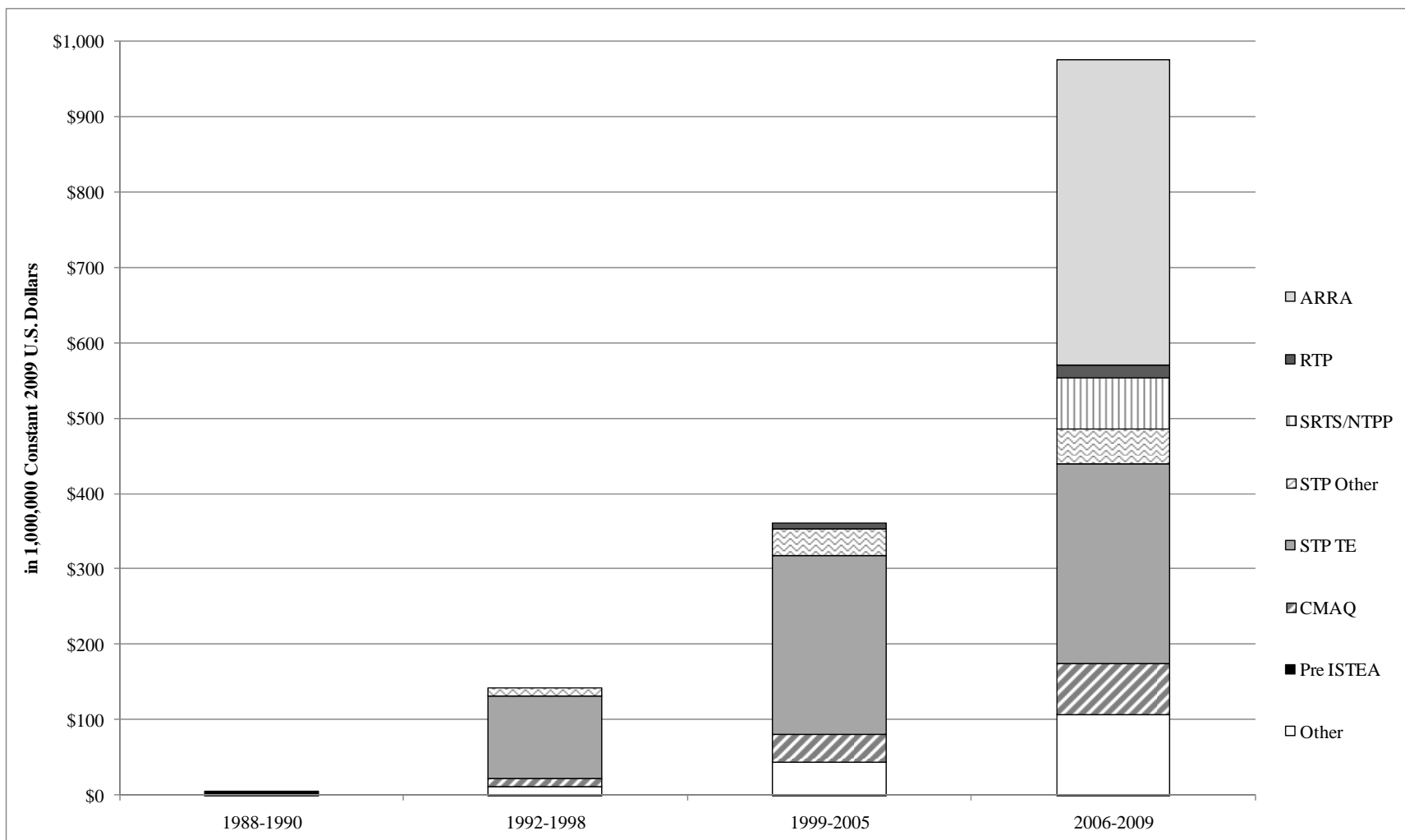


Fig. 2. Inflation Adjusted Average Annual Federal Obligations for Cycling and Walking, 1988-2009. Sources: (Rails to Trails Conservancy, 2010a; USDOT, 2010c)

Note: ARRA (The American Recovery and Reinvestment Act of 2009 including 3% set-aside for TE); RTP (Recreational Trails Program); SRTS & NTPP (Safe Routes to School and Nonmotorized Transportation Pilot Programs. These programs had their first obligations in FY 2006); STP Other (Surface Transportation Program (STP except TE; includes STP Safety); STP TE (Surface Transportation Program set-aside for Transportation Enhancement Activities); CMAQ (Congestion Mitigation and Air Quality Improvement Program); Other includes: High Priority Projects; National Highway System; Bridge; Interstate Maintenance; Federal Lands Highway Program (primarily Public Lands Highway Discretionary earmarks); Corridor Planning and Development and Border Infrastructure; Transportation, Community, and System Preservation; National Scenic Byways; Ferry Boats; Congressionally-earmarked funds, etc. Prior to 1999, this categories includes the Recreational Trails Program.

5. Impacts of bike paths and lanes on cycling in large American cities

The mounting body of evidence on the health benefits of cycling has led government agencies, public health organizations, and medical journals to advocate more cycling as a way to improve individual health as well as reduce air pollution, carbon emissions, noise, traffic dangers, and other harmful impacts of car use (BMA, 1992; Cavill et al., 2006; CEMT, 2004; Dora and Phillips, 2000; IOTF, 2010; NACTO, 2010; USDHHS, 1996, 2008; USDOT, 1994, 2004). Cities around the world have been implementing a wide range of infrastructure, programs, and policies to encourage more cycling (Alliance for Biking and Walking, 2010; Heinen et al., 2010; Krizek et al., 2009; Pucher et al., 2010a). Most American cities have focused on providing separate bicycling facilities such as off-street bike paths and on-street bike lanes (Alliance for Biking and Walking, 2010; NACTO, 2010; Pucher et al., 1999). Past research suggests that separate cycling facilities are associated with higher cycling levels. There is contradictory evidence on the impacts of different kinds of facilities. Some studies find that bike paths are associated with higher cycling levels, but that lanes are not. Other studies find that lanes are related to more cycling, but paths are not. Most prior research that distinguishes between paths and lanes focuses on only one city per study. Most comparative analysis of different cities is hampered by small sample size—usually fewer than 45 cities.

This report examines the impacts of cycling facilities by using new data on bike lanes and paths in the 100 largest U.S. cities. The League of American Bicyclists and the Alliance for Biking and Walking collected the data for the authors directly from planners, transportation experts, and government officials in each city for the year 2008. Our multiple regression analysis focuses on measuring the differential impacts of bike paths and lanes on cycling levels while controlling for land-use, climate, socioeconomic factors, cycling safety, and geography.

5.1 Determinants of cycling: The role of off-street paths and on-street lanes

Several studies have estimated the impact of bike paths and lanes on cycling levels. Results from aggregate cross-sectional studies indicate that there is a positive correlation between cycling levels and the supply of bike paths and lanes (Dill and Carr, 2003; LeClerc, 2002; Nelson and Allen, 1997; Parkin et al., 2008). Based on a sample of 18 small and large U.S. cities, Nelson and Allen (1997) find that one additional mile of combined bike paths and lanes per 100,000 residents is associated with a 0.069% increase in commuters cycling to work. Based on a sample of 43 large U.S. cities, Dill and Carr (2003) find that each additional linear mile of bike lanes per square mile of city area is associated with an increase of roughly one percentage point in the share of bike commuters, even after controlling for days of rain, automobile ownership, and state spending on walking and cycling.

Analyzing data from the 1990 and 2000 U.S. Census, Barnes et al. (2006) find that increases in bike commute levels in Minneapolis and St. Paul were concentrated around newly constructed bike paths and lanes. Douma and Cleaveland (2009) apply the same methods in their case study analysis of six cities and report that the relationship of bike facilities and cycling levels is mediated by local circumstances, such as network connectivity, bike promotion programs, and location of bike facilities along commuting routes leading to downtown.

Disaggregate, individual-level studies report a preference for separate paths and lanes over cycling in traffic (Abraham et al., 2002; Akar and Clifton, 2010; Dill, 2009; Dill and Gliebe, 2008; Howard and Burns, 2001; Hunt and Abraham, 2007; Krizek et al., 2007). In a study of Calgary, Canada, Abraham et al. (2002) find that cycling along roads is perceived to be two to four times as onerous as cycling on a bike path in a park. Dill and Gliebe (2008) report that

women and inexperienced cyclists in Portland (OR) prefer riding on bicycle paths, lanes, and low traffic volume roads over cycling on busy streets.

Findings on the relative importance of paths compared to lanes are contradictory. Vernez-Moudon et al. (2005) report that household proximity to bike paths in Seattle, WA increases the likelihood to cycle by 20%, but they find no effect for bike lanes. Using a wide range of datasets and methods, Cervero et al. (2009), de Geus et al. (2008), and Dill and Voros (2007) report no positive correlation between bike lanes and cycling levels. By comparison, a Minneapolis, MN study by Krizek and Johnson (2006) reports an increased likelihood of cycling for individuals living within 400m of a bike lane, but no significant impact of bike paths.

Controlling for other determinants of cycling, before-and-after studies show increased levels of cycling after the installation of bike lanes, but report mixed results for bike paths (City of Toronto, 2001; City of Vancouver, 1999; Cohen et al., 2008; Evenson et al., 2005). A revealed preference survey by Dill (2009) finds that cyclists in Portland are willing to increase trip distance and travel time to ride on bike paths compared to shorter, more direct routes that require cycling on roads with motor vehicle traffic. However, a revealed preference study by Aultman-Hall et al. (1998) finds that bike paths in Guelph, Ontario are more likely used by recreational cyclists than commuters.

In short, many studies conclude that there is a significant relationship between cycling facilities and cycling levels, but regression analysis cannot determine the direction of causation. Moreover, regression analysis of cycling levels is almost always cross-sectional, thus limiting inferences about changes over time. Measurements of cycling volumes before and after the installation of specific facilities provide the simplest kind of time-series evidence, but they almost never control for the range of other factors affecting cycling levels. Moreover, most individual level studies focus on one or a few cities and are not representative for the country as a whole. Aggregate studies rely on few observations, such as Nelson and Allen (1997) and Dill and Carr (2003), with samples of 18 and 43 cities, respectively. Thus, all studies of the impacts of cycling facilities have their limitations. Our own study is no exception, but it enables analysis of an extensive new dataset of 100 U.S. cities that permits differentiation between the impacts of bike paths vs. lanes while controlling for a range of other variables.

5.2 Data sources and variables

Our regression analysis investigates the relationship between bike lanes and paths and cycling levels in the largest 100 U.S. cities as determined by population estimates of the 2008 American Community Survey (USDOC, 2009a). The dependent variable—cycling level—is measured in two different ways: (1) percentage of commuters by bicycle—bike mode share—which controls for the number of workers in each city; and (2) the number of bike commuters per 10,000 population, which controls for population size.

5.2.1 Data on cycling levels and bikeway facilities

Data on the share of workers regularly commuting by bicycle was collected from the American Community Survey (ACS) 2006-2008 three-year average sample. Pooling data from the ACS surveys for 2006, 2007, and 2008 increases sample size and improves the reliability of estimates. Ideally, we would have measured cycling rates for all trip purposes, but the ACS data only report information on commuting to work, and the ACS is the only source of comparable travel data for all 100 cities.

Table 4 displays the top ten of the 100 largest U.S. cities based on three measures of bike commute levels. Large cities dominate the list of total bike commuters, while cities in the Midwest, West, and Southwest have the highest share of bike commuters on a per capita basis.

Table 4.

Top Ten of 100 Largest U.S. Cities by Daily Bike Commuting Levels, 2006-2008

Rank	<i>Bike Commuters in 1,000</i>	<i>% of Commuters by Bike</i>	<i>Bike Commuters per 10,000 Population</i>
1	New York City, NY (24.0)	Portland, OR (4.7)	Portland, OR (24.0)
2	Portland, OR (13.2)	Madison, WI (3.9)	Madison, WI (22.2)
3	Chicago, IL (12.8)	Minneapolis, MN (3.5)	Minneapolis, MN (18.9)
4	Los Angeles, CA (12.6)	Boise, ID (3.4)	Boise, ID (17.8)
5	San Francisco, CA (10.7)	Seattle, WA (2.5)	Seattle, WA (14.2)
6	Seattle, WA (8.1)	San Francisco, CA (2.5)	San Francisco, CA (13.5)
7	Philadelphia, PA (7.5)	Sacramento, CA (2.0)	Washington, D.C. (9.9)
8	Minneapolis, MN (6.8)	Washington, D.C. (2.0)	Sacramento, CA (8.9)
9	Washington, D.C. (5.8)	Oakland, CA (1.9)	Oakland, CA (8.8)
10	San Diego, CA (5.3)	Tucson, AZ (1.8)	Denver, CO (8.4)

Source: (USDOC, 2009a)

The League of American Bicyclists and the Alliance for Biking and Walking collected data for the authors on the supply of bike lanes and paths by directly contacting bike planners, transportation officials, and bicycling experts in each city. Data for 10 of the 100 cities were not available even after multiple attempts to obtain the information. In spite of the missing cities, the resulting database for 90 cities is the most current and extensive source of information on the extent of bikeway networks in large U.S. cities.

Cities use different methods for recording the extent of their facilities. To control for that and to ensure the comparability of data among cities, the League of American Bicyclists and the Alliance for Biking and Walking used a uniform definition of bike lanes: centerline miles of roads with bike lanes. In order to be included, bike lanes had to be clearly designated with pavement markings and signage. They exclude shared bus and bike lanes as well as “sharrows” lanes intended for joint use by motor vehicles and bicycles. All 90 responding cities were able to calculate this statistic based on their own data. Bike paths comprised both exclusive off-road facilities for cycling as well as multi-use paths intended for joint use by cyclists, pedestrians, joggers, in-line skaters, and other non-motorized users. In fact, most bike paths in American cities are such multi-use paths, while in Europe, they are usually exclusively for cyclists, probably due to the much higher cycling volumes needed to justify completely separate paths for cyclists (Alliance for Biking and Walking, 2010; Fietsberaad, 2010).

Table 5 shows the extent of the bikeway network for the ten cities with the greatest supply of bike lanes and paths in total and per 100,000 population. On a per capita basis, 9 of the 10 cities with the most extensive bikeway networks were in the West and Southwest of the USA.

Table 5.

Top Ten of 100 Largest U.S. Cities by Supply of Bike Paths and Lanes

Rank	Miles of Bike Facilities		
	<u>Lanes</u>	<u>Paths</u>	<u>Lanes and Paths</u>
1	New York City, NY (440)	Scottsdale, AZ (339)	New York City, NY (666)
2	Phoenix, AZ (349)	New York City, NY (220)	Phoenix, AZ (468)
3	San Diego, CA (312)	Aurora, CO (213)	Scottsdale, AZ (449)
4	Tucson, AZ (306)	Anchorage, AK (204)	San Diego, CA (385)
5	Irvine, CA (242)	Omaha, NE (166)	Tucson, AZ (362)
6	Sacramento, CA (234)	Albuquerque, NM (135)	Sacramento, CA (314)
7	Philadelphia, PA (210)	Phoenix, AZ (118)	Albuquerque, NM (300)
8	San Jose, CA (190)	Colorado Springs, CO (118)	Irvine, CA (287)
9	San Antonio, TX (189)	Austin, TX (117)	Philadelphia, PA (260)
10	Portland, OR (176)	St. Paul, MN (110)	Austin, TX (257)

Rank	Miles of Bike Facilities per 100,000 Population		
	<u>Lanes</u>	<u>Paths</u>	<u>Lanes and Paths</u>
1	Irvine, CA (125)	Scottsdale, AZ (158)	Scottsdale, AZ (210)
2	Reno, NV (73)	Anchorage, AK (73)	Irvine, CA (148)
3	Chandler, AZ (61)	Aurora, CO (71)	Reno, NV (92)
4	Tucson, AZ (57)	Omaha, NE (43)	Aurora, CO (82)
5	Sacramento, CA (52)	St. Paul, MN (41)	Anchorage, AK (76)
6	Scottsdale, AZ (51)	Lincoln, NE (34)	Sacramento, CA (70)
7	Orlando, FL (45)	Henderson, NV (31)	Tucson, AZ (68)
8	Boise, ID (35)	Colorado Springs, CO (30)	Orlando, FL (67)
9	Albuquerque, NM (32)	Albuquerque, NM (27)	Chandler, AZ (66)
10	Portland, OR (32)	Minneapolis, MN (23)	Albuquerque, NM (59)

Source: Data collected for the authors from each city by the League of American Bicyclists and the Alliance for Biking and Walking.

5.2.2 Control variables

In estimating the separate impacts of bike paths and lanes on cycling levels, our multiple regression analysis controls for other determinants of cycling commonly cited in the literature. Previous studies have shown that cycling levels are higher in dense and mixed-use developments with short trip distances and proximity of households to destinations such as offices, stores, and restaurants (Baltes, 1997; Ewing and Cervero, 2001, 2010; Handy, 1996; Moudon et al., 2005; Pucher and Buehler, 2006). We incorporate the impact of land use through a variable measuring population density.

Studies find that a grid-pattern road network increases levels of cycling because short blocks and frequent intersections provide easier bike access and more flexible bicycle route choice to most destinations (Ewing and Cervero, 2010). Our dataset did not include information on intersection density or block size. However, we follow Dill and Carr (2003) by including a

variable measuring the share of housing stock built before 1950, which serves as a proxy for shorter city blocks and a more grid-like street pattern.

Two socioeconomic variables we included were share of students in the population and percent of households without automobile. Studies find that individuals in households with more automobiles are less likely to ride a bicycle, while students are more likely to cycle (Dill and Carr, 2003; Heinen et al., 2010; Pucher and Buehler, 2006). We did not include per-capita income because of its high correlation with car ownership. Moreover, the most important impact of income on cycling levels is via car ownership.

Cycling safety is an important determinant of cycling levels. The causation probably goes in both directions. Several studies confirm that increased cycling safety encourages more people to cycle (Alliance for Biking and Walking, 2010; Fietsberaad, 2006, 2010; Jacobsen et al., 2009; Pucher and Buehler, 2008). Conversely, the concept of 'safety in numbers' proposes that, as more people cycle, it becomes safer because more cyclists are more visible to motorists, and an increasing percentage of motorists are also cyclists, which probably makes them more considerate of cyclists. With increased cycling, there is also more public and political support for more and better cycling facilities. Regardless of which explanation is correct, several studies find significant time-series as well as cross-sectional evidence of 'safety in numbers' (Elvik, 2009; Jacobsen, 2003; Robinson, 2005). In our analysis, we measure safety as cyclist fatalities per 10,000 bicyclists. Reliable cyclist fatality rates are not available at the city level. Cyclist fatalities are rare events, so cities with little cycling have few fatalities and do not collect such data systematically. State fatality rates are available, but they are only rough approximations of differences in urban cycling safety. Nevertheless, the state rates help capture the sharp differences in cycling safety across states: ranging from less than 2 fatalities per 10,000 cyclists in the Alaska, Colorado, Minnesota, and Oregon to over 20 in Alabama (Alliance for Biking and Walking, 2010).

Much precipitation and extremely cold and hot temperatures discourage cycling, while moderate climates encourage cycling (Baltes, 1997; Heinen et al., 2010; Pucher and Buehler, 2006). Our analysis includes a variable measuring the average annual number of days that reach temperatures of over 90°F. We used 30 year average data for each city provided by the National Climatic Data Center (2010). We also analyzed the impacts of two other climate-related variables: annual precipitation levels and number of days below 32°F per year. We did not include them in the final analysis, however, because we found them to have small and statistically insignificant relationships to cycling levels.

Other geographic differences within the USA are measured through a dummy variable flagging cities in the Western Census Region—where cycling levels are higher than elsewhere in the country (USDOD, 2010b)¹. The Western dummy variable is intended to capture possible differences in culture, outdoors orientation, and concern with fitness. It might also reflect the much lower humidity level in the West and Southwest of the USA, especially compared to the East and Southeast. Details on data sources, descriptive statistics, and measurement of variables are listed in Table 3. Our analysis does not control for topography because data were not available for all 100 cities, and it would be difficult to come up with a standardized measure at any rate.

Similarly, it was not possible to include variables measuring the extent and quality of the many other policies and programs that might potentially affect cycling levels (Heinen et al., 2010; Krizek et al., 2009; Pucher et al., 2010a). These measures include, for example, bike

¹ The "West" Census Region comprises the Pacific and Mountain Census Divisions.

parking, bike racks on buses, bike sharing programs, cycling training courses, media campaigns, and educational events (APBP, 2002; Brons et al., 2009; Fietsberaad, 2010; Givoni and Rietveld, 2007; Hegger, 2007; Hunt and Abraham, 2007; Martens, 2007; Netherlands Ministry of Transport, 2009; Noland and Kunreuther, 1995; Taylor and Mahmassani, 1996; TRB, 2005; Wardman et al., 2007). Comparable data for these programs are not available for most of the 100 cities. Even if they were available, multicollinearity would probably prevent their inclusion in the regression equations.

Table 6.
Descriptive Statistics for Variables in the Analysis

Variable	Mean	Median	SD	Cases	Description & Measurement	Source
Bike Share Commuters	0.8	0.6	0.80	100	Percent of workers regularly commuting by bike	ACS, 3 year averages 2006-2008; Alliance for Biking and Walking, 2010
Bike Commuters per Population	3.9	2.6	4.40	100	Daily total number of workers regularly commuting by bike per 10,000 population	
Bike Lane Supply	13.40	7.10	19.3	90	Miles of bike lanes in city per 100,000 population	Data collected from each city individually; Population data from ACS, 2006-2008
Bike Path Supply	13.10	7.90	19.9	90	Miles of bike and shared-use paths in city per 100,000 population	
Population Density	4,768	3,600	3,900	100	City population divided by land area in square miles	Population from ACS 2006-2008; Land Area from U.S. Census, 2000
Age of housing Stock/Road Network Proxy	23.9	15.2	21.50	100	Percent of housing stock built before 1950	U.S. Census, 2000
College Students	9.3	7.7	2.90	100	Percent of total population enrolled in college or university	ACS, 2006-2008
Car Access	12.7	9.7	9.40	100	Percent of households without a motorized vehicle	ACS, 2006-2008
Extreme Weather	54.4	35.5	46.8	100	30 year average of annual number of days above 90 °F	National Climatic Data Center (NCDC), 2009 and 2010
Bike Safety	6.7	5.8	4.10	100	State level data: three year average of bicyclist fatality rate per 10,000 cyclists	Alliance for Biking and Walking, 2010
Geography	0.4	0	n.a.	100	Dummy variable flagging cities in "West" Census Region	U.S. Census Bureau

Sources: (Alliance for Biking and Walking, 2010; National Climatic Data Center, 2010; USDOC, 2009a, b)

5.3 Bivariate relationships

Bicycling levels are positively correlated with both bike paths and bike lanes (see Table 7 last column). Bivariate Pearson's correlations between cycling levels and bike lanes are slightly larger than the correlations between cycling levels and bike paths. Our grouping of cities into quartiles of bike path and lane supply corroborates this bivariate correlation. Cycling levels in cities with the most bike lanes per 100,000 population (4th quartile) are three to four times higher than in cities with the fewest bike lanes (1st quartile). The difference between quartiles is less pronounced for bike paths—with roughly twice as many bike commuters per capita in the 4th compared to the 1st quartile. The table also displays the combined relationship of bicycle paths and lanes per 100,000 population on bike commuting. There is four times as much cycling in cities with the most paths and lanes (4th quartile) as in cities with the least bike path and lane supply (1st quartile).

The coefficients of the control variables have the expected direction. Bicycling levels are higher in cities with higher population density. However, differences in cycling levels between second, third, and fourth quartiles of population density are small. Cycling levels are higher in cities with a larger share of buildings dating from before 1950. Cities with a large percentage of

students have higher levels of bike commuting. Lower levels of car ownership are associated with higher levels of bike commuting, but the bivariate correlation is not statistically significant. Cycling to work is most common in cities in the Western U.S. Census Region, followed by cities in the Midwest and Northeast. Cycling levels in cities in the Southern Census Region are only a third as high as in the West.

As found by earlier studies, extreme weather conditions deter cycling. Our dataset shows that cycling levels are lower in cities with more days per year with temperatures of 90°F or higher. Finally, city cycling levels and state bike fatality rates show a statistically significant negative correlation. The actual relationship might be stronger, but the state data are obviously an imperfect proxy for city cycling safety.

Table 7.
 Bike Commute Levels by Quartile of Independent Variables and Bivariate Pearson’s
 Correlations for the 100 Largest U.S. Cities

	Share of Bike Commuters by Quartile of Independent Variable				Difference Fourth Minus First Quartile	Bivariate Correlation with Share of Bike Commuters
	First Quartile	Second Quartile	Third Quartile	Fourth Quartile		
Bike Lanes per 100,000 pop.	0.4	0.7	0.9	1.3	+0.9**	0.4*
Bike Paths per 100,000 pop.	0.5	0.8	1.0	1.0	+0.5**	0.2**
Bike Paths and Lanes per 100,000 pop.	0.4	0.7	0.7	1.5	+1.1**	0.3**
Population Density	0.4	0.8	0.9	1.0	+0.6**	0.2*
% Housing Stock before 1951	0.5	0.7	0.7	1.6	+1.1**	0.2*
% College Students	0.4	0.5	1.0	1.2	+0.8**	0.4**
% Households without Car	0.7	0.4	0.8	1.2	+0.5**	0.2
Days above 90 °F	1.4	0.6	0.7	0.5	-0.9**	-0.3**
Cyclist Fatality Rate	1.5	0.6	0.6	0.4	-1.1**	-0.5**
	<i>South</i>	<i>Northeast</i>	<i>Midwest</i>	<i>West</i>		
U.S. Geography	0.4	0.8	0.9	1.2	+0.8**	0.3**

	Bike Commuters per 10,000 Population by Quartile of Independent Variable				Difference Fourth Minus First Quartile	Correlation with Bike Commuters per 10,000 population
	First Quartile	Second Quartile	Third Quartile	Fourth Quartile		
Bike Lanes per 100,000 pop.	1.7	3.4	4.6	6.8	+5.1**	0.5**
Bike Paths per 100,000 pop.	2.4	3.7	4.8	5.1	+2.7**	0.4**
Bike Paths and Lanes per 100,000 pop.	2.0	3.2	3.5	7.8	+5.8**	0.5**
Population Density	2.0	4.1	4.4	4.9	+2.9*	0.2*
% Housing Stock before 1951	2.7	3.5	3.6	5.8	+3.1**	0.1
% College Students	1.9	2.4	5.0	6.3	+4.4**	0.5**
% Households without Car	3.4	2.1	3.9	5.9	+2.5*	0.2
Days above 90 °F	7.0	3.0	3.4	2.3	-4.7**	-0.3**
Cyclist Fatality Rate	7.3	2.6	2.7	1.8	-5.5**	-0.5**
	<i>South</i>	<i>Northeast</i>	<i>Midwest</i>	<i>West</i>		
U.S. Geography	2.1	3.3	4.5	5.7	+3.6**	0.4**

** significant at the 95% level; *significant at the 90% level

5.4 Multiple regression analysis

The quartile and correlation analysis presented above only investigate the relationship between cycling levels and each independent variable, one at a time. The multiple regressions presented below examine the impact of bike paths and lanes while controlling for safety, land use, socioeconomic variables, climate, and geography.

We estimated two sets of models. The first model is a log-log Ordinary Least Square (OLS) regression with the natural log of bike commuters per 10,000 population as dependent variable. The second model is a Binary Logit Proportions Model with the share of bike commuters in each city as dependent variable. In both types of models the independent variables are expressed as natural log to assure a more normal distribution of otherwise skewed explanatory variables.

The log-log specification for the first set of models has two advantages. First, it normalizes the skewed independent and dependent variables, thus helping to meet assumptions of the OLS regression. Second, it allows interpreting the regression coefficients directly as

elasticities or percentage changes in cycling levels, which makes the results more intuitive and easier to understand².

Models 1 through 4 in Table 5 present the results of the OLS regression with the natural log of bike commuters per capita as dependent variable. The independent variables of Model 1 have joint significance at the 99% level ($F=16.4$) and account for over 60% of the variability in bike commuters per capita ($\text{Adj. } R^2=0.61$).

All of the variables have the expected signs, but not all are statistically significant, possibly due to high correlations among some of the independent variables. The coefficients indicate that both bike lanes and bike paths per 100,000 population are significant predictors for bike commuters per 10,000 population. A 10% greater supply of bike lanes per 100,000 population is associated with a 2.5% greater number of bike commuters per 10,000 population. Similarly, a 10% greater supply of bike paths per 100,000 population is associated with a 2.6% higher level of bike commuters per 10,000 population. A t-test comparison shows that the coefficients for bike lanes and paths per 100,000 population are not statistically significantly different from each other at the 95% level.

Cycling safety has a statistically significant impact as well. A 10% higher bike fatality rate per 10,000 cyclists is associated with a 2.3% lower number of bike commuters per 10,000 population. A 10% higher share of students in the population is associated with 10% more bike commuting. Compared to other parts of the USA, cities in the Western Census Region of the country average 56% more bike commuters per 10,000 population. The coefficient for the number of days per year with temperatures of 90°F or higher is not statistically significant, but that does not take humidity into account. As noted earlier, the dummy variable for West might indirectly reflect that factor.

The coefficients for the control variables population density, share of housing stock built before 1950, and share of households without vehicles have the expected signs, but are not statistically significant at the 90% level in Model 1. Tests for multicollinearity do not indicate any serious problem for the model as a whole. For example, Variance Inflation Factor (VIF) yields scores for individual variables below 4.0 and a score of 2.3 for the overall equation. Tolerance values are all above 0.25. However, moderate to strong correlations (Pearson's $r=0.5$ and higher) between the three variables may prevent them from jointly entering the model significantly (Kennedy, 2003).

Model 2 includes a composite variable (derived by factor analysis³) that measures the joint effect of population density, age of the housing stock, and automobile access on cycling levels. The composite variable is an attempt to overcome the potential multi-collinearity problems among those three variables in the first model. The composite variable yields high values for older cities with higher population density and a larger share of residents without a car score. Cities mainly built after 1950, with lower population density, and few residents without cars yield low values. The cities in our dataset that score highest on this factor are New York

²Seven cities reported 0 miles of bike lanes and bike paths. These cities would have been lost in our models, because the natural logarithm of 0 is not defined. Thus, we followed the standard procedure of transforming the bike lane and path per 100,000 population variable by adding 1, which yields a log value of 0 for the 7 cities. We also estimated the model without this transformation, with only 83 cities. Significance, sign, and magnitude of coefficients and goodness of fit were very similar to the results of the models presented in this paper.

³Our principal component analysis resulted in one factor for all three variables—based on the Kaiser Criterion of a cut-off for Eigenvalues of individual components that are larger than 1.0 and a graphical scree test. We also confirmed that our analysis truly resulted in one factor only by attempting to force different kinds of rotations (Varimax and Oblimin) and by lowering the Eigenvalue cut-off criterion to 0.5.

City, San Francisco, Chicago, and Washington, DC. Cities that scored lowest are Anchorage, Scottsdale, and Irvine. Thus, the composite variable appears to yield the expected classification of cities by land use.

Model 2 suggests that the composite variable is significantly related to bike commuters per 10,000 population. Interpretation of the combined factor is difficult, but the positive sign of the coefficient indicates that older cities with higher population density and a lower car ownership are likely to have more bike commuting. Goodness of fit measures and the direction, magnitude, and significance of the model coefficients are almost identical in Models 1 and 2. Most importantly, the coefficients for the key explanatory variables of interest—bike paths and bike lanes—remain the same in both versions.

Prior research suggests that bike paths and lanes contribute to lower cycling fatality rates (CEMT, 2004; Fietsberaad, 2010; Pucher and Buehler, 2008). In our dataset of 90 cities, bivariate Pearson's correlations between the supply of bike facilities and fatality rates are below 0.3, and tests for multicollinearity do not indicate any serious problem. One reason may be that state cyclist fatality rates are imperfect proxies for actual city fatality rates. Models 3 and 4 replicate the regressions in Models 1 and 2, but exclude the variable measuring fatality rates. Compared to Models 1 and 2, the coefficients for bike paths, the Western Census Region, share of students in the population, and the composite variable are slightly larger in Models 3 and 4. However, t-tests show that the coefficients for each variable are not statistically different across the models. For models 1 to 4, the coefficients for bike paths and lanes are significant, positive, and not statistically different from each other at the 95% level.

Table 8.
Multiple Regression Analysis of Bike Commuters per 10,000 Population and Bike Commute Share

	OLS Regression of ln(bike commuters per 10,000 population)				Binary Logit Proportions Model for Share of Bike Commuters ¹	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ln(bike lanes per 100,000 population)	0.248 (3.40)**	0.247 (3.43)**	0.236 (3.22)**	0.235 (3.25)**	0.329 (4.10)**	0.294 (3.45)**
ln(bike paths per 100,000 population)	0.262 (3.21)**	0.266 (3.31)**	0.312 (4.06)**	0.315 (4.19)**	0.176 (2.46)**	0.215 (2.95)**
ln(fatality rate per 10,000 cyclists)	-0.226 (1.66)*	-0.226 (1.66)*			-0.380 (3.23)**	-0.393 (2.82)**
Geography (1= Western Census Region)	0.563 (2.61)**	0.545 (2.66)**	0.713 (3.61)**	0.694 (3.73)**	0.493 (2.90)**	0.408 (2.48)**
ln(percent of students in population)	1.026 (4.13)**	1.030 (4.21)**	1.080 (4.34)**	1.086 (4.43)**	0.911 (4.29)**	0.864 (3.53)**
ln(percent hh w/o car)	0.213 (1.02)		0.220 (1.05)		0.265 (1.58)	
ln(population density)	0.108 (0.93)	0.314† (3.71)**	0.130 (1.12)	0.353† (4.29)**	-0.052 (0.50)	0.408† (3.53)**
ln(percent of housing stock built prior to 1950)	0.108 (1.07)		0.128 (1.26)		0.260 (3.28)**	
ln(number of days above 90 °F)	-0.001 (0.01)	-0.004 (0.06)	-0.034 (0.45)	-0.039 (0.54)	-0.026 (0.46)	-0.010 (0.19)
Constant	-3.636 (3.22)**	-2.070 (2.93)**	-4.383 (4.19)**	-2.588 (4.04)**	-8.586 (9.95)**	-7.464 (11.04)**
Observations	90	90	90	90	90	90
Adjusted R ²	0.61	0.62	0.60	0.61	<i>Pseudo LL (Intercept):</i> -9.049	-9.050
F-Statistic	16.37 0.000**	21.54 0.000**	17.71 0.000**	24.15 0.000**	<i>Pseudo LL(Full):</i> -3.395	-3.403
					<i>Pseudo R² (McFadden):</i> 0.62	0.62

* significant at 10%; ** significant at 5%. Absolute value of t/z statistics in parentheses.

† variable created by factor analysis, measuring the combined effect of population density, car access, and age of housing stock

¹Logistic Regression estimated via STATA GLM (Generalized Linear Models) with Logit Link Function and Binomial Distribution

To verify the robustness of our results we estimated a second set of models with the share of bike commuters in each city as dependent variable. For this dependent variable, an OLS regression might estimate values beyond the range of actual possible values of the bike share of commuters (0 to 1.0). To address this issue, we followed Xing, Mokhtarian, and Handy (2010) by estimating a Binary Logit Proportions Model for bicycle mode share. This estimation technique transforms the dependent variable into the ‘log of odds’ of the bike share of commuters and approximates Maximum Likelihood estimation (Xing et al., 2010). Transformation of the dependent variable and nonlinear estimation of the model assure that predicted mode shares lie between 0 and 1.0.

Models 5 and 6 display the results of the Binary Logit Proportions regressions. Standard test statistics suggest the models are a good fit. For example, McFadden’s Pseudo R^2 equals 0.62. All coefficients have the expected signs. As for Models 1 through 4, the coefficients for bike paths and lanes are again significant and positive, even after using a very different estimation technique. The point estimates for lanes are larger than for paths in these models, but as in Models 1 through 4, the two coefficients are not statistically significantly different from each other. Population density and car availability in Model 5 are not significant individually, but the composite land-use variable in Model 6 indicates joint significance. Results from Models 1, 2, 5, and 6 are similar. In particular, both specifications and estimation techniques yield statistically significant positive coefficients for the two main variables of interest: bike paths and bike lanes. Models 1 and 2 are probably preferable since they are simpler and easier to interpret intuitively.

5.5 Limitations

Our cross-sectional study cannot assess the impact of bike paths and lanes on cycling levels over time. Moreover, the analysis relies on aggregate, city-level data, which mask variations within cities, among neighborhoods, and individuals. The results suggest a statistically significant relationship between bike paths and lanes and cycling at the city level, but results do not permit to draw conclusions about individual travel behavior. As in any regression analysis, none of our models can prove causality, although the significant associations we measured are consistent with the hypothesis that bike paths and lanes encourage more cycling.

Totally aside from the inherent limitations of any regression analysis, there is important endogeneity in our models. Cycling levels and the extent of the bikeway network almost certainly affect each other simultaneously. In this paper, we have focused on measuring the impact of bike paths and lanes on cycling levels. But rising cycling levels can generate demand for more cycling facilities. Thus, increased supply may induce more demand, just as growing demand evokes increased supply. Endogeneity and simultaneous equations bias are unavoidable problems in our regression analysis because the key explanatory variables—bike paths and bike lanes—are also a function of the dependent variable. Similarly, as discussed earlier, cycling safety is a function of cycling levels, just as cycling levels are a function of cycling safety. Including fatality rates in the equation adds to the endogeneity problem. Models 3 and 4 in Table 5 avoid that particular source of endogeneity by removing the cycling fatality rate from the model. That adjustment, however, risks potential bias in the estimated coefficients due to possible underspecification of the model.

In an attempt to model the simultaneous dependencies among the variables, we experimented with several alternative instrumental variables to estimate a simultaneous equation system using two-stage regressions. Unfortunately, none of the available variables in the dataset

were sufficiently exogenous or strong enough to serve as instrumental variables. They failed on one or more criteria required for statistically robust and valid instrumental variables: (1) underidentification (Anderson LM statistic), (2) weak identification (Cragg-Donald Wald F statistic), (3) overidentification (Sargan statistic), (4) or robust instrument inference (Anderson-Rubin Wald test).

The best instrumental variable in the dataset was city land area—since area is fully exogenous and correlated with the total number of bike commuters and the extent of bike paths and lanes. The technical estimation procedure of two-stage least squares (2SLS) required combining the length of bike paths and lanes into one variable, because there was only one instrumental variable available. Moreover, the model was re-specified with the log of total number of bike commuters as dependent variable and the log of total length of bike paths and lanes as regressor. This model satisfied most of the statistical tests for appropriateness of the instrument, but failed to reject the null hypothesis of the Sargan test for overidentification—which casts some doubt on the validity of the instrument.

Estimating a 2SLS equation with this imperfect instrumental variable yields results for the bikeway variable that are similar to those for an OLS regression (see Table 9). In the 2SLS model, bike paths and lanes are statistically significant predictors of cycling levels—even after accounting for endogeneity bias. Another instrumental variable we examined—measuring city population per bicycling advocacy group member—yielded similar results: statistical tests point to weak instrumentation, but bike paths and lanes retain their significant and positive coefficient.

Table 9.
Results of 2SLS and OLS Multiple Regression Analysis of Bike Commuters

Dependent Variable: ln(Number of Bike Commuters)		
	Model 1: 2SLS	Model 2: OLS
ln(bike lanes and paths per 100,000 population)	0.891 (6.34)**	0.667 (9.05)**
ln(fatality rate per 10,000 cyclists)	-0.028 (0.18)	-0.079 (0.52)
Geography (1= Western Census Region)	0.442 (1.89)*	0.610 (2.84)**
ln(percent of students in population)	0.559 (2.05)**	0.669 (2.53)**
ln(percent hh w/o car)	0.767 (3.57)**	0.695 (3.31)**
ln(percent of housing stock built prior to 1950)	0.072 (0.62)	0.087 (0.75)
ln(number of days above 90 °F)	-0.088 (0.96)	-0.046 (0.52)
Constant	0.127 (0.12)	0.959 (1.01)
Observations	90	90
Adjusted R ²	0.66	0.67
F-Statistic	18.79 0.000**	26.78 0.000**

* significant at 10%; ** significant at 5%.

Absolute value of t statistics in parentheses.

Aside from methodological limitations, the data collected by the League of American Bicyclists and the Alliance for Walking and Cycling do not distinguish between the specific nature and quality of different types of lanes and paths. For example, bike lanes have varying widths, markings, signage, coloring, and intersection treatments. They can be on the right or left side of the street, or even between traffic lanes. Moreover, cities have different policies about maintaining bike lanes and keeping them clear of illegally parked or stopped motor vehicles. Similarly, bike paths vary in their width, pavement, design, and especially in the extent to which they are shared with other users such as pedestrians. Some mixed-use paths provide suggestive markings to help separate cyclists from pedestrians, but most do not. Some bike paths require cyclists to dismount when crossing a road, while others stop automobiles at crossings and give cyclists the right of way. None of the cities in our dataset provided detailed information on these sorts of variations in the types of bike paths and lanes. Better statistics on cycling facilities would enable more precision in the analysis of their impacts.

It is also important to note that the very term ‘bike path’ is a bit of a misnomer in the USA. Most bike paths included in U.S. statistics are simply multi-use paths shared with pedestrians (Alliance for Biking and Walking, 2010; Pucher et al., 1999). In contrast, bike paths in most northern European cities are completely separate facilities for the exclusive use of cyclists (Fietsberaad, 2006, 2010; Pucher and Buehler, 2008; Pucher et al., 2010a). Thus, bike

paths in the USA might have less impact on cycling levels than the higher-quality, fully separate bike path in the Netherlands, Germany, and Denmark.

Whatever the shortcomings of our regression models, our estimated equations are consistent with the hypothesized direction of the relationship of the explanatory variables and cycling levels. Without exception, all the coefficients have the expected signs, and most are statistically significant. Our attempt to refine the basic models to overcome the statistical problem of endogeneity and simultaneous equations bias suffered from weak instrumental variables. Nevertheless, the adjusted 2SLS models yielded positive and statistically significant coefficients for bike paths and lanes, even after attempting to control for endogeneity.

5.6 Conclusion

Over the last 20 years, many American cities have focused on building bike paths and lanes to increase cycling levels (Alliance for Biking and Walking, 2010; Thunderhead Alliance, 2007). This analysis of a new dataset confirms that cities with a greater supply of bike paths and lanes have higher cycling levels—even after controlling for other determinants of cycling. The findings are in line with earlier studies that point to the importance of separate facilities (Dill and Gliebe, 2008; Dill and Voros, 2007; Krizek et al., 2007; Moudon et al., 2005; Nelson and Allen, 1997). Stated and revealed preference surveys indicate that cyclists prefer separation from traffic. Some studies also suggest a preference of bicycle paths over on-street bike lanes.

Most cities build both bike lanes and paths. Combining both facilities can provide cyclists with route and facility choice. Prior research has shown that some cyclists prefer bike lanes, while others favor bike paths. Some studies found that commuters prefer on-street bike lanes over paths because lanes follow the road network and provide more direct routes (Aultman-Hall et al., 1998). Our results suggest that bike paths and lanes have a comparable relationship with cycling levels for the commute. Indeed, bike paths are usually located in parks or along bodies of water and can provide a more pleasant, less stressful environment with greater separation from motor vehicle traffic. However, if designed well, paths can also provide crucial connections across city blocks—allowing cyclists to leave the road network and take a short cut. For example, the Minneapolis Midtown Greenway is the backbone of the city's bike network. It traverses the City of Minneapolis (MN) south of downtown and connects many other lanes and paths serving the rest of the city. Similarly, the mixed-use paths on either bank of the Willamette River in Portland (OR) provide crucial connections to other lane and path facilities in the bike network.

The multiple regression coefficients in all variants of the models estimated in this paper indicate inelastic demand with respect to the supply of cycling facilities. A one percent difference among cities in supply of bike paths and lanes is associated with much less than a one percent difference in cycling levels. This highlights the need to complement cycling paths and lanes with the many other programs and policies to encourage cycling. These include intersection modification and priority traffic signals for cyclists, bike parking, coordination with public transportation, traffic education and training, and bike promotion and public awareness campaigns. Perhaps even more important, American cities have almost entirely failed to adopt measures to restrict car use. Many of these measures reduce the speed and convenience of car use while encouraging cycling (Fietsberaad, 2010). Traffic calming of residential neighborhoods is the most obvious example, but there are many others. Successful Dutch, Danish, and German cycling cities have lower speed limits and impose a wider range of turn and one-way restrictions on cars. Car-free zones prohibit motor vehicle traffic altogether. Most successful European

cycling cities have implemented this entire gamut of policies (Pucher and Buehler, 2008). The less comprehensive pro-bike policy package might help explain the much lower levels of cycling in American cities.

6. Analysis of cycling trends and policies in nine large North American cities

The aggregate national data presented earlier in this paper hide the variation among cities in cycling levels, safety, and policies. Virtually all infrastructure measures and programs are actually implemented at the local level, even if funding comes partly from the federal or state level. Thus, it is crucial to examine what is happening at the local level and how that varies among cities.

6.1. Choice of case studies

The remainder of this paper examines cycling developments in six large cities in the USA (Chicago, Minneapolis, New York, Portland, San Francisco, and Washington) and three large cities in Canada (Montréal, Toronto, and Vancouver). The nine cities cover a broad range of locations, climates, topographies, demographics, density, history, and urban structure. We have restricted our case studies to large cities because that is where most Americans and Canadians live. Towns such as Davis, CA and Boulder, CO are more bike-oriented than most of the large cities we chose, but they are atypical and small. Moreover, in recent years, the most innovative cycling developments have been in large cities (ABW, 2010). The nine case study cities comprise the full range of policies and programs being implemented in North American cities to encourage more cycling and make it safer.

We explicitly excluded large cities with extremely low levels of cycling such as Dallas, Detroit, Houston, Kansas City, and Memphis, all of which have less than 0.3% of commuters by bike (ABW, 2010; USDOT, 2009a). Not only do these cities have very low levels of cycling, but they have done very little to increase cycling. Thus, case studies of them would mainly entail listing all the things they do not do, which offers little guidance to cities seeking to promote cycling.

6.2. Data sources

Our case study analysis relies on information from four categories of sources:

- Federal, state/provincial, and local government statistics and reports providing information for specific cities (such as the Census, traffic injury databases, and travel surveys)
- Transportation sections of each city's official website, which generally include long-range bike plans, cycling statistics, bike maps and route planning, updates on infrastructure expansion, and guides to the cycling programs and activities in each city
- Websites of national cycling organizations and research centers, such as the League of American Bicyclists (LAB, 2010), Alliance for Biking and Walking (ABW, 2010), Pedestrian and Bicyclist Information Center (PBIC, 2010), and National Center for Walking and Bicycling (NCBW, 2010)
- Unpublished information and feedback provided directly by bike planners, city planning departments, transportation departments, and cycling organizations in each of the nine cities.

6.3. Descriptive statistics for case study cities

Table 10 summarizes some key demographic and climatic information about the nine case study cities. The population size of the cities themselves ranges from 8.4 million in New York to 361,000 in Minneapolis, a ratio of about 20-to-1. Population density of the cities also varies greatly: from 10,576 per km² in New York to 1,584 per km² in Portland. Studies suggest that larger cities tend to have lower cycling levels due to their greater land area, longer trip distances, and more extensive public transport systems (Heinen et al., 2010). The higher densities of larger cities might be expected to facilitate cycling due to the concentration of many origins and destinations, but density might also discourage cycling due to high traffic levels on roads and limited space for bikeway facilities.

The nine cities also vary considerably along two dimensions that probably affect cycling: percentage of college students and car-free households. Several studies show that college students are among the most likely to cycle, so that cities with high shares of students tend to have higher bike mode shares (Dill and Carr, 2003; Heinen et al., 2010; Nelson and Allen, 1997). Similarly, low rates of car ownership are also associated with higher rates of cycling. Among the nine case studies, the percentage of college students ranges from about 5% in Toronto to 12% in Minneapolis. The percentage of car-free households ranges from 15% in Portland to 54% in NYC.

Several studies find that climate and topography can affect cycling levels (Baltes, 1997; Dill and Carr, 2003; Heinen et al., 2010; Pucher and Buehler, 2006). The nine case studies cover a wide range of climates with considerable variation in temperature and precipitation. Most studies suggest that high precipitation levels discourage cycling. Very cold weather as well as hot weather may also discourage cycling. As shown in Table 4, there is a ratio of 2-to-1 in the amount of precipitation per year, ranging from 126cm in New York to 57cm in San Francisco. The average number of days with temperature below freezing (0°C/32°F) ranges from 164 in Montréal and 154 in Minneapolis to only one in San Francisco. The average number of days with temperature of 32.2°C (90°F) or higher ranged from 36 in Washington to none in Vancouver. Of all the cities, San Francisco has the least precipitation as well as the mildest climate, with few days that are very hot or very cold. There are no comparable statistics for humidity, which raises the heat index and further discourages cycling during hot summers. Washington probably has the most humid summers of our case study cities.

Similarly, we could not find standardized statistics on topography, but San Francisco is the hilliest of the nine cities, followed by Vancouver and Portland, while Chicago, Minneapolis, and New York are all quite flat. While cycling in some cities such as Minneapolis or Chicago is favored by their flat topography, their harsh climates would be expected to discourage cycling. Conversely, cities with hilly topography, such as San Francisco, have very mild climates that favor cycling. One might expect a city such as Portland, which is both hilly and rainy, to have little cycling, but in fact, it has the highest cycling rates in the USA, as noted below.

Table 10.

Demographic and climatic characteristics of nine case study cities.

	Population (1,000)		Population per km ²	Percent of University Students	Percent of Car-free Households	Annual Precipitation (cm)	Annual Days ≤ 0° C	Annual Days ≥ 32.2° C*
	City	Metro						
New York	8,364	19,007	10,576	7.4	54.2	126	77	17
Chicago	2,741	9,570	4,633	7.6	25.9	92	129	17
Toronto	2,503	5,113	3,972	5.2	-	83	107	10
Montréal	1,621	3,636	4,439	10.7	-	105	164	9
San Francisco	809	4,275	6,600	9.4	29.3	57	1	3
Washington	592	5,358	3,700	10.8	35.5	100	68	36
Vancouver	578	2,117	5,039	10.1	-	120	46	0
Portland	560	2,207	1,584	8.1	14.8	94	40	11
Minneapolis	361	3,230	2,524	11.9	18.4	75	154	14

Notes: Precipitation and temperature data are 30-year averages from 1970 to 2000

* ≥ 30° C for Canadian cities

Sources: (*City of Toronto, 2010c; City of Vancouver, 2008; Environment Canada, 2010; McGill University, 1998; Statistics Canada, 2010; USDOC, 1980-2000, 2009a, 2010a*).

6.4. *Variation in cycling levels and trends*

Over the past two decades, cycling has increased considerably in all nine cities. Figure 3 shows trend data from the U.S. and Canadian Censuses on the share of commuters who bike to work, the only comparable statistics for all cities. The most impressive growth has been in Portland, where the bike mode share rose more than 5-fold between 1990 and 2009, from 1.1% to 5.8%, the highest rate of cycling of any large North American city. Chicago quadrupled its bike mode share (from 0.3% to 1.2%) and San Francisco tripled its bike share (from 1.0% to 3.0%). All the other cities at least doubled their bike share of work commuters. These large increases in cycling in the case study cities contrast sharply with the slow growth in the bike share of work commuters for each of the two countries as a whole (0.4% to 0.6% in USA; 1.1% to 1.3% in Canada). Thus, our case studies stand out as being far more successful than other American and Canadian cities at promoting cycling—all the more reason to examine in detail what they have been doing to promote cycling.

While cycling has grown in all nine cities, there are large differences in cycling levels, ranging in 2009 from only 0.6% in NYC to 5.8% in Portland, a ratio of almost 10-to-1. There is also great spatial variation in cycling levels within each metropolitan area, with central cities having much higher cycling rates than their corresponding metro areas (see Figure 4). The difference between bike mode share in the central city and the overall metropolitan area ranges from about 4-to-1 in Washington and Minneapolis to 3-to-1 in Portland and about 2-to-1 in most of the other cities. All nine of the cities show the same pattern of cycling rates being much higher in the central cities.

Even within the cities themselves, there is much spatial variation. Cycling rates tend to be higher in older, gentrifying neighborhoods near the city center. Such bike-friendly neighborhoods are usually located within close cycling distance of university campuses and downtown jobs and feature a mixture of residential and commercial land uses. For example, the bike mode share for work commutation reaches almost 2% in Lower Manhattan and northwestern Brooklyn but falls to only 0.2% in Staten Island and the outer portions of Brooklyn, Queens, and the Bronx (Pucher et al., 2010b). The bike mode share exceeds 10% in several of the central neighborhoods of both Toronto and Vancouver compared to less than 1% in most of their outlying residential districts (City of Toronto, 2010b; City of Vancouver, 2009, 2010). The Inner Northeast and Inner Southeast sections of Portland have bike commute mode shares of 13%, over six times higher than the 2% bike share in outlying districts such as Outer East Portland (City of Portland, 2010a). In short, all the cities exhibit much higher bike mode shares in central vs. outer neighborhoods, with yet lower cycling rates in suburbs.

Aside from the Census data shown in Figures 3 and 4, most of the case study cities have their own sources of information on cycling levels, either through travel surveys or cordon counts of cyclists at particular locations. Without exception, they also confirm strong growth in cycling, especially since 2000. For example, the annual survey by the City of Portland (2008b) reports almost a tripling in bike mode share of work commuters from 3% in 2000 to 8% in 2008. Similarly, cordon counts for the four main Willamette River bridges in Portland show almost a tripling in cycling volume over the same period (178% increase) (City of Portland, 2008a). Screenline counts of bike trips to and from the Manhattan CBD indicate a tripling (220% increase) between 2000 and 2009, far higher than the 51% increase in bike commuting in New York reported by the U.S. Census for the same period (NYCDOT, 2010a; Pucher et al., 2010b; USDOT, 1980-2000, 2010a). Although most of the case study cities have such cordon counts or

travel surveys, we are not reporting them in detail because they use different methodologies, trip definitions, geographic coverage, and timing and are thus incomparable.

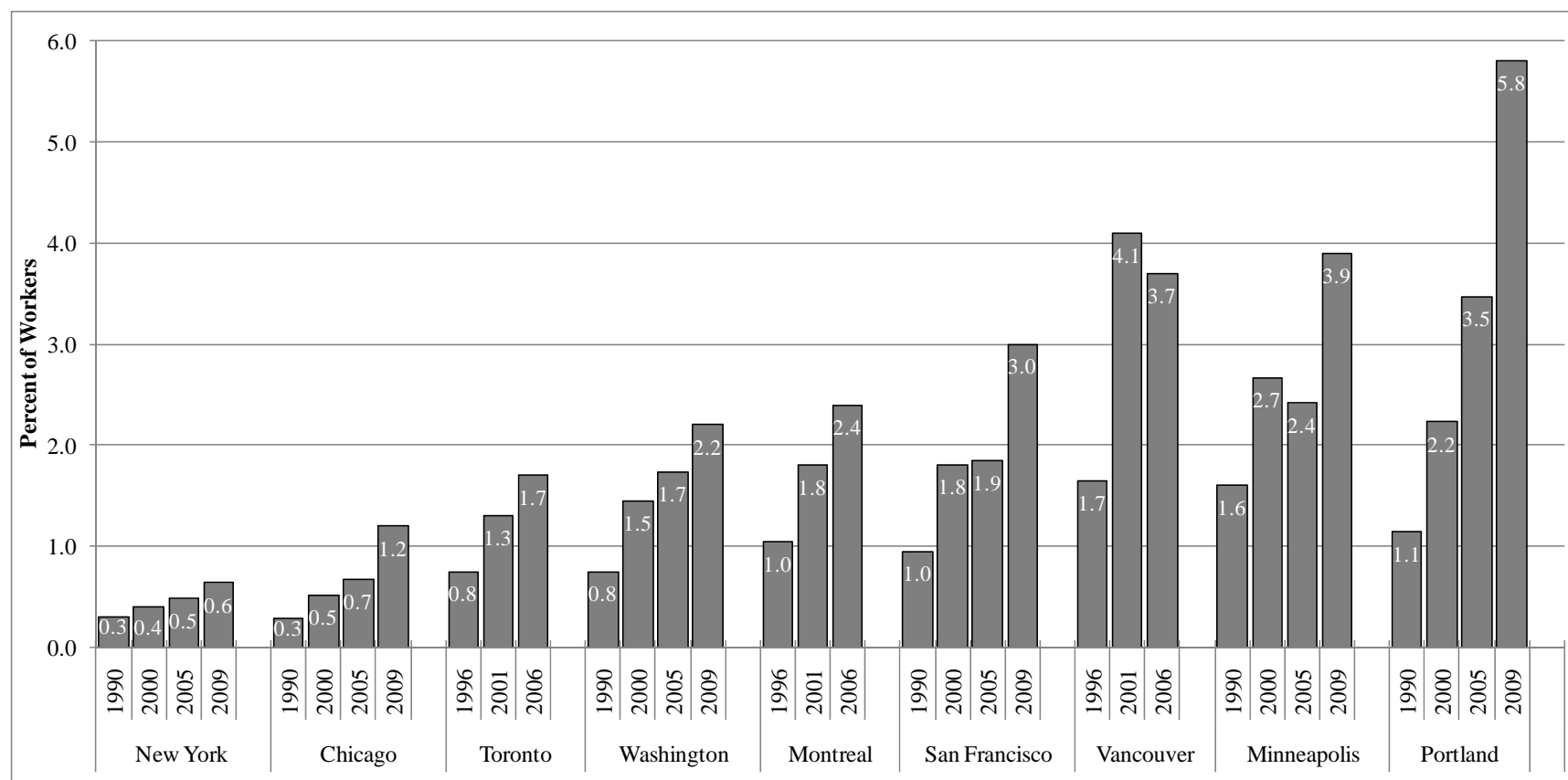


Fig. 3. Trend in Share of Workers Commuting by Bike in Large North American Cities, 1990-2009. Sources: (Statistics Canada, 1996-2010; USDOC, 1980-2000, 2010a)

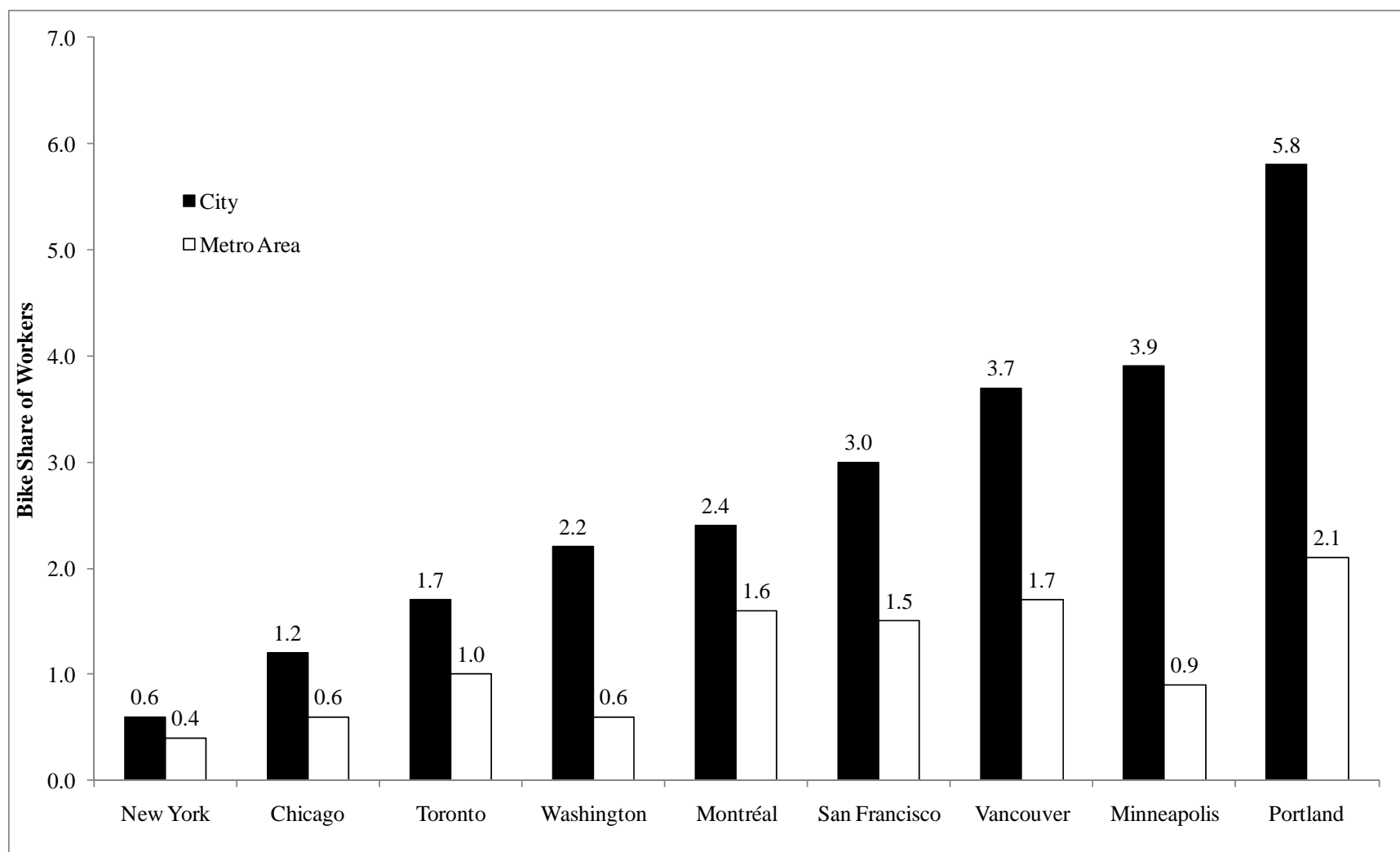


Fig. 4. Bike Share of Workers in U.S. and Canadian Cities and Metropolitan Areas, 2006/2009. Sources: (Statistics Canada, 2010; USDOT, 2010a).

6.5. Gender differences

As noted earlier, cycling is slightly less male-dominated in Canada than in the USA: 29% vs. 24% female share of bike commuters for the countries as a whole. For the specific case study cities, women make up 35%-37% of bike commuters in Vancouver, Montréal, and Toronto, higher shares than in any of the six U.S. cities (Figure 5). Washington and Portland come closest at 34% and 33%, respectively. New York has, by far, the lowest percentage of women bike commuters, only 20%, perhaps due to the relatively high cyclist fatality rate there compared to the other cities. Data are not available for comparison of other socioeconomic characteristics of cyclists in the cities. The U.S. and Canadian Censuses only report on work commuters, thus distorting both age and income characteristics.

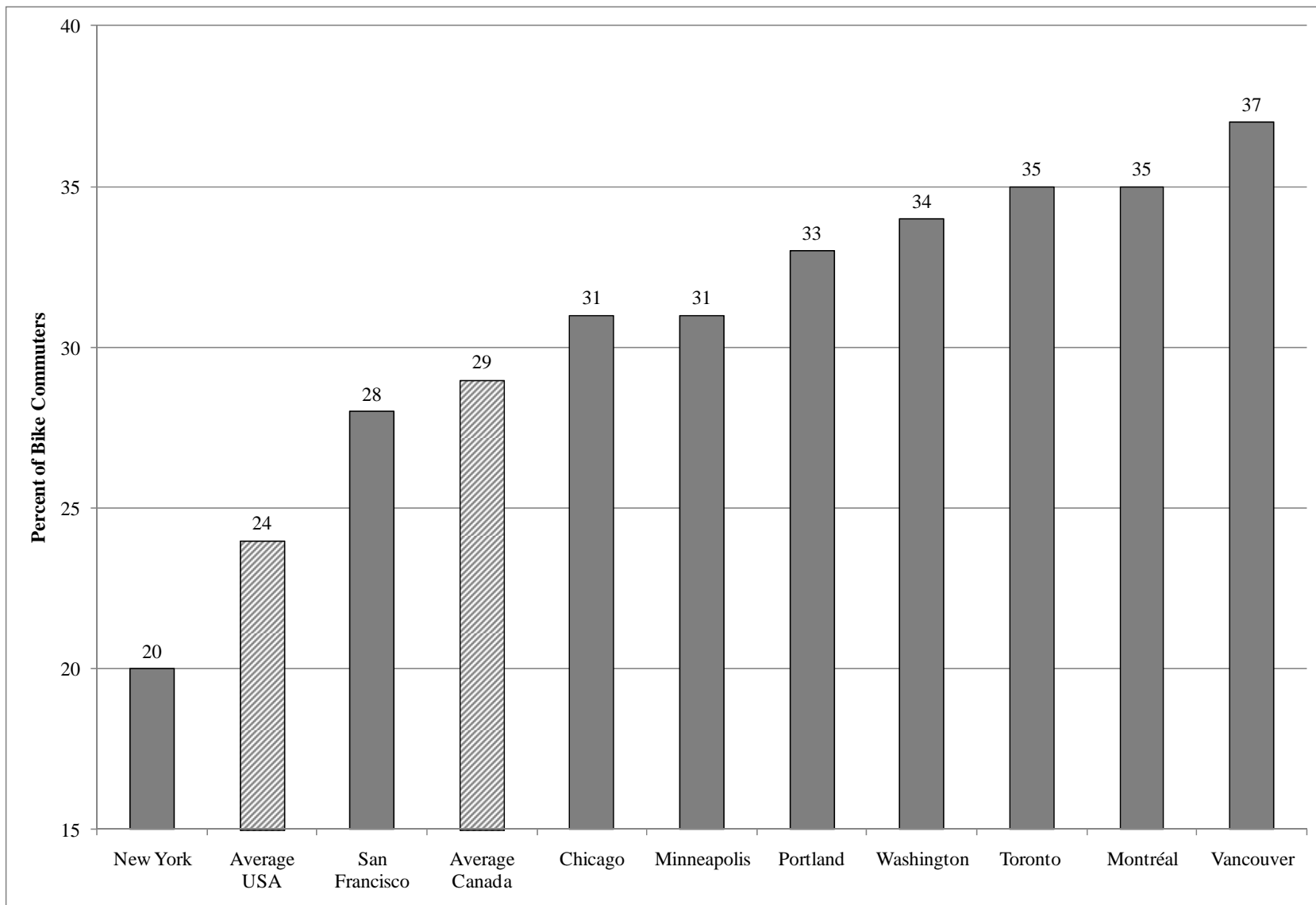


Fig. 5. Percent of Female Bike Commuters in U.S. and Canadian Cities, 2006/2008. *Sources: (Statistics Canada, 2010; USDOC, 2009a).*

6.6. Cycling safety

Figure 6 shows the cyclist fatality rate per 10,000 daily commuter cyclists in each of the nine cities, ranging from 8.58 in NYC to 0.93 in Vancouver. Because the number of cyclist fatalities fluctuates from year to year, we calculated the average number of fatalities over the past five years for each city. For the exposure rate, we used the number of daily commuter cyclists because those data are derived from very large Census surveys that can be disaggregated to the city level. There is no other source of nationally comparable and statistically reliable data on cycling levels in each city in either country. The problem with this methodology is that the number of fatalities in the numerator is due to cycling for all trip purposes, while the number of cyclists in the denominator only includes work commuters. Despite its limitations, the indicator provides the only feasible adjustment for different levels of cycling, and thus different exposure rates across the nine cities.

Figure 6 plots the different cycling fatality rates against the bike mode shares of the nine cities. The relationship appears to be consistent with the principle of safety in numbers (Elvik, 2009; Jacobsen, 2003). Cities with highest bike mode shares have the safest cycling, and cities with the lowest bike mode shares have the most dangerous cycling. It is likely that causation runs in both directions: safer cycling encourages more cycling, and more cycling encourages greater safety. A closer look at Figure 6 reveals that city size might also be a determining factor. New York and Chicago, the largest cities, have the lowest bike mode shares and, by far, the most dangerous cycling. Vancouver, Portland, and Minneapolis are the smallest of the nine cities and have the safest cycling. Thus, city size may also play an important role in affecting cycling safety, perhaps due to denser motor vehicle traffic. It is not clear to what extent differences in fatality rates among cities are really due to differences in cycling rates (via safety in numbers) or differences in city size or some other factor, such as better infrastructure. At any rate, Figure 6 highlights the vastly different levels of cycling safety in the nine cities, with a 9-to-1 ratio of cyclist fatality rates between New York and Portland, almost exactly matched in reverse by the 10-to-1 ratio of bike mode shares in the same two cities.

It is difficult to compare non-fatal injury data across cities because each city collects its injury data in a somewhat different way, using different definitions and methodologies. Yet cyclist injuries in the USA outnumber fatalities by at least 100-to-1 (CDC, 2010). Thus, only examining fatalities presents an incomplete picture of overall cycling safety.

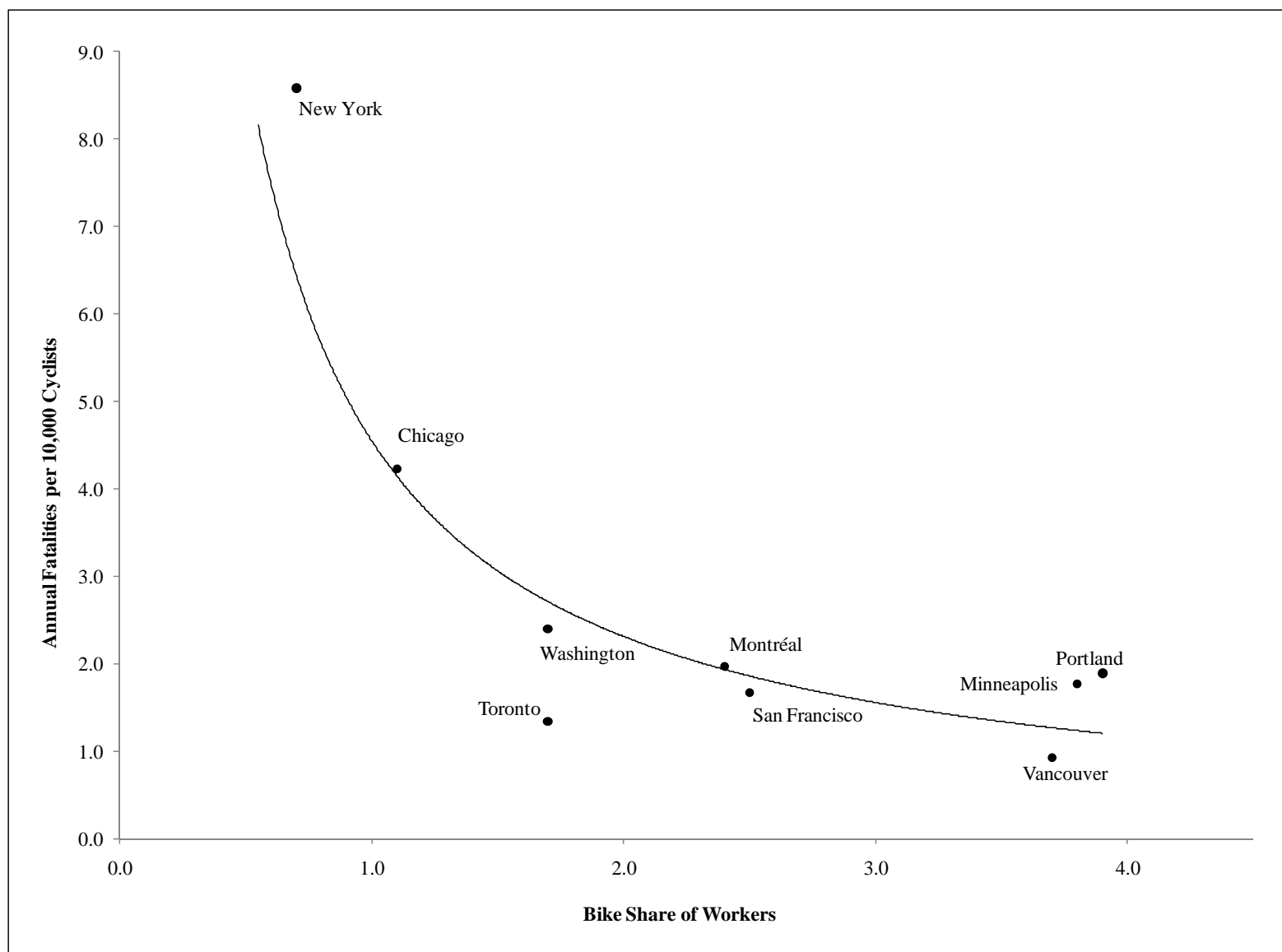


Fig.6. Bike Share of Workers and Average Annual Fatality Rate per 10,000 Cyclists, 2004-2009. Sources: (USDOC, 2009a, 2010a); and injury data collected by the authors directly from the case study cities.

6.7. Cycling policies and programs

All the case study cities have been implementing a wide variety of infrastructure, programs, and policies to promote cycling. There is considerable variation among the cities, however, both in the overall extent of their efforts and in the specific mix of measures.

6.7.1. Expansion and improvement of bikeway networks

Without exception, the focus of cycling policy in all nine cities has been the expansion and improvement of bikeway facilities, including on-street bike lanes, on-street bike paths (cycle tracks), and off-street bike paths. As shown in Figure 7, Minneapolis and Portland have, by far, the largest supply of bike lanes and paths per capita of any of the cities, with 70km and 73km, respectively, per 100,000 population. At the other end of the spectrum, New York and Chicago have the fewest bike lanes and paths per capita, at 8km and 9km per 100,000 residents, respectively. That is only about an eighth the supply in Minneapolis and Portland. Nevertheless, New York almost tripled the extent of bike lanes and paths between 2000 and 2010 (from 274km to 670km), and Chicago has more than doubled its network (from 121km to 253km) (CDOT, 2010; NYCDOT, 2010a). The largest increase on a per capita basis has been in Minneapolis, which added 29km per 100,000 population over the ten year period (City of Minneapolis, 2008, 2010b).

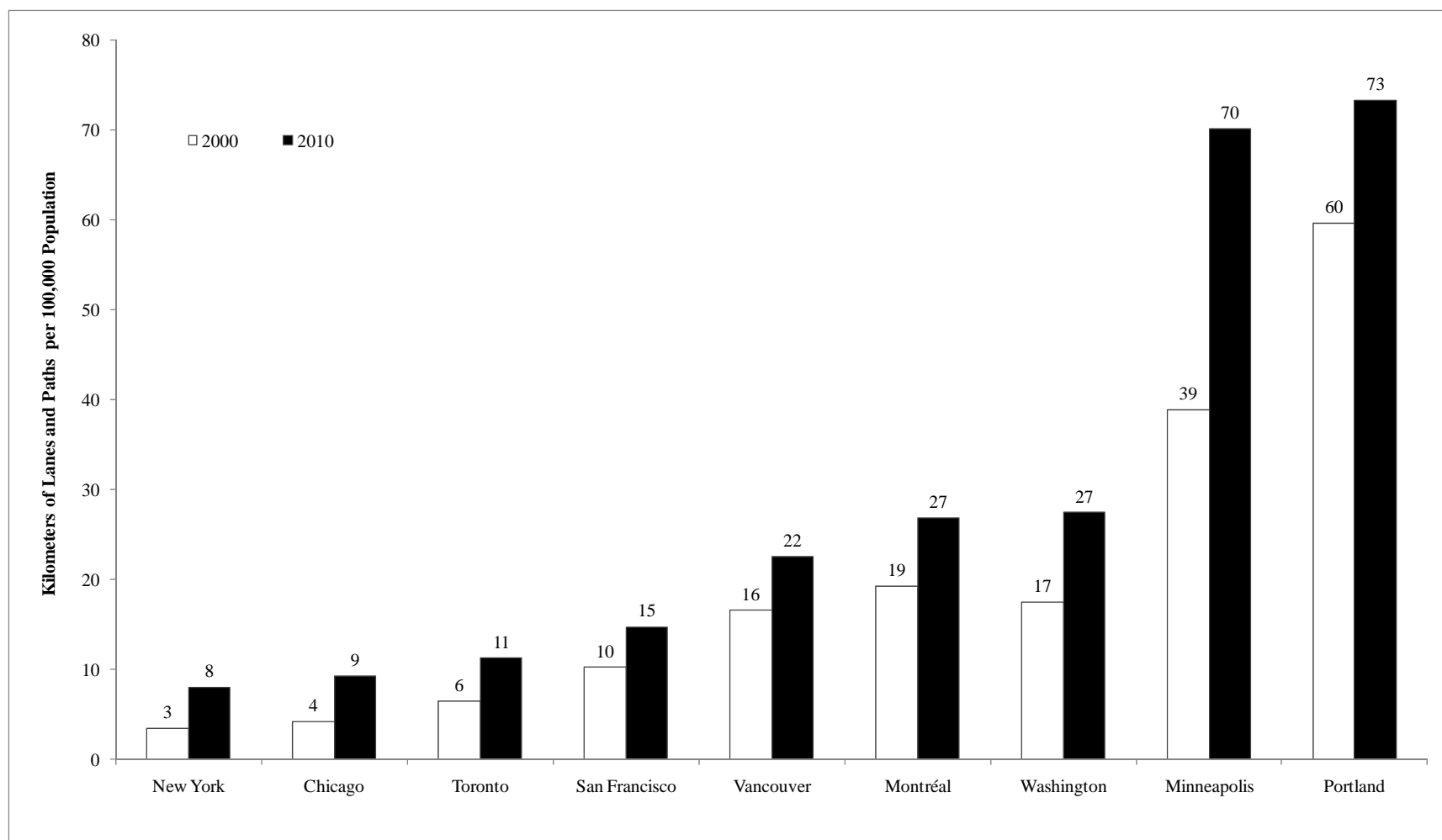


Fig. 7. Trend in Bike Paths and Lanes per 100,000 Population in Nine Large North American Cities, 2000-2010. *Source: Information collected by the authors directly from the case study cities.*

As shown in Table 11, the bike lane and path networks in some of the cities such as Chicago, New York, and Portland consist mainly of on-street bike lanes while in other cities, such as Montréal and Minneapolis, bike paths make up more than half of the overall network (with paths including physically separated on-street cycle tracks in this table). In almost all the cities, however, recent investment has been mainly in on-street bike lanes, probably due to higher cost and space requirements of off-street paths. Between 2000 and 2010, for example, km of bike lanes increased about twice as much as km of bike paths in Toronto and Portland, three times as fast in Washington and Minneapolis, and ten times as fast in Chicago and New York (CDOT, 2010; City of Minneapolis, 2010a; City of Portland, 2008a, 2010b; City of Toronto, 2010a; DDOT, 2005, 2010; NYCDOT, 2010a). The two largest cities, in particular, have opted for bike lanes instead of bike paths. Bike paths tend to serve mainly recreational purposes, while on-street bike lanes generally are more useful for reaching practical destinations and offer a more direct route (Pucher et al., 2010a). Thus, the increased focus on bike lanes might also reflect a shift toward promoting daily, utilitarian cycling and away from the previous emphasis on recreational cycling.

Table 11.
Supply of bike lanes and paths and bike parking in nine case study cities, 2008.

	Bike Lane and Path Network				Bike Parking	
	On-Street Lanes (km)	Off-Street Paths (km)	On-Street Lanes and Off-Street Paths (km)	Kilometers of Bike Paths and Lanes per 100,000 Population	Bike Parking Spaces	Bike Parking Spaces per 100,000 Population
New York	454	216	669	8	6,260	221
Portland	291	119	411	73	4,059	725
Montréal	107	328	435	27	13,000	802
Toronto	113	168	281	11	32,200	1,286
Minneapolis	116	137	253	70	16,600	4,599
Chicago	185	68	253	9	30,720	1,121
Washington	72	90	162	27	6,249	1,056
Vancouver	60	70	130	26	n.a.	n.a.
San Francisco	69	50	119	15	3,773	466

Source: Information collected by the authors directly from the case study cities.

Cycle tracks, which are typical in northern Europe, are now being installed in some North American cities. Unlike regular bike lanes, they are on-street bike paths separated by physical barriers from motor vehicle traffic. Montréal was the first city in North America to install such cycle tracks, which are bi-directional in Montréal and located on one side of the street (75km in 2010) (Pucher and Buehler, 2006, 2007; Ville de Montréal, 2010). New York was the first U.S. city to introduce cycle tracks, partly as response to the serious problem of motor vehicles blocking bike lanes. As of 2010, there were 16km of cycle tracks on 10 streets, featuring innovative traffic signals that reduce conflicts between cyclists and turning motor vehicles at intersections (NYCDOT, 2010a). There are also cycle tracks on three streets in Washington, two streets in Portland, and on two bridges and one street in Vancouver.

New York, Portland, San Francisco, and Vancouver have been painting some of their bike lanes bright green, blue, or red to enhance visibility and increase cycling safety, especially

where conflicts between cars and bikes are most problematic. New York and Portland have installed buffered bike lanes (City of Portland, 2010b; NYCDOT, 2010a). Unlike cycle tracks, they provide no physical barriers from cars but offer some separation from motor vehicles via a diagonally striped lane between the bike and car lanes.

Many of the cities have also been installing bike boxes with advance stop lines for cyclists at key intersections, about 3-5 meters ahead of the stop line for cars, thus enhancing cyclist visibility and safety. New York has taken the lead, with 215 bike boxes in 2010, almost always connected to on-street bike lanes (NYCDOT, 2010a). In the same year, there were 20 bike boxes in Vancouver, 17 in Portland, 6 in Minneapolis, and 2 in San Francisco and Washington (City of Minneapolis, 2010a; City of Vancouver, 2010; DDOT, 2010; SFMTA, 2009).

Although the recent focus has been on expanding bike lanes, off-street bike paths are often the most heavily used and highest profile cycling facilities. Off-street paths provide the most separation from motor vehicle traffic and the highest level of comfort and perceived safety for most cyclists (Pucher et al., 2010a). Most bike paths in North America are, in fact, multi-use paths shared with pedestrians and located in parks or along rivers, lakes, or harbors, and mainly used for recreational cycling. All nine of the case study cities provide such paths, and they generally are the best known and most popular of the cycling facilities: e.g., the Hudson River Greenway in New York; the Midtown Greenway in Minneapolis; the Willamette River Esplanade paths in Portland; the Seaside Greenway and Central Valley Greenway in Vancouver; and the Lakefront Trail in Chicago.

Traffic-calmed residential streets can serve as convenient, comfortable, and safe bike routes, even without any special bike facilities. Many Dutch, Danish, and German cities, for example, impose speed limits of 30km/hr (19mph) or lower on most residential streets, often accompanied by infrastructure modifications such as street narrowing, chicanes, traffic circles, speed humps, median islands, curb extensions, raised intersections and crosswalks, special pavement, diverters, and mid-block street closures with pass-throughs for bikes (Pucher and Buehler, 2008). Vancouver has been at the forefront of traffic calming in North America. It has reduced speed limits to 30-40 km/hr (19-25mph) on many residential streets and reinforced those legal limits through extensive redesign of streets (City of Vancouver, 2009; TransLink, 2010). Vancouver has focused on providing safe and convenient bike routes on low-volume, traffic-calmed streets instead of building extensive systems of bike lanes and paths. Chicago, Portland, San Francisco, and Toronto also have some traffic calmed neighborhoods, but not nearly as many as Vancouver (CDOT, 2010; City of Portland, 2010a; City of Toronto, 2010b; SFMTA, 2008).

Bicycle boulevards are a modification of traffic-calmed streets specifically designed to facilitate cycling. Special pavement markings and signage reinforce bicycle priority on such streets, which includes right of way when riding through most intersections (i.e. stop signs for traffic crossing bike boulevards), and special bike traffic signals to cross arterials. Various traffic calming devices—such as traffic circles, median refuges, and curb extensions—are used to encourage lower motor vehicle speeds and discourage through traffic. The legal speed limit is also reduced. In Vancouver, the speed limit on bike boulevards is 30km/hr (19mph), the same as for traffic calmed streets in Europe. Portland and Minneapolis permit 40km/hr (25mph), which is typical in American cities for reduced speed districts such as near schools. In 2010, there were 129km of bike boulevards in Vancouver, 58km in Portland (with another 30km planned and

funded), and 16km of bike boulevards in Minneapolis (City of Minneapolis, 2010a; City of Portland, 2010b; City of Vancouver, 2010).

Most of the case study cities have been experimenting with innovative measures such as cycle tracks, bike boxes, buffered bike lanes, bike boulevards, bike traffic signals, and bike routes on traffic calmed neighborhood streets. Nevertheless, the main approach of most North American cities in recent years has been the provision of unprotected, on-street bike lanes, supplemented by off-street multi-use paths intended mostly for recreational uses.

6.7.2. Bike parking

As shown in Table 11, the nine case study cities vary widely in the amount of bike parking provided in 2010, from only 221 spaces per 100,000 residents in New York to 4,599 in Minneapolis, about twenty times as much. Even without controlling for population size, New York falls far short of Toronto and Chicago, each of which has five times as much bike parking as New York, although they are much smaller cities. Only Portland and San Francisco have less total bike parking than New York, but on a per capita basis, they have more than twice as much. Moreover, the bike parking in New York is lacking in quality, with no secure public bike parking anywhere in Manhattan.

The supply of bike parking has been increasing in all nine of the case study cities. Even New York expanded bike parking by more than 10-fold between 1996 and 2009, from 600 to 6,100 spaces and is planning to provide additional bike parking spaces in each of the coming years through their CityRacks program (NYCDCP, 2009; NYCDOT, 2010b). Chicago, Minneapolis, and Toronto have been expanding public bike parking in sidewalk racks by about 1,000 additional racks each year, thus further widening their lead over other cities in total bike parking (Bike Walk Twin Cities, 2008; CDOT, 2010; City of Minneapolis, 2010a; City of Toronto, 2010b). Portland has been especially innovative at installing so-called “bike corrals”, on-street bike parking converted from one or two car parking spaces. As of 2010, Portland had over 61 such bike corrals, each with a capacity of 10-20 bikes, providing 1,098 parking spaces in total (City of Portland, 2010b). The corrals have been attracting customers for local businesses, prompting even more requests to the city to convert on-street car parking to bike corrals. Except for New York, the case study cities have also been providing more long-term parking in bike lockers or bike stations, often located near transit stops, as described in the following section.

In addition to the increased supply of public bike parking, all of the case study cities now have laws that require the private provision of bike parking in both commercial and residential buildings (City and County of San Francisco, 2010; City of Chicago, 2009; City of Minneapolis, 2009; City of Portland, 2010b; City of Toronto, 1999; DDOT, 2010; NYCDCP, 2009; Ville de Montréal, 2008). Vancouver, San Francisco, Toronto, and Portland were the first cities to implement such bike parking ordinances, but the other case study cities have followed their lead in recent years. Although they vary from city to city, the requirements generally involve either a minimum percentage of bike parking relative to car parking (e.g., Chicago and Washington) or a minimum number of bike parking spaces per residential unit, per 1,000 ft² of commercial space, or per 10,000 ft² of general floor area of retail stores, sports facilities, community centers, etc. Bike parking requirements for private parking garages are generally based on the size of the garage, with bike parking often set as a percentage of car parking spaces. City ordinances in Portland, Minneapolis, San Francisco, Toronto, and Vancouver also include requirements or incentives to provide lockers and showers, which facilitate bike commuting to work.

In sum, all nine of the case study cities have greatly increased their supply of public bike parking since 2000, mostly in sidewalk racks, while requiring significant levels of bike parking in both residential and commercial buildings. Just as car parking is essential to car use, bike parking is essential to cycling. Thus, the recent expansion of bike parking is an important measure to encourage more cycling in North American cities.

6.7.3. Integration with public transport

With the sole exception of New York, the case study cities have made impressive progress at integrating bicycling with public transport (Pucher and Buehler, 2009). As shown in Table 12, most of the cities have equipped 100% of their buses with bike racks. Only New York and Montréal have no racks at all on their buses. Most of the rail systems in the nine cities permit bikes on board except during peak hours on weekdays. Except for New York, rail systems in the case study cities have vastly improved bike parking at stations by providing racks for short-term parking and bike lockers for long-term parking. The Chicago Transit System has been a leader in integrating bike racks into the stations themselves to increase shelter, convenience, and security (CTA, 2009). San Francisco and Washington, however, have been the leaders in providing secure bike lockers at most stations. Overall, the metro/subway and regional rail systems in Chicago (6,720 spaces) and San Francisco (6,472 spaces) provide the most bike parking at their stations, with Washington a distant third (3,250 spaces). New York again takes last place, with no bike parking at all provided by its extensive subway system and major bus, train, and ferry terminals, although the NYC Department of Transportation provides racks on sidewalks near a few key stations (Pucher and Buehler, 2009).

Table 12.
Supply of bike parking at transit stations and share of buses with bike racks, 2008.

	Parking at Transit Stations				Bike-Transit Integration
	Racks	Lockers	Spaces in Bike Stations	Total	Percent of Buses with Bike Racks
Chicago	6,420	0	300	6,720	100
San Francisco	3,703	2,110	659	6,472	100
Washington	1,800	1,300	150	3,250	100
Toronto	1,771	114	180	2,065	90
Montréal	1,500	0	0	1,500	0
Vancouver	660	400	0	1,060	100
Portland	350	320	0	670	100
Minneapolis	271	226	0	497	100
New York*	0	0	0	0	0

Sources: (APTA, 2008; Pucher and Buehler, 2009); and information collected by the authors directly from the case study cities.

Note: Table shows parking for entire regional rail systems and not just the central city.

*The NYC subway system does not directly provide any bike parking at its rail stations, but the city provides some sidewalk parking near some stations. Those sidewalk parking spaces are included in Table 5. The Long Island Railroad and Metro-North Railroad provide some parking at suburban stations, but were not able to provide any data on the number of spaces.

Bike stations are the most recent development in bike-transit integration, providing secure, sheltered bike parking, usually with an attendant, as well as bike rental and repair services. Bike stations are usually sited adjacent to a public transport terminal or key rail station. Chicago has the largest bike station, with 300 spaces, but the San Francisco Bay Area has five bike stations with a total of 659 spaces (CDOT, 2010; SFMTA, 2010). In 2009, Washington and Toronto opened up bike stations next to their main railroad terminals (both called Union Station), with 150 and 180 bike parking spaces, respectively (City of Toronto, 2010b; DDOT, 2010). Several of the case study cities are planning additional or expanded bike stations in the coming years.

6.7.4. Bike sharing programs

Following the boom in bike sharing programs worldwide, four of the case study cities now have bike sharing systems (DeMaio, 2009; Shaheen et al., 2010). Montréal's BIXI bike sharing is North America's largest, by far, with 5,000 bikes, 400 stations, and over a million rides in 2009 (BIXI Montréal, 2010). Washington's SmartBike started in 2008 with 120 bikes and 10 stations, but will soon be expanded to 1,100 bikes and 114 stations and renamed Capital Bikeshare (Capital Bikeshare, 2010; SmartBike DC, 2010). In 2010 Minneapolis inaugurated Nice Ride Minnesota, a bike sharing system with 700 bikes and 65 stations (City of Minneapolis, 2010a). B-Cycle started operations in Chicago in 2010 with 100 bikes and 6 stations (Chicago B-Cycle, 2010). Bike sharing is scheduled to start in Toronto in mid-2011 with BIXI Toronto, which will feature 1,000 bikes and 80 stations (BIXI Toronto, 2010).

The available evidence indicates that bike sharing programs in Europe have encouraged more cycling as well as improved coordination of cycling with public transport (DeMaio, 2009; Ecoplan, 2010; Pucher et al., 2010a; Shaheen et al., 2010). Thus, the rapid expansion of bike sharing in North America may provide further impetus to the growth of cycling.

6.7.5. Training and education

All of the case study cities have some sort of bike training programs for children as well as adults, but they all fall far short of the comprehensive bike training and traffic education programs in most German, Dutch, and Danish schools (Pucher and Buehler, 2008). Unlike northern Europe, cycling training programs in North America are offered in only a small percentage of schools, thus reaching a limited number of children.

Thanks to \$612 million in Federal funding from SAFETEA-LU, 6,489 schools in all 50 states have been participating in the Safe Routes to School Program (SRTS). Coordinated by state departments of transportation, the program supports both infrastructure improvements (such as sidewalks, crosswalks, bike paths, and better signage) and education and enforcement efforts to improve conditions for children walking and cycling to school (PBIC and FHWA, 2010). This is the most important initiative for walking and cycling education in the USA for decades, but it reaches less than 7% of the 98,706 primary and secondary schools in the country (NCES, 2010).

All of the U.S. case study cities have schools taking part in the SRTS program. In Minneapolis, for example, 10 of 66 schools participate, but only 700 schoolchildren took part since SRTS is voluntary, and it is up to the parents whether or not to participate (Bike Walk Twin Cities, 2008). Similarly, 25 of 155 schools in Portland participate, reaching 2,250 students (City of Portland, 2010c). In short, the SRTS programs around the USA are a promising first step but need to be expanded to reach more children.

There are many other cycling training programs in the case study cities, often coordinated with community outreach, such as the Bicycling Ambassador programs in Toronto, Chicago, Minneapolis, and Portland, which send well-trained cyclists into neighborhoods throughout their cities to promote cycling and offer bike training (CDOT, 2010; City of Minneapolis, 2010a; City of Portland, 2010a; City of Toronto, 2010b). CAN-BIKE courses are offered in most of Canada (including Vancouver and Toronto) for a wide range of age groups, skill levels, and purposes. Local cycling organizations often offer cycling training courses in cooperation with the League of American Bicyclists, which trains instructors for such courses throughout the USA. Many courses target specific groups such as children, women, older adults, and recent immigrants, who have special needs. In addition to courses, there are bike camps, rodeos, races, and festivals for children.

Some of the case study cities have made a special effort to educate motorists about cyclist rights and their legal responsibility to avoid endangering cyclists. All nine cities have “share the road” campaigns of some sort. Chicago has been a leader on this front, requiring “share the road” instruction in high school driver education classes as well as for all taxi and bus drivers (CDOT, 2010). The states of California, Illinois, Minnesota, New York, and Oregon have added questions to their driver license exams to highlight the responsibility of motorists to respect the rights of non-motorists. Portland employs plainclothes police to catch motorists guilty of endangering cyclists, and then requires the offending motorists to take a special “share the road” safety class (City of Portland, 2010b). Chicago, Minneapolis, Portland, San Francisco, and Washington provide their police with special training on cyclist rights. Putting police on bikes helps convey the perspective of cyclists, and again, Chicago is in the lead, with 306 full-time equivalent police on bike, followed by San Francisco, with 89 (ABW, 2010; CDOT, 2010; SFMTA, 2010). By comparison, relations between police and cyclists are highly confrontational in New York, as documented in a report by the NYC Department of City Planning, with many cyclists accusing the police of harassment, mistreatment, and ignoring the needs of cyclists (NYCDCP, 2005; Pucher et al., 2010b).

6.7.6. Information and promotional programs

All nine cities distribute free printed bike maps as well as interactive, on-line versions that permit trip planning. The Cycling Route Planner developed by the University of British Columbia for Metro Vancouver is especially impressive, allowing cyclists to choose routes with the shortest distance, least traffic, least pollution, most vegetation, fewest hills, or most separation from motor vehicle traffic (Su et al., 2010; UBC, 2010). But all of the cities have bike route planners of some sort, often integrated with Google Maps. Most city departments of transport have extensive websites offering a wide range of information on cycling routes, parking, safety, training, special events, recent and proposed projects (CDOT, 2010; City of Minneapolis, 2010a; City of Portland, 2010b; City of Toronto, 2010b; City of Vancouver, 2010; DDOT, 2010; NYCDOT, 2010a; SFMTA, 2010; Ville de Montréal, 2010).

There are Bike-to-Work days and/or months in all nine of the cities as well as Bike-to-School days in some of the cities, coordinated with the Safe Routes to Schools programs mentioned earlier. The case study cities offer a wide range of group bike rides and races, bike festivals and art shows, food and wine tours by bike, and fundraising rides for special causes. Portland leads with over 4,000 rides, races, festivals, and special cycling events per year, including the Naked Bike Ride, which averages over 5,000 participants, and the Bridge Ride, which had 18,500 participants in 2010 (Birk and Roberts, 2008; City of Portland, 2010a; Maus,

2010). The other cities have fewer but similar large group rides: DC Bike in Washington, with almost 10,000 participants; Bike the Drive in Chicago, with about 20,000 participants; and the Five-Borough Bike Tour in NYC, with over 30,000 riders.

Ciclovías are an important development of recent years. An increasing number of cities throughout the world have been closing down parts of their street network to motor vehicle traffic on selected weekends (Sarmiento et al., 2010). Cycling, walking, and other non-motorized modes can use the car-free streets for recreation and physical activity, encouraged by a wide range of educational and fun events. Four of our case study cities have established ciclovías since 2008. The ciclovía in New York is called Summer Streets and attracts over 150,000 cyclists and pedestrians on the three Saturdays in August when it is held (ABW, 2010; NYCDOT, 2010a). Ciclovías are called Open Streets in Chicago, Sunday Parkways in Portland, and Sunday Streets in San Francisco. Participation in those three cities ranges from 15,000 to 50,000 per ciclovía, and the number of ciclovías has been increasing each year. Unlike some group bike rides, ciclovías are designed to appeal to all age groups and skill levels.

In addition to organized rides and officially sanctioned ciclovías, there are Critical Mass rides, which started in San Francisco in 1992 and eventually spread to over 300 cities worldwide, including most of the other case study cities (Blickstein and Hanson, 2001). Critical Mass rides often involve thousands of riders, usually meeting on the last Friday evening of the month at a pre-arranged place but without a predetermined route, and then proceeding spontaneously through the city streets. It is not entirely clear what role Critical Mass has played in encouraging cycling, but it has engendered a vibrant cycling subculture in some cities (Blickstein and Hanson, 2001; Pucher et al., 1999). Critical Mass rides attracted tens of thousands of riders in New York as well until a police crackdown in 2004, with massive arrests and confiscation of bikes.

6.7.7. Advocacy and policy implementation

Cycling advocacy organizations have played a key role in cycling promotion in all of the case study cities, sometimes even more important than the city departments of transportation. Some cities have several cycling organizations, but the most important in our case studies are the Active Transportation Alliance in Chicago (ATA, 2010; Bike Walk Twin Cities, 2008; BTA, 2010; SFBC, 2010; TA, 2010; TCU, 2010; VACC, 2010; VC, 2010; WABA, 2010). These cycling organizations disseminate information about the benefits of cycling to generate public and political support, and they have actively lobbied for more funding for cycling programs and infrastructure. They help organize and publicize many of the cycling events and group rides in their cities. They also provide useful information for cyclists and sometimes offer bike training programs in conjunction with their city departments of transport and the League of American Bicyclists.

San Francisco probably has the strongest bike advocacy in North America, with the most members, funding, and staff per capita. For example, the San Francisco Bicycling Coalition has 16 times as many members per capita as New York's Transportation Alternatives (1,316 vs. 85 per 100,000 population), six times as many full-time equivalent advocacy staff per million population (10.5 vs. 1.8), and six times as much advocacy funding per capita (\$1.35 vs. \$0.24) (ABW, 2010). Most of the other cities fall between these two extremes.

Comprehensive, long-range bike plans have been crucial in almost all of the case study cities for guiding overall strategies to increase cycling, coordinating a range of programs, and phasing infrastructure investments over time so they are most effective (CDOT, 2006; City of Minneapolis, 2010b; City of Portland, 2010a; City of Toronto, 2010b; City of Vancouver, 2009;

DDOT, 2010; NYCDOP, 1997; SFMTA, 2009; TPB, 2006; Ville de Montréal, 2008). These plans set overall goals and lay out in detail the measures that will be taken to increase cycling. They also provide a look back at recent trends in cycling levels and cycling safety, and recap what has been done so far. But the most important issue has been the funding and actual implementation of those plans.

Strong leadership by charismatic and/or powerful individuals has been crucial to the implementation of pro-bike policies and programs. Mayor Sam Adams of Portland, Transportation Commissioner Janette Sadik-Khan of New York, and Mayor Richard Daley of Chicago have been avid supporters of cycling and key to advancing cycling interests in their respective cities. But even the most committed of politicians depends on the coordinated efforts of NGOs, city departments of transport, talented bike planners, and public relations experts to garner the necessary public and political support. The story of cycling policy implementation is somewhat different in each city, but in all nine of the case study cities, it has required the complementary efforts of many different individuals and interest groups.

An analysis of the political and institutional process of cycling advocacy and implementation of pro-bike policies is beyond the scope of this report. Readers interested in this important issue can consult three recent books, which provide in-depth case studies of cycling policy implementation in several cities, including four of our case study cities: Chicago, New York, Portland, and San Francisco (Birk, 2010; Mapes, 2009; Wray, 2008).

6.8. Case study highlights and lessons

Table 13 lists four policy highlights for each of the nine case study cities, summarizing some of the special aspects of cycling policies and programs in each city. As promised at the outset of this report, all nine of the cities have indeed been implementing innovative measures to increase cycling, but each city has a somewhat different mix and focus.

Portland does almost everything, but it is most notable for its bike boulevards, dense bikeway network, innovative bike corrals, large number of cycling events, and lively bike culture. Minneapolis has an extensive system of off-street bike paths, the most bike parking per capita of any city, and offers an impressive adaptation of cycling to cold, snowy winters. Vancouver has been a model of traffic calming, bike boulevards, and bike-transit integration. San Francisco has been at the vanguard of bike culture in the USA for two decades, leading the way in bike advocacy and cyclist rights as well as bike-transit integration. Montréal has North America's largest and oldest network of cycle tracks as well as the largest bike sharing system. Washington has the first bike sharing program in the USA, excellent bike-transit integration (including a bike station), and an extensive mixed-use trail network that extends into the entire region. Toronto stands out for its bike parking and pioneering role in bike training and community outreach with the bicycling ambassador program. Chicago has led the way in bike-transit integration, bike parking, community outreach, and enforcement of cyclist rights.

New York is a special case. Not only is New York by far the largest of the case study cities, but it has the most mixed record on cycling policies and accomplishments. New York has built the most bikeways since 2000 and has been especially innovative in its use of cycle tracks, buffered bike lanes, bike traffic signals, bike boxes, and sharrows. Yet New York has almost completely failed in the important areas of bike-transit integration and cyclist rights and falls far short on bike parking and cycling training. Moreover, the refusal of New York's police to protect bike lanes from blockage by motor vehicles has compromised cyclist safety (Pucher et al., 2010a).

New York and Chicago had the same bike mode share in 1990 (0.3%), but by 2009 Chicago's rate was twice as high as New York's (1.2% vs. 0.6%). The much slower growth in cycling in New York is instructive. It emphasizes the need to implement a coordinated package of complementary policies. That was also the main conclusion of a recent international review of the entire range of infrastructure, programs, and policies to increase cycling (Pucher et al., 2010a). The review found that individual measures, such as the extensive bikeways built in New York since 2000, help promote cycling, but that they have limited impact unless supported by many other kinds of programs and policies. Portland is the American city that comes closest to implementing a truly comprehensive, well-integrated, long-term package of infrastructure, programs, and policies to promote cycling. Portland's success is evident in the numbers, with a 6-fold increase in cycling levels since 1990, compared to a doubling in New York.

Table 13.

Policy highlights in the case study cities.

Portland	Tightly connected bike network with access to bike facilities within three to six blocks from anywhere in the city. Extensive network of bike boulevards with traffic calming and priority for bicycles. Lively bike culture, including bike education, promotion, and fun events such as Ciclovias (up to 25,000 participants). Regulations require new or reconstructed roadways to include bike facilities.
Minneapolis	Most bike parking per capita in North America. Annual dedicated cost sharing fund for bike racks for private businesses. Metro area received \$25 million from federally funded Nonmotorized Transportation Pilot Program (NTPP). Extensive network of off-street bike paths serves as backbone of the city's bikeway network. The city plows all multi-use paths within 24 hours of the end of a snowfall.
Vancouver	Only case study city with helmet law for adults. Extensive bike training programs for all age groups. Most extensive bike boulevard network in North America (139km). Leader in traffic calming and intersection treatments to accommodate cyclists. Strong regional bike-transit integration under TransLink.
San Francisco	Good bike-transit integration, with most bike stations of any city in North America. Extensive road-based bike network, including numerous road diets and traffic calming programs. Leader in bike training and education, including bike clubs at high schools, bike safety courses, and training parcours. Strong bike advocacy, lively bike culture, and originator of Critical Mass rides, which spread throughout the world.
Montréal	Most extensive off-street path network of any case study city (328 km). North America's largest network of cycle tracks. Largest bike sharing system in North America (BIXI), with over 5,000 bikes. During cold winter months BIXI is discontinued and cycle tracks are used for snow storage.
Washington	Extensive regional mixed-use trail network. First regional bike sharing program in North America (Capital Bike Share). All Metrorail stations have elevators for easy bike access during off-peak hours. Bike station at Union Station offers parking for 150 bicycles, bike rentals, and bike repair.
Toronto	Iconic post-and-ring bike racks doubled from 7,500 to over 16,000 from 2000 to 2010. Bike station at Union Station offers parking for 180 bicycles; 2 more bike stations under construction. First city with bicycling ambassador program, providing community outreach and range of bike training programs. Length of bikeway network more than doubled between 2001 and 2010, from 166 km to 425km.
Chicago	Best bike parking at transit stations, racks inside stations for shelter and security. Largest bike station in USA, 300 spaces. Over 12,000 parking spaces in sidewalks racks, with continuous expansion every year based on usage survey Extensive bicycling ambassador program for community outreach, bike training, and cycling promotion New bike safety ordinance increases penalties for motorists who endanger cyclists or block bike lanes.
New York	Biggest increase in bikeway network: built over 450 km of lanes and mixed-use paths between 2000 and 2010. Innovative infrastructure including cycle tracks, bike boxes, green bike lane markings, and bike only traffic signals. Police failure to enforce bike lanes leads to frequent blockage of lanes by motor vehicles. Worst bike-transit integration of any city; no racks on buses, no bike parking at subway stations or major transit terminals.

Source: Information collected by the authors directly from the case study cities.

The comparative case studies offer a few other possible lessons. Climate does not appear to be a serious obstacle to increasing cycling, as shown by Portland and Vancouver, with their rainy climates, and Minneapolis and Montréal, with their long and very cold winters. Similarly, even hilly cities like San Francisco can generate high cycling levels with the right infrastructure and policies in place. Very large cities appear to present special challenges to cycling: high density of traffic, long trip distances, and the sometimes harrowing experience of cycling in heavy traffic with high levels of noise and air pollution. Those factors might help explain the relatively low bike mode shares in both New York (0.6%) and Chicago (1.2%). The two largest cities in Europe, London (1.6%) and Paris (2.5%), also have relatively low bike mode shares in spite of many policies to encourage cycling (Pucher et al., 2010a).

7. Conclusions: Bicycling renaissance in North America?

Cycling has certainly been on the rise in most parts of the USA and Canada. The boom in cycling, however, has been limited to a few dozen cities which have implemented a wide range of programs to aggressively promote cycling, such as the nine case study cities portrayed in this report (ABW, 2010; LAB, 2010). Even in those cities, cycling growth has been highly concentrated in the central cities, and especially in gentrifying neighborhoods near the CBD and university districts, while cycling remains at very low levels in most suburbs. Moreover, cycling levels vary greatly by region. The western states/provinces of the USA and Canada have, by far, the highest cycling rates, while most states in the American South, from Texas all the way to North Carolina, have extremely low levels of cycling (ABW, 2010; Pucher and Buehler, 2006).

Over the past decade, there has been a large increase in funding for cycling and in the range and magnitude of pro-bike policies to promote cycling. That suggests that cycling is less of a fringe mode than it was considered even a decade ago. Indeed, cycling is becoming a mainstream mode in a few cities. Portland's 2008 survey found that 18% of its residents used bikes as their primary or secondary mode for the work trip. That is comparable to cycling mode shares in northern Europe (City of Portland, 2010a; Pucher and Buehler, 2008). The success of Portland is important because it shows that even car-dependent American cities can greatly increase cycling by implementing the right package of infrastructure, programs, and policies.

Thus, a bicycling renaissance is indeed underway in many cities of North America, but so far, they remain islands in a sea of car-dominance. Over the 19-year period from 1990 to 2009, the bike share of daily commuters in the USA rose from 0.4% to 0.6%, and from 1996 to 2006, bike share of commuters in Canada rose from 1.1% to 1.3% (Table 1). That is quite a slow pace for the countries as a whole. But for individual cities, truly dramatic progress has been achieved, and they offer superb examples that other cities can follow.

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