Bicycling for Transportation and Health: The Role of Infrastructure

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ABSTRACT

This paper aims to provide insight on whether bicycling for everyday travel can help US adults meet the recommended levels of physical activity and what role public infrastructure may play in encouraging this activity. The study collected data on bicycling behavior from 166 regular cyclists in the Portland, Oregon metropolitan area using global positioning system (GPS) devices. Sixty percent of the cyclists rode for more than 150 minutes per week during the study and nearly all of the bicycling was for utilitarian purposes, not exercise. A disproportionate share of the bicycling occurred on streets with bicycle lanes, separate paths, or bicycle boulevards. The data support the need for well-connected neighborhood streets and a network of bicycle-specific infrastructure to encourage more bicycling among adults. This can be accomplished through comprehensive planning, regulation, and funding.

Journal of Public Health Policy (2009) 30, S95–S110. doi:10.1057/jphp.2008.56

Keywords: bicycling, bicycle infrastructure, bicycle lanes and paths, global positioning system, active living, active transport

INTRODUCTION

To help address health and other policy concerns, policy makers and professionals are looking at ways to increase the use of walking and bicycling for everyday travel. While most of the focus on "active living" has been on walking, bicycling may have a greater potential to substitute for motorized vehicle trips because of its faster speed and ability to cover greater distances. Bicycle commuting has been shown to be an activity that meets recommended intensity levels (1) and to be related to lower rates of overweight and obesity (2).

The potential for bicycling as a transportation mode has been recognized nationally through objectives to raise bicycling rates (3) and significant increases in funding for building new infrastructure (4). Several states and cities have also adopted aggressive policies and programs to increase bicycling (5,6). However, the United States lags far behind many other developed countries, particularly several European countries, with respect to the share of people traveling by bicycle (7,8). Moreover, most bicycle travel in the United States, particularly among adults, is for recreation, not daily travel. This is in contrast to bicycling in countries such as the Netherlands, Denmark, and Germany (7,9).

This research aims to provide insight on whether bicycling for everyday travel can help US adults meet recommended levels of physical activity and what role public infrastructure, particularly bicycle lanes, paths, and bicycle boulevards, may play in encouraging this activity. Using global positioning system (GPS) technology, the study collected information on bicycling behavior from adults in the Portland, Oregon metropolitan area. The results can lead to policy recommendations for infrastructure investments and planning and zoning policies to encourage more bicycling for everyday travel.

LITERATURE REVIEW

Few Americans, particularly adults, ride a bicycle for everyday travel. In the United States, the 2001 National Household Travel Survey (NHTS) found that only 1% of all one-way trips were made on bicycle. Only about 30% of adults said they had ridden a bicycle in the past week (10). Nationally, only about one-half of 1% of workers regularly commuted by bicycle in 2006 (11). US studies consistently find that women are less likely to bicycle than men (12–16). One explanation is that some studies find that women are more concerned about safety, particularly from vehicle traffic (17,18). In the United States, bicycling rates also decline with age (13). Several researchers have found that bike lanes and paths are correlated with higher rates of bicycling or willingness to cycle (5,7,19–22). However, cities need to know what type of infrastructure will be most effective.

Several studies have tried to assess the relative effects of specific types of infrastructure, including bike lanes (a striped lane on a roadway) and paths separated from motor vehicle traffic, using both stated and revealed preference methods. Stated preference methods ask participants what they would do given a hypothetical situation. Revealed preference methods collect data on how participants *actually* behave. Simple stated preference studies usually find that people prefer bike paths and lanes or indicate that having such infrastructure would encourage them to bicycle more (19,22). Some studies present respondents with two options, trading off a higher quality facility (e.g., a dedicated bike lane) with a longer travel time. At least two such studies have found that bicyclists value bike lanes and off-street paths (23,24).

Findings from revealed preference studies are mixed. At a city level, two studies have found that bike lanes are associated with higher rates of bicycle commuting (21,25). However, at an individual level, other studies have not found such a link (14,16). Several studies have found that bicyclists will take a longer route to use bicycle facilities, such as lanes or paths (15,26,27). Preference for lanes or paths may depend upon the type of bicyclist. One study found that bicycle *commuters* diverted very little from the shortest path and preferred not to ride on paths or trails (28). A national survey found that frequent bicyclists preferred bike lanes rather than paths. Infrequent bicyclists were more likely to want more bike paths rather than lanes (29).

We do not fully understand bicycling behavior and the influence of infrastructure because our current data sources are limited. The revealed preference studies cited above provide route information based upon the respondent's recall, but can be limited in sample size. Most large sample surveys do not include questions about routes or facility preferences. And, because bicycling is a rare activity, the surveys still may not capture much bicycling activity. Health-related surveys, such as the Behavioral Risk Factor Surveillance System, typically have very large samples. However, until 2001 the questions on physical activity focused on leisure-time activity, thus missing bicycling for transportation (30). Another limitation of self-reported travel data is that people often round-off their travel times to the nearest 5-minute increment and overestimate travel times (31). These surveys rarely assess total amounts of bicycling over more than one day, making it difficult to estimate whether people achieve weekly physical activity objectives.

When large sample surveys do ask about route choice, the methodology limits the level of detail and accuracy of the data. For example, a random phone survey of adults found that only 5.2% of bike trips were made mostly in bicycle lanes and 13.1% were mostly on paths or trails (13). However, because the question asked where the person "mostly" rode for that trip, it is impossible to get an accurate estimate of where all of the bicycle travel occurred. Respondents to a non-random survey of nearly 2,500 US bicyclists found that nearly one quarter of all of their bicycle commuting occurred in bike lanes or paths (32).

SETTING AND SAMPLE

This study took place in the Portland, Oregon metropolitan area ("region"), with a population of about 1.6 million (33). The City of Portland (about one third of the population) has received national attention and awards for its commitment to bicycling (34). The city has a relatively high number of bike lanes, compared to other large US cities (21). Rates of bicycle commuting are higher in the region than most comparably sized regions (35). Yet only about 1.2% of the region's and 4.2% of the City of Portland's workers regularly commuted by bicycle in 2006 (11).

Bicycle infrastructure in the region includes bike lanes on streets, separate bike paths, and "bicycle boulevards." Bicycle boulevards are low-traffic, minor streets, usually running parallel to a major road, that use traffic calming features to give priority to bicycles over motor vehicles. For example, barriers at some intersections force cars to turn while bikes can continue on a through path. Traffic signals allow bikes traveling on the boulevard to cross busy streets safely. The bicycle boulevards are located in the older neighborhoods that are covered with a grid-type street pattern made up of small blocks.

The study collected data from a convenience sample of 166 bicyclists from March to November 2007. The participants were recruited by two primary methods. First, an earlier phase of the project included a random phone survey of adults in the region. All bicyclists identified through that survey were invited to participate, though only eight did. Second, the study was described in two articles in the region's major daily newspaper, which was then circulated on various e-mail lists and websites. Flyers soliciting participants were also placed at bicycle shops and events. About 400 people responded to these methods and were directed to complete an online version of the phone survey. The GPS participants were then selected using a random sampling method, stratified by geography, sex, and frequency of bicycling. Participants received a $40 gift card from a choice of retailers at the end of the study. The study was reviewed and approved by Portland State University's Human Subjects Research Review Committee.

DATA COLLECTION AND PREPARATION

Each participant was provided with a specially programmed personal digital assistant with GPS to carry on all bicycle trips for 7 days. These units were chosen because they could be programmed for the participant to enter some data. Several actions were taken to try to improve the accuracy of the GPS data. Prior to use, the units and software were tested in different weather conditions, in various parts of the city, including downtown and under tree cover, and on different places on the bicycle. Clouds and tree cover did not pose problems. Tall buildings downtown did pose some localized problems. Therefore, individual data points with high error values (determined by the unit's software) were not used in creating the route map. With location points collected every 3 seconds, the remaining points usually provided enough data to recreate the route. Participants were also asked to turn the unit on and wait for satellites to be detected before starting their trip. At the start of each bike trip, the participant tapped on the screen to enter his or her trip destination (e.g., work, shopping, exercise) and the weather details. The unit could be placed either on the bike's handlebars using a special bracket, or on a back rack. Plastic sleeves protected the units from rain and dirt. Once on and within view of three or more satellites, the unit recorded its position and speed every 3 seconds. The unit did not display a map or other location data, so that participants would not be distracted.

At the end of 7 days, the data were downloaded and converted to a route using geographic information systems software and customized programming scripts. Within a day, each route was displayed on a map for the participant to view on a secure website. For each trip, the participant answered questions about whether the depicted route was accurate. The participant was also asked to rate the importance of various factors in choosing that particular route and whether bicycle trips that were not shown were taken. Just over half (53%) of the participants indicated that all of their trips were recorded, 18% said that one trip was missed, 8% said that two trips were missed, and 18% said that more than two trips were missed. Trips were missed both due to technical failures (e.g., the device not working) and users not bringing the unit for some reason. A total of 1,955 trips were recorded and 177 were reportedly missed, representing an undercounting of 8%. After the trips were corrected based on participant feedback, it was possible to calculate the mileage by facility type.

RESULTS

As a result of the sampling methodology, a majority of the participants were very frequent, regular bicyclists. Half of the participants cycled 5 days a week during the summer, and about one third did so during non-summer months. The phone survey found that less than 15% of bicyclists region-wide bike at this frequency level. Of the participants, 45% were women and 86% were Caucasians. The ages of participants ranged from 18 to 80 years, with an average age of 41 and a median of 40. The mean household income of participants was US$75,000–$99,999, compared to $50,000–$74,999 for regular bicyclists from the phone survey, though the median incomes were the same ($50,000–$74,999).

Participants recorded an average of 1.6 bicycle one-way trips per day. A trip was defined as any time the participant traveled between one place and another. If the participant stopped for more than 5 minutes at a location, a new trip was created. The majority of the participants' bicycling was for utilitarian purposes (Figure 1). Only 5% of the trips were for exercise, with no destination. This contrasts with most bicycling in the United States, due to the participant sample. The distribution of trip destinations indicates that the participants were linking several trips together, rather than simply traveling from home to a destination and back. If participants were not linking trips, about half of the trips would be to their home, rather than one third. The median trip length was 2.8 miles. Exercise trips were the longest (median = 8.5 miles), followed by work (3.8 miles). The average trip speed was 10.8 miles per hour. Half of the time spent in bicycling was on trips that averaged 10–13.9 miles per

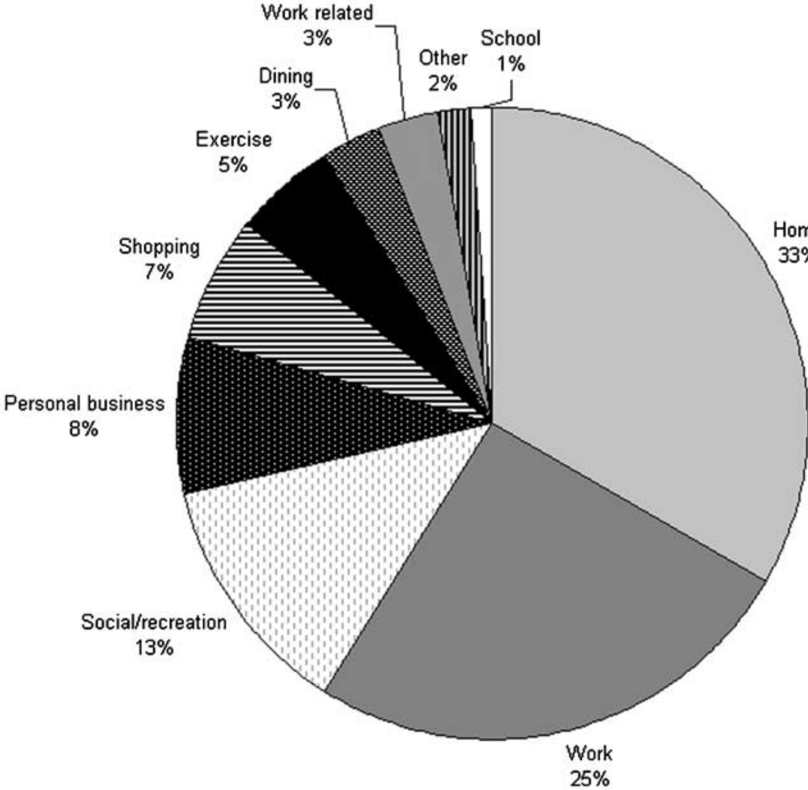

Figure 1
Recorded bicycle trip destinations

hour, which equates to 6–8 metabolic equivalents (36). A majority of the participants (59%) recorded at least 150 minutes of bicycling over the 7-day period (Figure 2).

About half of all the miles of bicycle travel recorded by the GPS units occurred on roads with bicycle lanes, paths, or bicycle boulevards; these facilities only make up about 8% of the available network (i.e., streets, roads, and paths on which a bicycle can be used) (Table 1). The distribution differed slightly when exercise trips were excluded, and only "utilitarian travel" was studied. Utilitarian travel was examined separately because it was thought that cyclists might have different route preferences for exercise trips, such as spending more time on a bike path. The distribution of bicycle

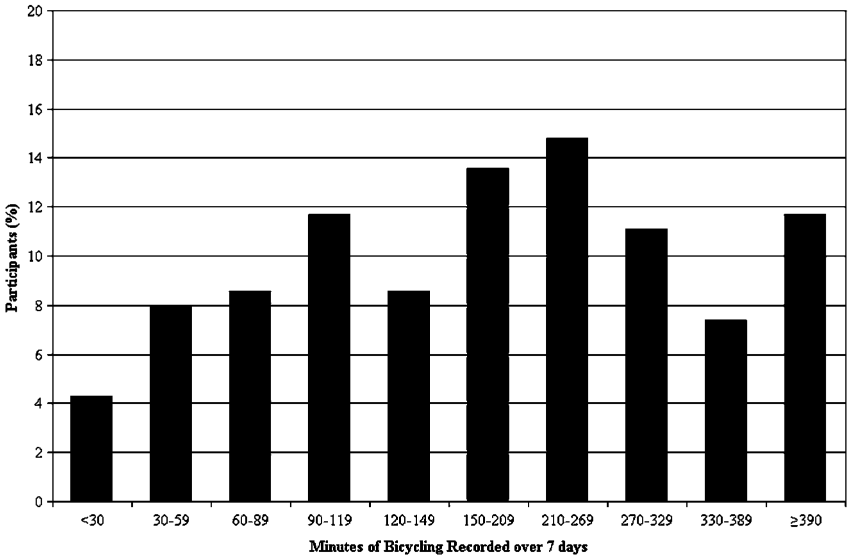

Figure 2
Distribution of minutes of bicycling recorded over 7 days

travels differs significantly from that of the network. The most notable is that 14% of the utilitarian bicycle travel occurred on paths and 10% occurred on bicycle boulevards. These types of facilities make up only 2% and less than 1% of the network available to bicyclists in the region, respectively.

For each trip, participants were asked in the follow-up online questionnaire to rate the importance of various factors in choosing that route. The highest rated factor was minimizing the total distance, followed by avoiding streets with lots of vehicle traffic (Table 2).

DISCUSSION

The study contributed to understanding bicycling behavior in notable ways. It is the only study that the author could find that collected this large a sample of daily bicycle travel, over multiple days, with detailed route information. The study included nearly 1,800 adult bicycle trips, more than twice as many as counted in the 2001 NHTS, which did not include route information (10). In

Table 1: Distribution of recorded bicycle travel by facility type, compared to network mileage

	% of bicycle travel (miles)		
	All travel (%)	*Utilitarian travel (%)*	*% of network*
Roads without bicycle infrastructure	51	48	92
Primary roads/highways, no bicycle lanes	4	3	4
Secondary roads, no bicycle lanes	19	16	13
Minor streets, no bicycle lanes	27	28	63
Driveways, alleys, unimproved roads	2	1	12
Bicycle infrastructure	49	52	8
Primary roads/highways, with bicycle lanes	9	9	3
Secondary roads, with bicycle lanes	14	15	2
Minor streets, with bicycle lanes	3	3	1
Bicycle/multi-use paths	14	14	2
Bicycle boulevards	9	10	<1
N (miles)	7,479	6,131	10,564

Table 2: Importance of factors in choosing bicycle route

	Mean score (1=not at all important, 5=very important)
Minimize total distance	3.60
Avoiding streets with lots of vehicle traffic	3.57
Riding in a bike lane	2.95
Riding on signed bike routes	2.62
Reducing wait time due to stop signs/lights	2.67
Riding on an off-street bike trail/path	2.21
Avoiding hills	2.10
N (trips)	1,739

Note: Exercise trips excluded.

addition, it is the only known US study that included an assessment of the use of bicycle boulevards, a relatively new concept for this country. The detail of the GPS data allowed us to assess how much physical activity adults can get while bicycling for daily travel, along with actual route preferences and behavior.

A large majority (59%) of the participants were able to meet the recommended 150 minutes of activity per week through the bicycling recorded by the GPS units. Nearly all of the bicycling was for utilitarian purposes. Although the participants represent a small share of all bicyclists, and an even smaller share of the population, this finding does indicate that regular bicyclists can achieve healthy levels of physical activity through daily travel.

Trip distances are sometimes cited as a barrier to bicycling (22). The median bicycle trip length recorded here was about 3 miles. About half of all daily trips made in the United States are 3 miles or less in length (10). Therefore, the potential to switch trips from driving to bicycling is large. In addition, participants were linking trips together, stopping somewhere on the way home from work, for example. This is made more feasible by Portland's policies and regulations that support mixing land uses, including commercial and residential uses. A well-connected network of bicycle-friendly infrastructure would also facilitate such linking of trips.

The participants were using the bicycle infrastructure (lanes, paths, and bicycle boulevards) to a great extent – for about half of their bike travel. Where participants bicycle is determined to some extent by where they live. If participants live in neighborhoods with more bicycle infrastructure, that would account for some of the difference between use (half of the bicycling) and the infrastructure (8% of the network). However, there are no neighborhoods where even 25% of the network has a bike lane, path, or boulevard. Therefore, the difference indicates that bicyclists are probably traveling out of their way to use the bicycle infrastructure. An analysis comparing the routes taken to the shortest path routes would confirm the extent to which this is occurring.

The preference for traveling on bike paths and boulevards is consistent with the priority the bicyclists placed on routes that avoid streets with lots of vehicle traffic. However, the participants placed almost equal importance on minimizing trip distances. Without a well-connected network of bike lanes, paths, and boulevards, along with low-traffic neighborhood streets without specific bicycle infrastructure, meeting these two priorities simultaneously would be difficult.

The study does have several other limitations. First is the under-representation of people who cycle only occasionally or even less than 5 days a week. Most of the participants were everyday bicyclists. Therefore, they are likely to be more confident than less frequent bicyclists. This is likely to affect route choices. Second, the data collection method may have influenced behavior. Six of the 164 participants noted that they bicycled more or on different routes than intended because of the GPS device. Third, at least 8% of the bicycle travel was not recorded by the GPS units. It is unknown whether or how the missed travel might have differed from the recorded travel in terms of route choice. Malfunction of the GPS units, including dead batteries, accounted for about half of the missed travel.

As with any research conducted in one location, care must be taken when applying the results to other locations. There is no comprehensive data set that includes the miles of bicycle infrastructure for other cities or metropolitan areas, so it is difficult to know exactly how Portland compares. In addition, the Portland region includes other bicycling supportive factors that were not examined as part of this study, yet likely influence behavior. The many types of innovative infrastructure to support bicycling installed by the City of Portland include special traffic signals, way finding signage (to help bicyclists orient themselves and find an appropriate route), on-street bike parking areas, and traffic signal detectors. Non-infrastructure programs and policies (e.g., marketing programs) and several independent bicycle organizations and events may also help create a "bicycle culture" that likely influences bicycling behavior.

CONCLUSIONS

The study demonstrated that bicycling for transportation can be used by adults to meet the recommendations for daily physical activity. A supportive environment, like that found in the Portland region, appears necessary to encourage bicycling for everyday travel, allowing more adults to achieve active living goals. The first part of that environment is bicycle infrastructure that addresses people's concern about safety from motor vehicles. In Portland, this includes a network of bike lanes, paths, and boulevards. Building such a network requires a comprehensive plan, funding, and political leadership. In Oregon, state law requires that both bicycle and pedestrian infrastructure be built whenever roads are built or rebuilt (with few exceptions), and that cities, counties, and the State spend a reasonable share of their state highway funds, usually defined as 1%, on pedestrian and bicycle features.

A network of different types of infrastructure appears necessary to attract new people to bicycling. Simply adding bike lanes to all new major roads is unlikely to achieve high rates of bicycling. For people concerned with safety and avoiding traffic, a well-connected network of low-traffic streets, including some bicycle boulevards, may be more effective than adding bike lanes on major streets with high volumes of motor vehicle traffic. Opportunities to build separate paths are often limited in existing neighborhoods due to space constraints and costs. Public agencies can, however, look for such opportunities when building other infrastructure, such as new rail transit lines, along existing transportation corridors, and when expanding to new undeveloped areas. Finally, the role of bike lanes should not be dismissed in planning for a bicycle-friendly community. A disproportionate share of the bicycling occurs on streets with bike lanes, indicating their value to bicyclists. These facilities may provide important links in the network, connecting neighborhoods when low-volume streets cannot.

The bicycle infrastructure in Portland appears to work, in part, because of a supporting land use and street network structure. The areas within Portland where the highest levels of bicycling occur also have a well-connected street grid and mix of land uses. This allows bicyclists to link their trips together in an efficient manner. The grid street patterns allows the installation of bike boulevards that provide options to bicycling on major streets with more traffic, without increasing travel distances too much. The older parts of many US cities have this same supportive structure. For new development, street connectivity standards and zoning that allows or even mandates a mix of land uses can create such an environment. The Portland region has adopted both of these strategies.

This study also demonstrated the benefit of using GPS to measure behavior. The main difference between using GPS and other measurement tools, such as accelerometers (which provide information on speed of travel), is that GPS provides location information. For behavior that is dependent upon infrastructure or otherwise influenced by the physical environment, this information is valuable in assessing the relative effects of different environments. With the cost of GPS devices falling, and the technical capabilities improving, this is now a very feasible tool for collecting data on travel and physical activity (37).

The findings and limitations of this study point to additional analysis and research. The detail of the data allows for more extensive analysis than presented here. Comparing different types of bicyclists (e.g., men and women) may provide insights into how to increase bicycling among groups that traditionally do not bicycle for transportation in the United States. Comparing the actual bicycle routes to shortest path or other possible routes can provide estimates of how much bicyclists value different types of infrastructure, based on how far they went out of their way to use it. Collecting similar data from other locations and from a larger number of different types of bicyclists would be a valuable addition to this work. Recent improvements in GPS technology should also help address some of the technological problems encountered in this study.

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