

demand for new facilities (6). Although Pucher et al. (5) agreed that separate bike lanes and paths make cycling more attractive to non-cyclists, they did not find any rigorous statistical studies that demonstrated their impact on cycling. They also speculated that, to some extent, the provision of such facilities could be a response to the level of cycling in an area, rather than a cause.

Bicycling is predominantly a recreational activity in the United States. Data from the Bureau of Transportation Statistics (BTS) Omnibus Survey for 2002 reveals that 14.3% of the adult respondents rode a bicycle in the previous month (7). Of those, 53.9% did so primarily for recreation and 31.2% did so primarily for exercise. Only 4.9% bicycled primarily for commuting to work or school and 7.5% for personal errands. The survey did not ask for secondary purposes. Also, those people bicycling primarily for exercise might be going to work. Of the bicycle commuters, 11.0% rode primarily on bike lanes, compared with 5.6% of the recreational cyclists. Howard and Burns (8) found that regular bicycle commuters in Phoenix adjusted their routes to use bicycle facilities, lending support to the argument that providing facilities impacts behavior.

Nelson and Allen (9) used data from the NBWS to explain the relationship between bicycle commuting and bicycle pathways, controlling for extraneous variables. The data included 18 U.S. cities and used five explanatory variables:

1. Mean high temperature,
2. Number of days per year with more than 1/10 in. of rain,
3. Terrain,
4. Miles of bikeways per 100,000 residents, and
5. Percentage of college students compared with the overall resident population.

Their final linear regression model included bikeway mileage, rain days, and percentage of students as significant variables, with an adjusted R^2 of 0.825. They found that each additional mile of bikeway per 100,000 people is associated with a 0.069% increase in bicycle commuting, holding the other factors constant. The authors did not, however, interpret this as a cause-effect relationship.

Other researchers have explored the effect of additional variables on bicycle commuting. Baltes (10) used Census journey-to-work data from 284 metropolitan statistical areas (MSAs) to examine the relationship between bicycle commuting and various demographic and geographic factors. The analysis did not include data on bikeways, for this information is not included in the U.S. Census. A series of regression equations identified several significant variables, including the following:

1. Age (16-29 years),
2. Vehicle availability,
3. Race (Asian and nonwhite),
4. Home ownership,
5. Unemployment,
6. Percentage of students,
7. Poverty,
8. Agricultural and manufacturing employment, and
9. Share of workers and population living in the central city.

Baltes found that several variables were not significant, including population density and median income, although some of the significant variables are likely to be highly correlated with these two variables. The analysis was conducted at the MSA level for each Census region and all the MSAs combined, and it found that the

variables explained at least half of the variation in the level of bicycle commuting. Baltes did conclude that bicycle commuting was most prevalent in MSAs with unique communities, such as universities or colleges. Nankervis (11) found that short-term and long-term weather patterns affected cycling levels, although not to the extent that he originally anticipated.

Overall, the empirical evidence explaining the link between bicycle facilities and commuting is limited. Nelson and Allen (9) made several recommendations on how to improve on their analysis, including a larger data set, time-series data, before-and-after studies, and including additional factors that influence mode choice. Moreover, the quality of the original data used for the analysis was problematic. The NBWS noted that "innumerable difficulties were encountered when assembling the data" and that "the quality of the data varies so much" (4, p. 32, note 43). This was particularly true for the bicycle commuting data and bikeway mileage. Finally, of the 18 cities included in the Nelson and Allen study, the top 4 in terms of bicycle commuting are college towns: Boulder, Colorado (31.96%); Eugene, Oregon (16%); Gainesville, Florida (24.87%); and Madison, Wisconsin (22.24%). Although the percentage of people who are students was included as a control variable, these cities may be influencing the results and might not be considered useful as models for larger cities without a university focus.

DATA AND METHODOLOGY

This analysis builds on the work of Nelson and Allen (9) by using new Census data, a larger sample of cities, and additional explanatory variables. Much of the data used in this study comes from the Census 2000 Supplemental Survey (C2SS). The C2SS is a demonstration program to evaluate the feasibility of collecting economic, demographic, and housing data outside of the decennial census. The C2SS sampled 700,000 housing units in 1,203 counties, sampling approximately 58,000 addresses each month. The C2SS sampling rate for most geographic areas was 5% (12). Although the sample size is much smaller than that used for the long form of the decennial Census, the C2SS may be more useful for this analysis because it samples households throughout the calendar year, rather than on April 1, as the decennial Census does. If bicycle commuting is influenced by weather, a random sample throughout the year may present a more accurate picture of regular behavior. In addition, at the time this research was originally conducted, the U.S. Census had not released bicycle commute data at the city level.

The C2SS includes data for 64 incorporated or Census-designated places with a household population of 250,000 or higher. Three U.S. cities have a population greater than 250,000 but were not included in C2SS: Lexington and Louisville, Kentucky, and Corpus Christi, Texas. Bicycle commuting rates in the top 55 cities ranged from 2.63% (Minneapolis, Minnesota) to 0.04% (Dallas, Texas) (13). Nine cities had estimates of 0% of the workers' commuting by bicycle. This result is probably a result of the sample size. Bicycle coordinators or other staff at the top 50 cities were contacted to obtain information on the number of miles of Class I and Class II bike facilities that they had at the end of the year 2000. Class I facilities, also known as bike paths or shared use paths, are defined as bikeways physically separated from motorized vehicular traffic. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other nonmotorized users. Class II facilities, also known as on-street bicycle lanes, are defined as portions of a roadway that have been designated by striping, signing, and pavement

markings for the preferential or exclusive use of bicyclists (14). Some cities also had bike routes, wide shoulders, bike boulevards, and other facilities. Although these other facilities may have some impact on bicycle commuting, the analysis was limited to Class I and II facilities to maintain consistency among cities, as well as to focus the analysis on the highest level of facilities. Class I and II facility data were obtained from 43 cities. Also asked was whether or not the city had a designated bicycle coordinator on staff. This variable is an indicator of the amount of policy support at the local level for bicycling, which may or may not be reflected in the level of facilities existing in 2000.

From the previous research as mentioned, a number of other variables were selected that could influence the level of bicycle commuting in a city. These are shown in Table 1.

FINDINGS

Data for the top cities, of which 43 provided specific information about bike facilities, appear in Table 2, sorted by the percentage of bicycle commuters. The rankings in the first column are from the original list of 64 cities from the C2SS. When looking at the data, one can notice few consistent trends. The top four cities have some of the highest numbers of bike lanes and paths per square mile, although cities further down the list (e.g., St. Paul, Long Beach, and San Jose) also have high numbers. The aforementioned BTS data described above indicated that commuters are more likely than other cyclists to

use bike lanes. Therefore, the number of Class II bike lanes per square mile is also included in the table. Three of the top 10 cities have more than 100 days of rain per year, lending some doubt that rain is a significant deterrent to bicycle commuting. However, only 4 of the bottom 10 cities had under 100 days of rain. The maximum percentage of residents that are college students is 12.23% in Boston, (as shown in Table 2), significantly lower than rates found in Boulder, Gainesville, and Madison in the Nelson and Allen data (9). Most cities have a relatively high rate of vehicle ownership: more than one vehicle per household for all but five cities (Boston, Washington, D.C., New York City, Philadelphia, and Baltimore).

The percentage of people commuting by bicycle is significantly correlated with the bicycle infrastructure and gasoline price variables in Table 2, but not with any other variables listed in Table 1 or 2. The strongest and most significant correlation was with the number of Class II bike lanes per square mile (Pearson correlation = 0.49, $p < 0.01$). There was no significant correlation between state spending on bicycle and pedestrian projects or the presence of a bicycle coordinator and any of the three infrastructure variables—that is, bike lanes and paths per square mile, bike lanes per square mile, and bike paths per square mile. Several explanations are possible. First, the funding variable is for the state level and also includes pedestrian projects. Also, the funds could be spent on types of bicycle facilities and projects other than Class I or II paths and lanes, such as safety enhancements or intersection signals and detection equipment. The variable is included in this analysis as a possible indicator of states providing all types of bicycle facilities and overall public support for bicycling.

TABLE 1 Variables and Data Sources

| Variable | Source |
|--|--|
| Occupation/Employment | |
| Percentage of population that are college students | C2SS (15) |
| Percent of workers by industry category (agriculture, construction, manufacturing, wholesale trade, retail trade, transportation/warehousing/ utilities, information, finance/insurance/real estate, professional/scientific, education, arts/entertainment/recreation, and public administration) | C2SS (16) |
| Percent of workers by occupation category (management/professional, service, sales/office, farm/forestry, construction, and production/transportation/manufacturing) | C2SS (16) |
| Availability/Attractiveness of Other Modes | |
| Mean number of vehicles per household | C2SS (17) |
| Percentage of households with zero vehicles | |
| Transit Availability - | National Transit Database |
| Transit vehicle revenue miles per mile of service area | 2000 Transit Profiles |
| Gasoline price (state average, with taxes for 2000) | Energy Information Administration (18) |
| Land Use | |
| Percentage of housing units built before 1950 (a proxy for a grid-like street pattern) | C2SS (19) |
| Population density | 2000 Census (20) |
| Socio-economic Characteristics | |
| Median and mean household income | C2SS (16) |
| Percent of persons over 18 in poverty | C2SS (16) |
| Weather | |
| Average annual number of days of rainfall (.01 inches or more) | National Climatic Data Center (21), Western Regional Climate Center (22) |
| Average annual precipitation (total inches) | |
| (Data for next closest city if city data not available) | |
| Public Support for Bicycling | |
| Average per capita annual state spending on bicycle and pedestrian improvements, 1990-1999 (federal funds) | Surface Transportation Policy Project (23) |

TABLE 2 Cities and Data Used in the Analysis

| Rank | City | % Commuting by Bicycle | Bike Lanes & Paths per sq. mi. | Bike Lanes per sq. mi. | Average State Spending per Capita on Ped/Bike (1990-99) | Population Density (people/ sq mi land) | Days of Rain (historical average) |
|------|-------------------|---------------------------|--------------------------------------|---------------------------|---|---|---|
| 1 | Minneapolis, MN | 2.63% | 1.44 | 0.47 | \$0.45 | 6,970 | 116 |
| 2 | Sacramento, CA | 2.59 | 2.05 | 1.42 | \$0.09 | 4,189 | 58 |
| 3 | Portland, OR | 2.55 | 1.44 | 1.05 | \$0.94 | 3,939 | 153 |
| 4 | Tucson, AZ | 2.22 | 1.76 | 1.54 | \$0.26 | 2,500 | 53 |
| 5 | Fresno, CA | 1.96 | 0.13 | 0.00 | \$0.09 | 4,098 | 45 |
| 6 | Tampa, FL | 1.93 | 0.58 | 0.41 | \$0.58 | 2,708 | 106 |
| 7 | San Francisco, CA | 1.80 | 0.87 | 0.44 | \$0.09 | 16,634 | 68 |
| 8 | Oakland, CA | 1.77 | 0.20 | 0.09 | \$0.09 | 7,127 | 63 |
| 9 | Mesa, AZ | 1.64 | 0.37 | 0.36 | \$0.26 | 3,171 | 36 |
| 10 | Anaheim, CA | 1.59 | 0.45 | 0.29 | \$0.09 | 6,702 | 32 |
| 11 | Boston, MA | 1.48 | 0.28 | 0.01 | \$0.42 | 12,166 | 127 |
| 12 | Washington, DC | 1.42 | 0.78 | 0.10 | | 9,316 | 113 |
| 13 | Seattle, WA | 1.23 | 0.58 | 0.25 | \$0.83 | 6,717 | 151 |
| 14 | Albuquerque, NM | 1.16 | 0.61 | 0.31 | \$1.29 | 2,483 | 61 |
| 15 | New Orleans, LA | 1.14 | 0.06 | 0.00 | \$0.29 | 2,684 | 114 |
| 16 | Oklahoma City, OK | 0.90 | 0.02 | 0.01 | \$0.45 | 834 | 83 |
| 17 | Phoenix, AZ | 0.87 | 0.48 | 0.38 | \$0.26 | 2,782 | 36 |
| 18 | Buffalo, NY | 0.75 | 0.80 | 0.43 | \$0.48 | 7,206 | 169 |
| 19 | St. Paul, MN | 0.69 | 1.93 | 0.65 | \$0.45 | 5,442 | 116 |
| 20 | Long Beach, CA | 0.66 | 1.27 | 0.00 | \$0.09 | 9,150 | 32 |
| 21 | Santa Ana, CA | 0.65 | 0.36 | 0.04 | \$0.09 | 12,452 | 32 |
| 22 | Los Angeles, CA | 0.63 | 0.34 | 0.25 | \$0.09 | 7,877 | 35 |
| 23 | Philadelphia, PA | 0.63 | 1.30 | 0.96 | \$0.21 | 11,234 | 117 |
| 24 | Honolulu, HI | 0.61 | 0.46 | 0.25 | \$0.43 | 4,337 | 97 |
| 25 | Denver, CO | 0.53 | 0.62 | 0.07 | \$0.50 | 3,617 | 89 |
| 26 | Chicago, IL | 0.51 | 0.35 | 0.22 | \$0.24 | 12,750 | 125 |
| 27 | Pittsburgh, PA | 0.48 | 0.31 | 0.05 | \$0.21 | 6,019 | 152 |
| 28 | San Diego, CA | 0.48 | 0.92 | 0.77 | \$0.09 | 3,772 | 42 |
| 29 | San Jose, CA | 0.42 | 1.02 | 0.74 | \$0.09 | 5,118 | 58 |
| 30 | New York City, NY | 0.42 | 0.64 | 0.40 | \$0.48 | 26,403 | 121 |
| 35 | Houston, TX | 0.35 | 0.43 | 0.32 | \$0.17 | 3,372 | 105 |
| 36 | Raleigh, NC | 0.34 | 0.21 | 0.02 | \$0.35 | 2,409 | 113 |
| 37 | Milwaukee, WI | 0.27 | 0.26 | 0.08 | \$0.31 | 6,214 | 126 |
| 38 | Baltimore, MD | 0.26 | 0.06 | 0.00 | \$0.42 | 8,058 | 114 |
| 39 | St. Louis, MO | 0.26 | 0.45 | 0.06 | \$0.05 | 5,623 | 111 |
| 40 | Cincinnati, OH | 0.25 | 0.16 | 0.06 | \$0.47 | 4,249 | 137 |
| 41 | Riverside, CA | 0.23 | 1.10 | 0.85 | \$0.09 | 3,267 | 32 |
| 42 | Columbus, OH | 0.22 | 0.13 | 0.01 | \$0.47 | 3,384 | 137 |
| 43 | Omaha, NE | 0.19 | 0.06 | 0.00 | \$0.80 | 3,371 | 101 |
| 45 | Indianapolis, IN | 0.18 | 0.50 | 0.00 | \$0.41 | 2,161 | 126 |
| 46 | Charlotte, NC | 0.17 | 0.12 | 0.01 | \$0.35 | 2,232 | 111 |
| 48 | Wichita, KS | 0.14 | 0.01 | 0.01 | \$0.64 | 2,536 | 86 |
| 50 | Arlington, TX | 0.13 | 0.41 | 0.04 | \$0.17 | 3,475 | 79 |
| | Average | 0.91 | 0.61 | 0.31 | \$0.35 | 6,604 | 93 |

(continued)

