Empirical Evidence on Determinants of Mass Bicycle Commuting in the United States: A Cross-Community Analysis

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A nationwide study of determinants of mass bicycle commuting (10 percent or more of trips) is discussed. Numerous studies in specific cities and states have isolated important determinants of mass bicycle commuting, such as separation from high-speed, high-volume motor vehicle traffic and relative costs (including time). However, considerable political controversy exists over the proper policies for stimulating mass bicycle commuting, and no study systematically quantifies where mass cycling takes place in the United States or the correlates of mass cycling. Therefore, the data in this paper attempt to fill that research gap and reduce the area of policy controversy by reporting all the available examples of mass bicycle commuting in the United States. The data find almost 200 examples of mass cycling for educational institutions, but fewer than 10 examples of mass cycling to work and shopping destinations. Separation from high-speed, high-volume traffic correlates with mass cycling, although examples of mass cycling on wide moderate-speed, moderate-volume arteries exist. The relative cost of cycling, which includes time costs, correlates less strongly. However, correlation does not prove causation. The overwhelming majority of fatal accidents reported occurred on arteries and not on separate bicycle facilities or residential-type roads. Nevertheless, cycling appears to remain more hazardous than driving over a given route.

Short-distance bicycle commuting provides an example of appropriate technology for a substainable economy and society in a world of increasing scarcity, congestion, and pollution. Bicycles theoretically can provide rapid, flexible, low-cost, pollution-free transportation with consistent exercise for short trips in congested urban areas. Several groups have an interest in stimulating bicycle commuting: the U.S. government to save petroleum and reduce air pollution, the bicycle manufacturer's association to stimulate new bike sales, and local transportation planners and bike clubs.

All of these groups need solid information on the determinants of mass bicycle commuting (10 percent or more of trips), but unfortunately vigorous controversy has led to considerable misinformation and confusion. For example, the U.S. Department of Transportation (DOT) published a national comprehensive bicycle transportation program (1) that emphasized promotion and education and deemphasized separate bicycle facilities to shift 15 to 30 percent of a target group of short-distance urban drivers to safe bicycle commuting.

In a review of such an ambitious bicycle-marketing program, little or no support for its assumptions in the replicable, empirical, bicycle modal-choice or marketing literature could be found (2). The literature concentrated on several determinants of safe mass bicycle commuting. First, numerous surveys were found (including sophisticated logit models) that indicated that the overwhelming majority of actual and potential commuter cyclists wanted separation from high-speed, high-volume traffic (2, p. 38). Second, relative costs, which include time costs, played a major role in modal choice. Finally, evidence that separation would reduce the risk of fatal bicycle accidents, but not eliminate it, was presented (2, p. 38).

In the review of the DOT study, it was observed that known examples of mass cycling in the United States and Europe tended to support this literature. The cities of Davis and Santa Barbara, California; Madison, Wisconsin; and Amsterdam and Utrecht, Netherlands, incorporate substantial separation from high-speed, high-volume traffic along with short trips in areas where bicycles often provide faster and more flexible transportation than other modes. However, no statistical analysis of where mass bicycling takes place exists to support or refute these observations.

Therefore, data on the percentage of cycling were collected, and determinants of cycling (separation, distance, and relative time) from nearly 300 college communities in the United States were hypothesized in order to provide a quantifiable description of those areas in which mass bicycle commuting takes place. After the methodology for collecting the data is described, the data are analyzed in light of the available literature, and finally a nontechnical discussion of the results and their implication for planning are presented.

METHODOLOGY FOR DATA COLLECTION

The study sent a mail-back questionnaire to key respondents in all major college communities in the United States as part of several senior-level marketing research classes. The students made valuable contributions by reviewing, checking, and criticizing results. They also funded the survey with $10/student, or about $600 overall. East Tennessee State University provided the computer facilities and released time for this research.

A one-page (front and back) questionnaire was developed to collect data on the percentage of cycling and on the key variables that the literature suggested would affect the level of cycling and safety. The questionnaire was field tested on approximately 20 institutions where the levels for most of the variables were known. The respondents--typically university police, junior high school principals, and city traffic engineers--made estimates of the level of the variables that roughly coincided with the known knowledge of the institutions.

The sampling strategy focused on college and university communities. First a census was taken of all junior colleges, colleges, and universities [higher education (HE)], excluding technical, seminary, and other such specialized schools, that had a student enrollment (including part time) of 9000 or more based on the College Blue Book (3). Then about 95 percent of the junior high schools (JHSs) were sampled in the same communities as were the HEs and that had populations of approximately 300 000 or less based on Patterson's American Education (4). To double-check these responses and collect data on bicycle commuting to work and shopping, questionnaires were sent to traffic engineers (TEs) in all of the latter communities.

This sampling strategy was based on the assumption that most examples of mass cycling take place in smaller cities and college or university communities. Censuses and other published studies showed relatively little cycling in large cities (1 to 2 percent of the traffic flows on routes used by cyclists). Also, rather than lightly sampling a number of strata, it was decided to collect a large number of observations from one stratum to help smooth out respondents' estimates and approximations and to pick up as many examples of mass cycling as possible.

The strategy yielded a reasonable response rate and a large data set of more than 600 observations that had minimal nonresponse problems. The initial questionnaires went out by the end of September 1981; therefore, good weather for cycling was at least a recent memory in the northern states. By mid-November 1981 there was a 27 percent response rate for the JHSs and a 35 percent rate for the HEs and TEs combined. Follow-up questionnaires at that time netted an overall response rate of 51 and 58 percent, respectively. Given that TEs and HEs filled out the same questionnaire, the overall coverage of HE reached about 75 percent. The relations between the percentage cycling and key variables, such as type of access and percentage living near campus, remained similar for the original and follow-up groups, which indicates no serious biases from the nonrespondents in exploring the key determinants of mass cycling. However, budget constraints precluded a telephone sample of nonrespondents. Their lack of cooperation suggests they contained a disproportionately large number of schools with little or no cycling.

The students edited, coded, and checked the data, which resulted in a large, final, and usable data set with minimal opportunity for investigator bias. The students also checked and double-checked the questionnaires for errors. The researchers and students resolved serious conflicts between TE and HE responses on the percentage of cycling and other key variables by follow-up telephone calls. Finally, computer printouts were examined for outlayers and coding errors. This yielded a usable data set of 216 for HE, 308 for JHS, and 91 for TE, most of whom reported on several cycling areas in their community.

FINDINGS

Where Does Mass Bicycle Commuting Take Place in the United States?

Through more than a decade of observations in many parts of the United States, mass bicycle commuting (10 percent of trips or more) has been observed only around large institutions of higher education and public schools. Bicycles constituted less than 1 percent of vehicles in traffic counts on journey-to-work bike routes in large cities such as Washington, D.C., and Chicago.

Published censuses and studies corroborate these observations. A 1977 census report on travel to work (5) found only 11 cities with around 1 percent of the workers reporting the bicycle as their principal mode of transportation to work. Only Madison (4.5 percent) and Sacramento (3.2 percent) reported substantially higher levels. Moreover, a worker included persons 14 years and older who had a part-time job (5, p. 20). Other studies of specific cities and routes give similar results, which showed bicycle traffic as about 1 percent (6,7) of vehicles on heavily traveled bicycle routes for central business district (CBD) commuters.

The cross-community data also support these observations. TEs report that most of the high-percentage cycling is to schools and only 9 observations of mass cycling is to work or shopping destinations, even when the criterion was dropped to 5 percent of vehicles or more (Table 1). Only a maximum of 16 work and shopping examples of mass cycling in the 277 college communities of less than 300 000 population can be inferred from these data (Table 1). The overwhelming majority of mass cycling involved students.

Responses from the schools themselves corroborate this finding. The table below gives 63 examples of mass cycling to HE and 116 to JHS, with a maximum inferred level of 84 and 228 in the 277 college communities (note that high numbers are inferred maximums, and the percent cycling figures are in response to the following question: Approximately what percent of the total student body regularly uses a bicycle to commute to classes at this school during good weather?).

	No. of Examples Reported			
	HE		JHS	
Percent Cycling	Low	High	Low	High
0-4	103	137	132	259
5-9	42	56	57	112
10-19	31	41	60	118
>20	32	43	56	110
Total mass cycling (10 and over)	63	84	116	228

Surprisingly, these examples of mass cycling were spread more or less evenly across the country, with most states having at least one example of each (HE and JHS); most have two examples, and only six or seven have more than two.

Levels of cycling high enough to theoretically bestow net social benefits on society have not yet appeared for the work or shopping commuter in large cities and few examples exist in small cities. A nucleus of visible adult bicycle commuters exists in

Table 1. TE reports on bicycle commuting to work, shopping, and schools in college communities.

	No. of Examples Reported[b]							
	HE		Public Schools		Work Place		Shopping	
Percent Cycling[a]	Low-Side Estimate	High-Side Estimate	Low-Side Estimate	High-Side Estimate	Low-Side Estimate	High-Side Estimate	Low-Side Estimate	High-Side Estimate
1-4	28	48	11	19	25	43	10	17
5-9	18	31	6	10	5	9	3	5
10-19	9	15	5	9	1	2	0	0
⩾20	5	9	6	10	0	0	0	0

Notes: Low-side estimates represent actual reported number. High-side estimates indicate inferred maximum number of observations, which were inferred from the respondents to the overall target population, assuming nonrespondents had similar levels of cycling. They probably had lower levels, so high-side estimates represent inflated estimates.
In response to the question, "If no areas of substantial commuter cycling exist in your community, please just write in community name and return questionnaire," the total blank questionnaires were 24 and 41 for the low-side and high-side estimates, respectively.

[a]Responses to the following question, "During peak cycling hours bikes represent about what percent of total vehicles on, or alongside, the road or roads providing access to these commuter bicycle destinations?"

[b]Responses to the following question, "Please list the major commuter bicycle destinations in your community such as schools, work places, or shopping areas."

some large U.S. cities, whereas Europe and Asia have numerous examples of mass commuter cycling to work and shopping.

Determinants of Cycling: Separation from High-Speed, High-Volume Traffic

Numerous national, state, and local surveys show that the overwhelming majority of actual and potential commuter cyclists want separation from high-speed, high-volume traffic (HSHVT) and consider such separation a precondition for bicycle commuting (2,8). Sophisticated logit analyses, which are used in marketing research to go beyond what consumers say they want to actual prediction of their behavior, find that separate bikeways would substantially increase the propensity to cycle (9). Also, several studies of existing bikeway systems provide direct observation of separation diverting and increasing commuter cycling (10-12). Observations in many states and countries failed to provide examples of mass commuter cycling mixing with HSHVT.

Thus, it was hypothesized that separation from HSHVT constitutes an important determinant of mass commuter cycling. Note that separation does not necessarily mean grade or physical separation with a bikeway, raised beam, or even a striped-off lane. Low-speed, low-volume roads can provide the separation, particularly in combination with barrier-breaking bicycle facilities along major arteries.

The data generally support this hypothesis and help refine it. First, in Table 2, the data in column 1 reveal that the higher the traffic speeds and volumes, the fewer the examples of mass cycling. The table records 125 examples of mass bicycle commuting in the United States taking place on separate bike paths or lanes or low-speed, low-volume, nonarterial residential streets (answers a and b in Table 2). Only 48 examples of mass cycling exist where access involves higher-speed, higher-volume residential through streets or wide (including shoulder) moderate-speed, moderate-volume arterials (answers c and d). No HEs and only six JHSs reported mass cycling along narrow high-speed arteries without shoulders or heavily traveled multilane arterials (answer e). On follow-up calls to JHSs, moreover, it was found that students were cycling out of residential areas and crossing busy arteries to reach school rather than cycling along HSHVT arteries.

Furthermore, on average, schools with bikeways have a much higher percentage of students cycling than do schools that rely only on the road system for access. In Table 2, the data in column 2 reveal that, for all road categories except residential, bikeways along the road are associated with more than double the percentage of students cycling. Cycling averages 16 percent with bikeways and only 7 percent without. Without bikeways along high-speed, narrow, or congested multilane arteries, the percentage of students cycling drops to an average of 3 percent. With bikeways, the percentage stays up at mass cycling levels.

Finally, the data further suggest that mass cycling will mix with motor vehicle traffic up to and including wide (including shoulder) moderate-speed, moderate-volume arterials (Table 2, answer d). Although most examples of mass cycling have access on separate facilities, the other examples were spread out evenly over residential to wide, moderate-speed, moderate-volume arteries. The data do not separate the moderate arteries from through residential streets and do not provide a more detailed description of road width and surface or traffic volumes. However, Table 3 provides a list of seven universities that have high levels of mass cycling mixing with moderate to heavy, but slow-moving, motor vehicle traffic. European cities such as Amsterdam or Ursula, Sweden, also provide examples. These communities constitute laboratories for making precise field measurements of road types and traffic volumes to assess the outer limits of mass bicycling mixing with motor vehicle traffic.

The observed relation between separation from HSHVT and level of cycling does not prove that separation causes cycling to increase. First, causation could run either way. The emergence of mass cycling on a road could help motivate officials to construct a separate bicycle facility. Second, the data include a number of schools with separate facilities that provide access, but with less than 10 percent of the student body cycling (i.e., less than mass cycling). Third, Table 3 provides some examples of high levels of cycling mixing with moderate- to high-volume traffic. Finally, Pearson's squared and Kendall's tau rank-order correlation between type of access and percentage cycling explain only about 20 percent of the variation in cycling. Thus, other variables must play an important role in stimulating mass cycling.

Economic Determinants of Mass Cycling

Most studies of passenger transportation modal choice find that relative costs, including the time costs of the modes, play a major role (13). Computer simulations of cycling versus driving find that, although bicycles cost far less than automobiles to own and operate, the generally slower overall travel time of bicycles (cruising speeds as well as preparation time) cannot compete with vehicle savings (14). In these studies, only college students who live within 2 to 3 miles of a campus with limited convenient parking find cycling substantially less expensive than driving (14, p. 597). These findings remain consistent with the observation that few white-collar commuters cycle the relatively long distances from suburban areas to CBDs, but many examples exist of mass bicycle commuting of college students in small university cities. Thus, it is hypothesized that the costs (including time costs) of cycling constitute a major determinant of mass cycling.

The cross-community data, however, give only partial support to this hypothesis. Table 4 shows that the mean percentage cycling to classes during good weather usually associates strongly with relevant proxy variables for low costs of cycling relative to other modes. About twice as many students cycle to classes where cycling appears to provide a quicker, cheaper, or more convenient mode of transportation.

These variables, however, explain only a minor part of the variation of cycling between schools. The percentage of the student body living on or within 2 to 3 miles of campus explains 19 percent of the variation in the HE cycling, and speed of cycling relative to driving explains 7.7 percent (Table 4). The other variables explained only a small percentage of the variations and generally did not reach statistically significant levels. Taken together in stepwise linear regression models, these proxy economic variables explain about 25 percent of the variation in cycling among HEs ($R^2 = 0.266$) but only 6 percent of the variation among JHSs ($R^2 = 0.065$). Again "explain" or "correlate" do not necessarily mean cause. For example, people who do not own cars and who wish to cycle may choose to live close to campus.

These results suggest that either our proxy variables do not capture the real relative costs of cycling or that other variables explain the major part of the variation in the percentage of students cycling to class.

Other Possible Determinants of Mass Bicycle Commuting

The DOT study (1) assumed that bicycle promotion and education, along with safe bicycle parking and minor modifications in the road (wider lanes and safer drainage grates), constitute the major determinants of bicycle commuting. Other observers and practitioners have hypothesized that variables such as culture and weather play a major role. The cross-community data, however, fail to support these hypotheses.

The data suggest that promotion and education do play a role in existing mass bicycle transportation systems, but not the major role. The data in Table 5 reveal that miles of bike paths or lanes, number of bike racks, and dollars spent on bicycle promotion and education all correlate positively with the percentage of students cycling to classes. Promotion does explain more than 13 percent of the variation in the percentage of students cycling at different universities. But other variables explain

Table 2. Number of schools with mass bicycle commuting and average percentage of students cycling to class for all schools by type of bicycle access.

Type of Access[a]		Column 1: No. of Schools with Mass Cycling		Column 2: Avg Percentage of Students Cycling to All Schools[b]	
Answer	Description	HE	JHS	With Bikeways	Without Bikeways
a	Bikeway system with paths or lanes	40	54	-	-
b	Low-speed, low-volume, nonarterial residential streets	9	22	14	9.5
c	Combination of b and d	5	3	24	8.5
d	Higher-speed, higher-volume residential through streets or wide (including shoulder) moderate-speed, moderate-volume arterials	9	31	18	8.5
e	Narrow high-speed arterials without shoulders or heavily traveled, multilane arterials (or any combination that includes such arterials)	0	6	10	3
	Total	63	116	16	7

[a]Description of access type in questionnaire, which asked which description best fits the respondent's situation.
[b]Analysis of variance showed all the difference between percentage cycling with and without bikeways are statistically significant beyond the 0.01 level.

Table 3. Universities with mass cycling by moderate arterial access and no reported bike systems.

HE	Percentage Cycling	Type of Access
University of Wisconsin at Eau Claire	50	Moderate to high-speed, high-volume traffic
University of Kansas, Lawrence	45	Very congested; low speed (less than 20 mph)
University of Southern California, Los Angeles	35	Residential (apartments) to moderate arterials
Indiana University, Bloomington	30	Moderate- to high-volume arteries; lanes on campus
University of Kentucky, Lexington	15-50	Moderate speed, narrow, little room to cycle, but high level of protection on campus
Bowling Green State University, Bowling Green, Ohio	20-25	Residential to moderate arteries
Auburn University, Auburn, Alabama	15	Moderate

Table 4. Percentage of students cycling and percentage variation in cycling explained by proxy variables for relative cost of cycling, including time costs.

Proxy Variables for Relative Cost[a] (including time cost)	Mean Percentage Cycling to: HE	JHS	Percentage of Variation in Cycling that Proxy Variable Explains[b]: HE	JHS
"Approximately what percent of the student body lives on campus, or within 2-3 miles of this school?"			19	4.8
<50 percent	7	8		
≥50 percent	20	15		
"Does this school attempt to discourage automobile commuting?"			1[c]	NA
No	7.6	NA		
Yes	13.1	NA		
"What does a yearly student parking permit cost?"			0.06[c]	NA
0-$25	7.5	NA		
$26-$100	14.0	NA		
"Generally, for a student living within 2-3 miles of school, does bicycling to classes take less time than driving, parking, and/or walking?"			7.7	0.0[b]
No	6.6	13.8		
Yes	13.0	13.8		
"Does an adequate bus system provide access to classes?"			0.0[b]	0.5[b]
No	8.1[b]	9.9		
Yes	9.4[b]	17.0		

[a]From questions used in survey.
[b]Pearson's R^2 was used for numerically scaled data, su:h as percent and dollar cost, and Pearson's R and Kendall's tau for the discrete yes-no data. Although Kendall's tau represents the statistically correct procedure foı discrete data, it does not give the percentage of variation explained and it closely approximated Pearson's R. Also, the results were checked by using two statistical packages [Statistical Package for the Social Sciences (SPSS) and Statistical Analysis System (SAS)] and little difference was noted; therefore, an average wa; presented.
[c]Indicates differences or percentage variation explained that are not statistically sign ficant at the 0.05 level. Rest are significant well beyond the 0.01 level based on analyses of variance.

Table 5. Other determinants of mass cycling: percentage of total variation in cycling between schools explained (R^2).

Determinants of Mass Cycling[a]	Percentage of Variation (in cycling) Explained for HE	JHS
"Miles of paths and stripped-off lanes on school's campus (or for JHS feeding into schools)"	28	6.7
"This school has bicycle racks for approximately ________ bikes"	28	26.5
"This school and/or community spends approximately ________ dollars per year on the following programs[b] (e.g., maps and education) to promote cycling: __________."	13.5	2.2[c]

[a] Questions from mail-back survey.
[b] Answers that obviously included construction of bicycle facilities were removed or reduced to $10 000/year, which probably also includes some construction. Twenty-two HEs reported $2500 or more spent at the school or community level on programs that typically included maps, registration, bicycle clubs, bike week, and bike rodeos. Three had bicycle patrols, five reported education, and several mixed in bike racks, signs, routes, and planning in a way that could not be separated out.
[c] Not statistically significant at the 0.05 level; rest significant at well beyond the 0.01 level.

Table 6. Number of bicycle-related fatalities by location.

Fatality Location[a]	No. of Fatalities for HE: All	HE: With Mass Cycling[b]	JHS: All	JHS: With Mass Cycling[b]
On campus bike paths or lanes	2	2	5	0
On bike paths or lanes that provide access to the school	3	2	4	1
On campus streets	11	1	5	0
On streets that provide access to the school	44	15	28	10
On the general road system in the community	137	36	68	12

[a] Response to the following question, "How many bicycle-related fatalities can you recall in the last 5 years or so?"
[b] Includes separate bike system.

more. Miles of bike paths and lanes and number of bike racks explain 28 percent of the variation (Table 5), and the percentage of students who live near the campus explains 20 percent (Table 4). The direction of causation, moreover, remains unclear because increased cycling may motivate officials to spend more on safety programs, bike paths, and bike racks. Also, most institutions with mass cycling do not report any money spent on promotion and education.

Second, the data provide no evidence that culture constitutes a major determinant on bicycle commuting. Mass cycling is spread evenly over most of the country, with two or three examples from most states. Those states that did report substantially more examples of HE and JHS mass cycling represent diverse geographical regions: California, 50; Illinois, 15; Florida, 11; Wisconsin, 10; and Oregon, 7. These five states may share a similar high income, high education, and modern culture, but then why is mass cycling in the industrialized northeast, such as New York State, not found? Further, the existence of mass cycling among the university students in a community does not necessarily create a social climate for JHS students to cycle. Only about 20 percent of the JHSs have mass cycling in those communities where HEs have mass cycling, even when controlling for safe access.

Finally, the data provide no evidence that weather explains the difference in mass cycling. The questionnaire asked about the percentage of students who cycled during good weather. Some of the highest levels of cycling exist in northern schools, such as the University of Wisconsin at Madison and at Eau Claire. Moreover, some of the states that reported the most examples of mass bicycle commuting are located in the northern parts of the country that have severe winters: Wisconsin and Illinois. At the other extreme, Florida represents a climate that is too hot for commuter cycling.

Mass Cycling and Safety

The fear that mass cycling will lead to higher traffic fatality rates has focused attention on mass cycling and safety. Estimates from England put the per mile risk of a fatal accident on a bike at 10 times greater than in a car [see Everett (15) for citations to the safety literature]. The Dutch estimated a 3.5 times higher risk for cyclists (15). Many planners assume that separation, particularly with paths and lanes, will reduce this risk. However, some cyclists and planners who oppose bikeways theorize that bike paths and lanes only protect against the overtaking accident but expose cyclists to awkward positions at intersections, where most accidents occur (16).

No support for this latter position in the replicable, empirical bicycle literature could be found. There was a survey of bike club members who reported more accidents on bikeways than in the road (17). This and other studies indicate that bikeway accidents can cause serious injury (18). However, Wheatley and Cross, in their rigorous and well-funded nationwide study of bicycle fatalities (19), found that the largest group of fatal accidents (more than 37 percent of the total) entailed motor vehicles overtaking bicyclists. By definition, a separate bikeway should substantially reduce that type of fatal accident. Reports on studies in Europe (20) indicate that separate facilities reduced most types of intersection fatalities and overall fatalities.

The cross-community data also fail to support the notion that separate bicycle facilities increase the overall risk of fatal accidents. The data in Table 6 reveal that key informants recalled only 14 bicycle fatalities on separate paths or lanes for all 524 reporting schools. The informants reported that the overwhelming majority of the 307 fatalities occurred on the general road system. This, of course, may have resulted from more cycling taking place in the roads than on paths. Therefore, the number of fatalities for roads and facilities only in those schools with mass cycling and separate bike systems was calculated. It was assumed that most of the commuting to these schools takes place on the bikeways. Here the overwhelming majority of fatalities still occurred on the roads (Table 6). Moreover, the fatalities on the general road system apparently occurred on arteries or collector streets. None was reported on noncollector residential streets.

But the data, which are based on key informants' memory or record checks, remain crude. A number of respondents failed to specify the type of street where the accident occurred. For example, informants reported 17 fatalities on campus streets, but some of these included high-speed, high-volume arteries through the campus. Thus, much work remains before understanding the determinants of safe mass bicycle commuting.

DISCUSSION AND CONCLUSIONS

The data on bicycle commuting around schools across the United States tend to support the researchers' observations and hypotheses and the replicable, empirical literature. Few or no examples of mass bicycle commuting to work or shopping anywhere in the United States were found. The overwhelming majority of schools with mass bicycle commuting (10 percent or more of the students cycling to class regularly during good weather) have bicycle access separated from HSHVT. Note that separation does not necessarily mean a separate bicycle facility. Although most schools with mass cycling did have separate facilities, many relied on low-speed, low-volume, residential-type roads and 20 or so may have relied on moderate-speed, moderate-volume arteries. The bicycle also tended to provide the quickest and least expensive mode for students at schools that had mass cycling. The overwhelming majority of reported fatalities apparently took place on the arterial road system rather than on bikeways or residential streets, even when attempting to control for miles cycled.

No reasonable evidence was found to support the DOT study that hypothesized that promotion and education with minor road modifications would shift 15 to 30 percent of short-distance urban automobile drivers to bicycles for journey-to-work and shopping trips. First, only a few examples were found of mass cycling mixing with the kind of high-speed or high-volume traffic many drivers must use to reach urban work and shopping centers. Second, although dollars spent on promotion did correlate with mass cycling in this study, only a few schools reported such expenditures, and causation could run either way. Thus, no evidence currently exists that promotion or education played a major role in stimulating existing mass cycling.

This, of course, does not mean that aggressive, well-funded promotion and education along with minor road modifications could not generate mass cycling in urban areas. Theoretically, they could play an important role by making potential cyclists aware of favorable conditions, although education and promotion that point out the probabilistic hazards of cycling might substantially discourage the mode. Currently available data suggest that bicycle commuting, even with extensive education, traffic law enforcement, and separate bicycle facilities, remains much riskier than driving per mile. For example, the Dutch, who have instituted all of these bicycle program inputs, estimated the risk of a fatal accident on a bicycle at 3.5 times greater than in a car per mile traveled (15).

The preponderance of evidence suggests that bicycle planners who want to generate mass cycling generally will have to find ways of separating cyclists from HSHVT. In addition to the data, study after study (2), including sophisticated logit models (9), find that the overwhelming majority of actual and potential cyclists want separation and that separation can increase cycling substantially in certain situations. Observations of conditions under which mass cycling to work and shopping takes place in European cities suggest the same. Again, separation may involve use of existing low-speed, low-volume roads; widening of lanes and roads; or building separate bicycle facilities--a combination of all of these approaches would likely be involved.

This study does not present a tight predictive model for precise planning guidelines. First, the social costs and benefits of mass cycling are not addressed. Only the determinants of mass cycling are considered [for literature on the cost and benefits, see Everett (2)]. Second, although a correlation between the percentage cycling and inputs (such as separation, relative costs of mode, bike racks, and promotion) was found, correlation does not mean causation. Moreover, enough of the variation in cycling can be explained to build a model that would predict the impact of a change in one policy variable on percentage cycling. In some places, separation might have a strong impact; in another, changes in the relative cost of cycling might provide the greatest increase of cycling; and in yet another, promotion might be the most effective. Finally, the road, traffic, relative cost, and other conditions under which mass cycling takes place could not be precisely measured and defined.

Nevertheless, the study does isolate a number of communities for developing more precise measurements and guidelines on mass cycling. For example, on-site studies that measure the exact road types and traffic volumes in those communities where mass cycling mixes with moderate-speed, moderate-volume to congested low-speed arteries could indicate the limits of such mixing. This would provide much sounder guidelines for when to use minor road modifications or build separate bikeways than the current speculations.

Also, detailed on-site studies in these communities on safety and other determinants of cycling (such as time costs, promotion, and education) probably could yield valuable insights. The methodology description and questions in the tables provide a basis for replicating and extending the current study. (The actual questionnaires and data sets may be obtained from the authors at cost.) Although these detailed studies would require on-site data collection and cost more than the mail-back survey, they should cost less than recent government reports [such as the DOT reports (1,16)].

Discussion

Steven Faust*

Everett and Spencer state that they are attempting to identify the determinants of mass bicycle commuting in the United States. In their paper they

1. Introduce and define mass bicycle commuting,
2. Define and evaluate substantially separated bicycle facilities,
3. Determine the volume of cycling at a number of HEs and JHSs,
4. Determine modal choice and accident rates based on their data, and
5. Compare this work with the findings of the 1980 DOT study (1).

DOT REPORT

To begin with the last point, the authors have misstated both the intent and findings of the DOT bicycle energy conservation report. The mandate of this report was to develop an implementable program to conserve energy by reducing the share of trips taken by automobile in favor of the bicycle. DOT's findings support expenditures for both fixed-facility improvements as well as for education and promotion as part of a comprehensive regional transportation program. The DOT report is faulted for failing to address issues that were in fact covered, or issues, such as major capital investments, that were beyond the original mandate.

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MASS BICYCLE COMMUTING

The authors introduce a new concept to transportation planning: mass bicycle commuting. This term is defined as 10 percent or more of trips, and again later as 5 percent of vehicles, with no further explanation as to why these arbitrary figures are useful or meaningful. However, the authors also imply that this mass level of cycling is the trigger point for bestowing net social benefits on society. This, of course, presupposes that a valid cost/benefit analysis could be performed for the entire transportation system, including the bicycle mode.

Further, disaggregate data on the volume of bicycle use for all purposes are both limited and unreliable. Traffic counts omit bicycle traffic unless well-trained personnel directly observe the roadways. This is confirmed by work in such disparate environments as Boston, New York City, and Eugene, Oregon. One must note that heavily supported public mass transit ridership in cities of 300 000 population rarely reaches the 10 percent level, even for rush-hour work trips.

The authors further confuse their definition by using the term 10 percent of all traffic, without controlling for long-distance through traffic. More than 20 percent of all motor traffic in lower Manhattan's CBD is bridge traffic that connects Long Island with New Jersey. The DOT energy report focused on affecting only a portion of locally oriented traffic. No source for the authors' statement that the DOT report claims a 15 to 30 percent shift from driving to bicycling could be found.

The authors have correctly identified a need for better bicycle volume and origin and destination data. Unfortunately, the introduction of a new term--mass bicycle commuting--does not add to that data or to the understanding of events.

SEPARATED FACILITIES

The major premise of the paper revolves about the value of substantially separated bicycle facilities as the key determinant for the increase in bicycle use, including grade separation, physical separation with a bikeway, raised beam, a striped-off lane, and even low-speed, low-volume roads. These all met the authors' criteria for substantial separation. This list is so all-encompassing as to be practically meaningless for effective cross-community evaluation.

The use of a totally ambiguous definition of separate facilities results in a flaw that invalidates the analysis of reported data. Without a consistent and clear definition of right-of-way conditions, there can be no comparison of the various data collected or of the reports in the literature. Without uniform criteria, one traffic engineer's designated wide curb or bicycle lane is another's high-speed, high-volume roadway that is unfit for nonmotorized traffic. Even if the authors' generalization "that high-speed, high-vehicle traffic constitutes a serious barrier to mass cycling" were to be accepted, one cannot identify that condition or its absence from this study's criteria. The authors themselves confuse the use of separate bikeways along existing major arteries with special barrier-breaking facilities that provide totally new direct access where none existed before.

The paper cites the four Williamette River bridges in Eugene, Oregon (12) for increasing commuter cycling. Three of these bridges create entirely new gateways that cross a barrier that was otherwise at least 2 miles apart by any other route. Combined with the bridges is a riverfront path system, which is also a barrier edge route. These are site-specific, capital-intensive projects that have as much regional recreation benefits as transportation benefits. The Williamette River Greenway is far more an example of Olmstead's original linear park-parkway concept coordinated with short segments of barrier-breaking right-of-way.

Eugene is also an example of where citizen interest in cycling created a community organization that worked for more than 10 years to see these improvements put into place. Clearly, the cycling attitudes came before the cycling infrastructure.

Current bicycle design practice has attempted to move beyond simplistic rigid definitions of three classes of bikeways. The 1981 AASHTO bicycle design guidelines present a more functionally oriented approach to providing both dedicated and shared rights-of-way for bicycle travel.

ACCIDENT ANALYSIS

Bicycle accident analysis is seriously complicated by the authors' ambiguous definition of a bicycle facility. With limited exceptions, designated urban area bicycle routes either share streets with motor vehicles or with on-grade cross streets at frequent intervals. Due to limitations in police and motor vehicle department data-collection methods, virtually all accidents are reported as located on the motor vehicle roadway. Furthermore, police traffic data rarely include accident or fatality information for nonmotorized vehicle incidents. The result is that all formal accident reports will systematically underreport bicycle path involvement in bicycles-to-automobiles, as well as bike-to-bike, bike-to-pedestrian, bike-to-animal, or solo bicycle incidents.

Furthermore, the authors rely on the highly subjective memory of their respondents to document accidents. Nowhere was there discussion of whether a given accident occurred to a nonstudent such as a child, or whether the bike trip was in any way related to work or school commuting. At no point does the paper present reliable data for the volume of cycling compared to accidents at given points necessary to develop an accurate accident rate.

The authors cite European data and an Institute of Transportation and Traffic Engineering report, both a decade out of date, as solid and replicable bicycle literature. Neither European cycling nor motoring conditions are reliably transferable to U.S. urban areas.

DATA COLLECTION AND ANALYSIS

Data collection and analysis will get limited review here because, first, it is complex and detailed, and second, because both the bikeway and accident conditions are flawed; therefore, most of the conclusions are invalid.

Setting up the questionnaire to be answered by a single person opens the results to substantial uncontrollable variation. The questions themselves appear highly subjective because they focus on the respondents' opinions and memory of events.

In brief, the use of a two-page questionnaire to document detailed variables of conditions, as well as the student bodies' sociodemographic background, would appear to require some simplistic questions.

PARKING AND NON-RIGHT-OF-WAY INFRASTRUCTURE

The authors generalize from the literature that traffic conditions are a serious barrier to mass cycling. Two studies in the New York area find that safe bicycle parking is the limiting factor by more than half of the respondents, whereas traffic and roadway conditions are far less serious. In two different situations--a midtown Manhattan commuter bicycle study and a study at New Jersey commuter rail stations--commuters required safe and secure parking for any commuter cyclist. Note that secure parking was considered (i.e., lockers, not racks) unless full-time security was provided.

The authors repeatedly ignored all nonroadway facilities required to support cycle commuting. This is the same as encouraging automobile commuter park-and-ride programs by building the feeder highways and leaving out the parking lots. Commuters must expect their vehicle to be intact at the end of the day. The issue of bicycle access to commuter bus and rail park-and-ride stops was never raised in this paper. There are already substantial examples in Connecticut; New Jersey; Washington, D.C.; and the San Francisco Bay area of a shift to cycle access to transit when secure parking is provided.

CONCLUSIONS

The authors have repeatedly stated that separated bicycle facilities are the key determinant to generate a condition called mass cycling. Unfortunately, their research was not supported by real-world facts. The study has no reliable control for local bicycle volumes, a reporting bias toward roadways, a simplistic evaluation of campus transportation alternatives, and a preconceived hypothesis that a moderate-cost engineering, education, enforcement, and encouragement (4E) program would be counterproductive.

Yet the authors conclude that they could only find a correlation, but not a causal direction, between a number of relevant variables and percentage cycling. Moreover, their findings "cannot explain enough of the variation in cycling to build a model that would predict the impact of a change in one policy variable on the percentage cycling." This does not appear to support their sustained attack on the DOT report and its authors.

Although Everett and Spencer have found the DOT proposals unsatisfactory, what alternative program have they put forth? Do they propose a massive investment in a network of separate bicycle facilities, or do they propose that all encouragement of cycling be deferred until such a comprehensive system is in place? Their study fails to show how such a program can be financed, built, or maintained under current economic realities when the U.S. urban infrastructure has fallen into a state of total disrepair.

As noted before, the DOT mandate (1) was to develop an implementable and cost-effective program. To this end, Everett and Spencer's paper does not refute the DOT proposals, provide a viable alternative, or appreciably add to the body of bicycle planning knowledge.

Authors' Closure

Faust's comments excellently illustrate the vigorous and often emotional controversy that surrounds the role of separate bikeways in bicycle transportation systems. Commentators from the TRB Committee on Bicycling and Bicycle Facilities also made similar sweeping rejections of the study. Indeed, a sensitive nerve has been touched.

Planners who attempt to formulate rational, utility-optimizing transportation systems need to understand this controversy to avoid biases and distortions in the bicycle literature. It is believed that one basis of the controversy stems from special-interest group conflict. Historically, a relatively small group of cyclists often associated with bike clubs in the United States and England have vigorously opposed separate bikeways (2, p. 39). These cyclists fear law or custom would force them to use bikeways, which they consider generally slower and inferior to roadways. Their more extreme positions argue that bikeways would discourage cycling and make it more dangerous.

On the other hand, survey after survey shows that the overwhelming majority of actual and potential commuter cyclists want separation from HSHVT (a list and summary of surveys are available from the authors). This appears to imply that simply building bikeways would generate substantial safe bicycle travel. Although replicable, empirical studies suggest that a number of inputs, ranging from facilities to education, could play a role in generating increased cycling, the controversy continues to intensify.

It was hoped that the cross-community analysis of where mass cycling occurs would help end the more extreme arguments in the controversy and focus research and analysis on narrower issues such as the limits of mass bicycle and motor vehicle mixing. The vigorous opposition of the discussant, however, forces us to reconsider our work. Does it simply represent an attempt to rationalize our previously held working hypotheses? Or does it represent a reasonably sound attempt to observe systematically where mass cycling takes place and the correlates of that mass cycling?

After double-checking the data again, it was still found that mass cycling generally takes place where low-speed, low-volume residential streets or bikeways separate cyclists from high-speed, high-volume motor vehicle traffic. Continued data analysis and follow-up interviews have reduced the number of reported observations of mass cycling mixing with moderate traffic to HSHVT. Thus, the data strongly support our hypothesis, and our critics should replicate these studies if they do not have confidence in the data. However, the following analysis of each major criticism shows that a proper interpretation of the tables and text should remove most of their objections to the data.

INTERPRETATION OF DOT REPORT

Faust believes that the DOT report (1) "supports expenditures for fixed facilities." However, we strongly disagree and believe that the DOT and workshop reports (1,16) basically represent an attempt to propagate the positions of the antibikeway movement. For example, the DOT report (1, p. 33) repeats, with no support, the old argument that bikeways only help novice and recreational cyclists and do not protect cyclists at the intersections, where most accidents occur. The DOT report also recommends that the government publish a guide for state and local facilities that "would highlight the desirability of making minor modifications to the existing street system as a top priority with the construction of special bicycle facilities viewed only as a last resort" (1, p. 99). Finally, the DOT report based its conclusions on serious misinterpretations of two contracted studies [see Everett (2, p. 38) for support to this statement].

MASS CYCLING

The discussant criticizes the use of the mass cycling concept. A proper interpretation of the tables should overcome or reduce this objection. Mass cycling is defined as 10 percent or more of trips for schools, and the in-text table on bicycle commuting to HEs and JHSs refines that definition to 10 percent or more of students cycling to class during good weather. For work and shopping trips, 5 percent of vehicles along the road is used to adjust for the longer distance and through-the-city commuter (Table 1).

We do not accept the implication that one cannot generate and use bicycle volume data. First, several studies in the United States (6,7) and abroad (10) have reported such data; censuses (5) have collected the data; and we have personally made bicycle counts. Second, although the exact threshold to mass cycling cannot be agreed on (i.e., cycling that bestows net social benefits), most researchers can agree that massive cycling in college communities like Davis and Madison have substantially different impacts than the trickle of cyclists along roads in Chicago or Washington. Benefit-cost studies indicate that mass cycling generates large net social benefits, whereas a small group of cyclists may impose net social costs. Although the 10-percent-of-trips threshold remains somewhat arbitrary, changing the definitions to 5 or 15 percent of trips makes little difference in the statistical results and conclusions.

ACCURACY OF REPORTS ON SEPARATE FACILITIES

Faust's major criticism of the study involves the possible inability of respondents to distinguish consistently between the various types of bicycle access listed in the questionnaire. Although some inconsistency in categorizing bicycle access undoubtedly occurred, it could not invalidate the entire study. The range of possible accesses are quite wide--from separate paths and lanes to narrow high-speed arteries (see Table 2 for categories of access). The questionnaire explained formal bikeway systems as having separate paths or striped-off lanes. On field testing, the questionnaire respondents correctly categorized bicycle access. A large number of observations were made to help smooth out possible errors. Obviously deviant cases were double-checked with follow-up telephone calls, and the data results generally coincided with the replicable, empirical literature.

From a planning standpoint, formal bikeway systems (paths and lanes) and low-volume, nonarterial residential streets clearly characterize most mass cycling systems, whereas high-speed, high-volume arteries carry virtually no mass cycling. The middle category--moderate-speed, moderate-volume arteries--however, does create a problem. This was pointed out, 7 locations for on-site study (see Table 4) were isolated, and at least 20 others can also be shown. Analyzing this subset involves feasible, cost-effective, on-site research. Detailed questionnaires that ask for voluntary measurements undoubtedly would have suffered from low response rates.

ACCIDENT DATA

The discussant finds the accident data weak. We agree and pointed out the weaknesses. However, it was believed that the data would provide some valid insights to planners who attempt to assess controversies over bicycle safety. First, the data coincide with the informal field interviews where we could probe for bikeway relatedness. Second, the respondents overwhelmingly report fatalities that occur in the roadway, so that even considerable failure to report bikeway relatedness could still lead to the same basic conclusions. Third, no other cross-community data on bikeway versus road fatalities exist. Finally, the data coincide with other replicable, empirical studies.

The well-funded and rigorous Cross study (19), for example, found that the overtaking accident constituted the major category of bicycle fatalities (more than 37 percent). Bikeways should substantially reduce this type of fatal accident. The European studies, which find bikeways reducing intersection fatalities, remains less verifiable. Thus, only the available studies were stated in the paper, and the data failed to support the notion that bikeways increase the risk of fatal accidents. It is believed that the government reports should have looked more objectively at all the data and drawn similarly circumscribed conclusions.

BICYCLE PARKING

The discussant states that we "repeatedly ignored all nonroadway facilities required to support cycle commuting." But Table 5 clearly includes bicycle racks and promotional and educational programs and the text discusses these in the section on Other Possible Determinants to Mass Bicycle Commuting. Bike racks did correlate well with the percentage of students cycling to class, but causation obviously could run both ways. It was accepted as a reasonable proposition that, in some areas, safe bicycle parking would constitute a major determinant of mass cycling.

Bicycling interacting with mass transit and park-and-ride was not explicitly mentioned because of space and data limitations. However, it is believed that bicycles theoretically could play an important role in such systems if perceived safe bicycle access and secure parking exist. In essence, such systems could provide the short distances in congested areas where bicycles provide faster and more flexible transportation.

CONCLUSIONS

Basically, Faust takes us to task for emphasizing separate bicycle facilities as the key determinant of mass cycling and for rejecting DOT's moderate-cost 4E program.

Again, a proper interpretation of the study should reduce this criticism. Substantial evidence was found to indicate that separation from HSHVT with residential roads and bikeways correlates strongly with mass cycling. However, a number of communities were isolated where mass cycling appears to mix with moderate-speed, moderate-volume traffic and at times heavy-volume traffic. Relative cost, including time, was considered as important as separation, and considerable space was devoted to analyze cost. Evidence does suggest that education and promotion may play a role, particularly in safety, but no evidence that they play a major role could be found.

Proposing a comprehensive bicycle program is outside the scope of this paper. We believe the available evidence does not allow us to predict the impact on any set of variables with any degree of confidence. Given this uncertainty, we believe prudent bicycle planning would involve a reasonable balance of all inputs, including separation and education. Nevertheless, planners can no doubt generalize mass cycling from campuses to urban commuting without radically changing the relative costs of cycling and perceived safety by separating cyclists from HSHVT and probably from most moderate-speed, moderate-volume traffic. But there is the fear that, even with extensive education and traffic law enforcement, commuters who shift to bicycles will face substantially higher risks. To further test these hypotheses, a more detailed analysis of the limits to mass cycling and motor vehicle mixing in the communities that have been isolated is recommended.

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Statistical Cost Analysis of the Regulated Household-Goods Trucking Industry

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An investigation of whether the household-goods (HG) trucking industry, which is regulated by the Interstate Commerce Commission, will become concentrated (i.e., fewer HG truck carriers controlling a larger percentage of the industry's market) during the current deregulatory environment is presented. The likelihood of concentration is investigated by alternatively investigating the existence of economies of scale in the industry. It is concluded that the HG trucking industry exhibits economies of scale and therefore will likely become concentrated during the current deregulatory environment.

In July 1980 President Carter signed into law the Motor Carrier Act of 1980. This Act provided for deregulation of the Interstate Commerce Commission (ICC) regulated trucking industry. For example, the Act increased opportunities for new carriers to enter the trucking industry, established a zone of rate freedom, and expanded the number of commodities to be exempt from ICC regulation. One type of ICC truck carrier that was excluded from the Act was the household-goods (HG) carrier. Given the unique nature of HG carriers, regulatory reform for these carriers was considered by Congress apart from the Motor Carrier Act of 1980. In fall 1980 the Household Goods Transportation Act of 1980 was passed by Congress. This Act reduced unnecessary government regulation of HG truck carriers and furnished additional pricing options for the carriers and their customers.

An investigation of whether the deregulated HG trucking industry will become concentrated (i.e., fewer HG truck carriers controlling a larger percentage of the industry's market) during the current deregulatory environment is presented. The likelihood of concentration occurring in a deregulated industry has traditionally been investigated by