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The Determinants of Mass Bicycle Commuting Revisited

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ABSTRACT

In an earlier paper we found that mass bicycle commuting (10 percent of trips or more in an area) required separation from high speed-volume (SV) motor-vehicle traffic along with other conditions--commuting distances under several miles and trip times for bikes similar to or less than for cars. The present paper reports on follow ups on U.S. anomalies (i.e. reports of mass cycling mixing with moderate to high SV traffic) and the development of a regression model of mass bicycle commuting as a function of type of access and other key variables. The paper also provides estimates of threshold traffic levels which may inhibit mass cycling. The paper finds that cyclists in the anomalies had protection from high SV traffic by using sidewalks with curb cuts and low SV residential and campus roads. The regression model of mass bicycle commuting supports the above paradigm for mass cycling in U.S. and suggests it may occur where bicycling provides faster transportation than driving, trips are short, and access on low SV roads or bikeways exist. We estimate a SV threshold barrier for mass cycling at 33 mph and 300 cars per lane per hour, although combinations of road characteristics may raise or lower this threshold.

THE DETERMINANTS OF MASS BICYCLE COMMUTING REVISITED

Considerable agreement exists that mass bicycle commuting could generate substantial economic, environmental, and health benefits particularly for short trips in congested areas (Everett, 1977) such as to schools, central business districts, and mass transit terminals (Replogle, 1983). Consensus also exists that transportation mode choice depends on relative cost including time costs and other more difficult to measure forms of disutility. Everett (1974) cites the economic literature and demonstrates how bicycle time costs usually swamp vehicle savings to explain the general lack of commuter cycling in the United States (U.S.). Numerous surveys indicate that fear of traffic constitutes another important form of disutility for the bicycle mode. See Everett (1982) for a review of this literature.

Thus, we would expect mass bicycle commuting (10 percent of trips to a local destination)[1] to occur in areas where bicycles have protection from perceived "dangerous" traffic and provide faster more convenient transportation than cars. In the U.S. public schools and universities have provided good examples of these conditions. Trips are often short, most public school children are too young to drive, and many universities have restricted student parking and become so congested that the bicycle provides the most rapid and convenient mode to classes. Also schools often have low speed-volume (SV) residential streets surrounding them to provide perceived "safe" access for bicyclists. On the other hand, commutes to central and satellite business districts are generally longer and most cyclists would have to mix with high SV traffic.

Aside from the political problems in restricting cars, the major controversy over this paradigm involves the role of bikeways (paths and lanes in the road). Some major recreational bicycling organizations have opposed bikeways vigorously because they may lead to a dejure or defacto restriction of cyclists from the road. Some of these groups argue that bikeways actually will discourage bicycling by slowing bicyclists down.

On the other hand, in a study of over 200 U.S. college communities we found that mass cycling takes place in areas separated from high SV motor-vehicle traffic via low SV residential and campus streets or separate bicycle facilities (Everett and Spencer, 1983). That study, however, did isolate seven college communities with apparently high levels of cycling (15-50 percent) on moderate to high SV arterials (p. 30 and Table 3). The study urged closer analysis of such anomalies to ascertain the threshold levels of motor-vehicle traffic which may act as barriers to mass bicycle commuting.

The present paper refines and extends the 1983 study to focus on the limits to mass cycling mixing with motor-vehicle traffic in the U.S. After reviewing the 1983 study, the paper presents revised data on the seven anomalies. Then the paper retests the relationship between type of access and mass cycling and develops a planning model of the major determinants of mass bicycle commuting including relative time costs. Finally, the paper generates quantitative estimates of thresholds for high SV traffic which may act as barriers to mass bicycle commuting.

SYNOPSIS OF THE 1983 STUDY

The 1983 study focused on commuter cycling during good weather in college communities. We sent questionnaires to institutions of higher education (HE), junior high schools (JHS), and traffic engineers (TE) in all the U.S. communities with 2 or 4 year colleges and populations of 300,000 or less. Including follow ups the response rate exceeded 50 percent and yielded data on over 200 HE and 300 JHS.

The study found or estimated a number of examples of mass bicycle commuting to schools throughout the U.S. but very few examples for work and shopping (Table I). The low-side estimates represented actual responses and high-side estimate came from extrapolations to the entire population of college communities. The 1983 study also provided other evidence that mass cycling did not occur outside of such college communities (p. 29).

TABLE I

Percent of Trips By Bike During Good Weather

Percent Cycling	Higher Ed	Junior HS	Work	Shopping
0-4	103-137	132-259	25-43	10-17
5-9	42-56	57-112	5-9	3-5
10-19	31-41	60-118	1-2	0-0
Over 20	32-43	56-110	0-0	0-0

Table II suggests that separation from high SV traffic constitutes a necessary condition for mass cycling–only 6 JHS reported mass cycling using high SV roads and follow ups revealed that students crossed, rather than cycled along them. Table II also suggests that low SV, nonarterial residential type streets or bike paths and lanes constitute an important, if not necessary, condition for mass cycling. Over 75 percent of the schools with mass cycling reported it took place in areas with such access.

Nevertheless, a number of schools reported mass cycling with access including moderate SV arteries (C or D in Table II), while seven HE anomalies reported very high levels (15-50 percent). Unfortunately, the 1983 data did not provide quantitative estimates of traffic speeds and volumes which created thresholds between perceived "safe" and "dangerous" access.

Separation from high or moderate SV traffic did not constitute a sufficient condition for mass bicycle commuting. The type of access explained only about 20 percent of the variation in percent cycling (p. 30). Proxy variables for the relative cost of bicycle commuting such as distance and relative speed of cycling explained about 25 percent. Bicycle parking and education or promotion also correlated with percent cycling but causation could more easily go either way and few examples of bike education existed.

MODEL OF DETERMINANTS OF MASS BICYCLE COMMUTING

The present study revised and recoded the 1983 data set to develop a useful model for bicycle transportation planning. To revise the data set we visited five and corresponded with two of the higher education (HE) anomalies (college communities with high levels of cycling and only moderate to high SV access roads) in the data set to double check percent cycling and access type. We drove and cycled the access routes extensively but were not able to do systematic traffic counts during peak bicycle commuting periods. We also double checked the overall data set for possible errors, recontacted schools with questionable data, visited several new schools, and checked with key informants (e.g. Freeman, 1989) on possible new areas of mass cycling particularly to work and shopping in large urban non-university communities.

We found that the U.S. HE anomalies did have substantial defacto separation for bicyclists. The access at all the schools fell mainly into categories A or B (bike facilities or low

TABLE II

Number of Schools With Mass Cycling By Type of Access

Access choices on questionnaire	HE	JHS
A. Bikeway with paths or lanes	40	54
B. Low SV nonarterial residential streets	9	28
C. Combination of B and D	5	3
D. Higher SV residential through streets or wide (including shoulders) moderate SV arteries	9	31
E. Narrow high speed arteries without shoulders or heavily traveled multi-lane arteries (or any combination of access which includes such arteries	0	0
Total mass cycling	63	116

SV traffic) rather than C, D, or E (moderateto high SV traffic) in Table II. Although moderate to high SV arteries often surrounded these campuses, cyclists generally used side streets, sidewalks with curb cuts, and relatively protected campus streets for access to classes. Moreover, we still could not find examples of mass cycling for work and shopping.

Next we recoded the data to construct a linear regression model for percent cycling to HE classes during good weather as a function of ACCESS, BIKEFAST, and LIVCLOSE (Equation 1). The six access types from Table II fell into two groups--perceived safe (bike system, low SV residential streets, or a combination including some moderate SV streets) and perceived unsafe (moderate to high SV access). We also recoded bikefast into 0 (equal to or slower than driving) and 1 (faster than driving). Finally, we collapsed 14 cases of HE mass cycling exceeding 30 percent down to 30 percent to remove extreme values which very few schools could achieve.

PERBIKE = -2.8 - 6.5ACCESS + 3.1BIKEFAST + .14LIVCLOSE (1)
R sq=.34 (1.4) (1.2) (.02)

Where:

PERBIKE = percent of students cycling regularly to class during good weather.
ACCESS = 0=no bikeways and moderate to high SV roads (D and E in Table II); 1=bikeway, low SV residential roads, or a combination of low and moderate SV roads (A,B,or C in Table II).
BIKEFAST = 0=bike slower or equal to car; 1=bike faster than car.
LIVCLOSE = Percent of students living on campus or within 3 miles.
( ) = Standard errors.

The model closely predicts actual HE average percent of students cycling under various conditions (Table III) and supports the hypothesized determinants of mass cycling: With separation from high SV traffic, cycling faster than driving, and a substantial percent of the students living within 2 to 3 miles of classes, about 18 percent of HE students cycle on the average. Without these conditions less than 10 percent of the students cycle on the average.

The model, however, only "explains" 34 percent of the variation in the percent cycling between schools. Thus, as the standard deviations (SD) in Table III indicate, the actual percent cycling at any individual school could deviate widely from the average. For example, even with ideal conditions seven schools (33 percent of the subset) did not have mass cycling. Similarly 17 schools (20 percent) with perceived safe access reported bikes slower than cars and still had mass cycling. We could find no schools who had perceived dangerous access and mass cycling (i.e. access solely on moderate or high SV arteries).

TABLE III

Predictions of Percent Cycling Compared To Average Percent for Different Determinant Values

Determinants of Cycle			Average Percent Cycle			
Access	Bikefast	Livclose	Predicted	Actual	SD	N
0	0	<50	-.7	2.0	2.4	40
1	1	>50	17.9	18.3	11.0	32
1	0	33	8.2	7.7	9.0	87
0	1	33	4.9	3.0	2.6	9

For defintions of variables see equation 1. SD = Standard deviation, N = number of cases.

Adding bike racks, miles of campus bicycle systems, and money spent on bicycle education programs to the model (Equation 1) increases the R squared. We do not include these variables for several reasons. They correlate too highly with other independent variables. Only a few schools reported money spent on education and promotion programs. Moreover, the direction of causation remains unclear. The model, however, assumes safe bicycle parking exists.

THRESHOLD LEVELS OF SPEED AND VOLUME

This section attempts to provide quantitative estimates for the moderate SV arteries which seem to form thresholds between perceived safe and dangerous access and mass cycling. Since consumers often cannot accurately tell how heavily they weigh product or transportation mode characteristics, such as traffic speed and volume, researchers often ask consumers to rank products in terms of probability to use. Researchers can then estimate the average probability to use and infer the weights using statistical models (e.g. Green and Scrinivasan, 1978).

Thus, we developed a short questionnaire asking college students to rate the probability they would cycle to class during good weather under the following assumptions: 1) They lived within 2 miles of campus; 2) A bike provided the fastest transportation to class; 3) Bikeways or low SV residential roads provided "safe" access over the entire route; and 4) Safe bicycle parking existed. The probability ratings used a 5 point scale where 1=no, 3=maybe, 5=yes. If students indicated they might (3) or would (4,5) cycle to class under those conditions, we asked them to rate the probability they would cycle to campus on 10 specific roads ranging from residential to major four lane arteries, all of which existed around the campus.

We administered the questionnaire to 100 students in two sophomore economics classes at East Tennessee State University (enrollment 12,000) in Johnson City, Tennessee (population 40,000; trade area over 100,000). Seventy eight percent said they might or probably would cycle to class under the ideal conditions listed above and went on to rate different types of roads. That yielded 750 useable road ratings. Although very little commuter cycling presently takes place in the area, 62 percent of the students reported they had at least moderate bicycle commuting or touring experience and 11 indicated racing experience.

Table IV describes the 10 types of roads and the students' average stated probability to use each road type (column 3). The students strongly indicated they would not use four-lane arteries or most two lane collectors with moderate SV traffic. They would use low-speed or low-volume campus or residential type roads. Even though some of these roads had moderate to high volumes of traffic they had low speeds around 20 mph. The author's estimate of the probability that mass cycling would occur on such roads, based on over 20 years of experience and observation, closely paralleled the students' ratings in Table IV.

A multiple regression analysis of the data in Table IV with probability-to-use (PROBUSE) as the dependent variable and speed and traffic volume per lane per hour as the independent variables yielded equation 2 below. The coefficients for VOL (cars per lane per hour) and SPEED (mph) indicate how heavily the students weighed those variables in arriving at a probability that mass cycling would occur on a particular road.

TABLE IV

Road Description and Stated and Predicted Probability That Students on the Average Would Use the Road for Commuting To Class

Type of Road	Vol Per Lane/Hr (1)	Speed (mph) (2)	Probability Rating (3)	To Use * Projected (4)
Four Lane Arteries				
Commercial Strip w/Shoulders	650	43	1.1	1.5
Tree Lined Boulevard w/Curbs	575	45	1.7	1.5
Light Commercial By U w/Curbs	400	43	1.8	2.0
Two Lane Collectors				
To Student Apartments w/Curb	300	38	2.2	2.6
Com/Industrial, w/Wide Lanes	250	40	2.7	2.6
University Access Rds w/Curbs	150	35	3.3	3.2
Low Vol and/or Speed Roads				
Rural Type by Athletic Field	100	33	3.4	3.4
Interior Campus Roads	300	20	3.8	4.0
VA Hospital Rds w/Parking	200	23	4.0	4.0
Residential Oneway w/Parking	50	28	4.4	3.9
Threshold Speed/Vol				
Threshold	300	33	3.0	3.0
Above	400	37	2.4	2.5
Below	250	30	3.5	3.3

ADT = average daily traffic in thousands
*1 = No; 3 = Maybe; 5 = Yes.

$$PROBUSE = 6.12 - .0022VOL - .076SPEED \quad (2)$$
$$R\ SQ = .34 \quad (.000) \quad (.007)$$

The model projects probability to use ratings (column 4 of Table IV) which closely approximate the students' actual average ratings. The model allows us to generate a hypothetical SV threshold of 300 cars per lane per hour and 33 miles per hour (bottom of Table IV).

Student bicycle commuting and touring experience had little impact on threshold speed and volumes or probability to use roads above threshold. Students with moderate experience gave hypothetical threshold speed and volume roads an average 3.25 probability to use versus 3.00 for all students. These more experienced cyclists, however, gave virtually the same average probability to use above threshold roads as the inexperienced cyclists (1.75 versus 1.72).

Theoretically other road characteristics such as number of lanes and lane width also should affect threshold levels. To test these the author estimated the probability that mass cycling would occur on 91 different roads with widely differing characteristics in Johnson City. Multiple regression analysis of these data indicated that two lanes of traffic in one direction increased the thresholds but wider lanes did not. The existence of alternative routes with lower traffic and similar distances substantially lowered the thresholds. An ample parking lane or shoulder raised the thresholds while a noisy, polluted, commercial or industrial environment with much turning traffic lowered them.

These other road characteristics had less impact than speed and volume. For example, the four lane commercial strip artery in Table IV had a wide, little used parking lane which provided ample room for cyclists. Apparently the high SV and frequently turning traffic swamped this positive characteristic. We would need a much larger data set with more raters to generate reliable quantitative estimates of these other characteristics and their importance relative to speed and volume.

DISCUSSION

The data in this study supports the basic paradigm for mass bicycle commuting presented in the introduction of the paper. We continue to find mass cycling in the U.S. primarily to schools with access along low SV roads and separate bicycle facilities. We can find few examples of mass cycling to work and shopping, which generally would involve using moderate to high SV roads (Tables I and III).

Separation from high or even moderate SV traffic, however, does not constitute a sufficient condition for mass cycling. Like other transportation mode choice studies the relative cost (including time cost) constitutes a determinant of bicycle commuting (Equation 1 and Table III). Where campuses restrict driving and parking and a large portion of students live within 2 to 3 miles, the bicycle often provides the quickest, most convenient mode to classes. The model also assumes safe bicycle parking exists.

Thus, despite its crudeness the cross community regression model (equation 1) supports the paradigm for mass bicycle and may help provide rough guidelines to planners wishing to shift commuters from cars to bicycles for school, work, shopping, and recreation:

1. Concentrate on commutes under three miles and focus on areas where congestion or existing (or feasibly implemented) car restrictions make bicycles relatively fast. Beside school trips, trips to mass transit stops and short trips to satellite shopping and business areas may have potential for satisfying these conditions.

2. Break high to moderate SV access barriers with separate facilities or connecting residential roads. For example, use a net work of low SV roads where possible but hook them up with separate bike paths when necessary to avoid high and even moderate SV roads.

3. Build safe bicycle racks and provide responsible information on routes and safe cycling which indicate the dangers (e.g. Cross, 1978) as well as benefits of cycling.

We estimate that traffic becomes a barrier to mass cycling in the U.S. when it approaches 300 cars per lane per hour (or roughly an average daily traffic flow of 4,000 to 5,000 cars for the entire road) and 33 miles per hour (Table IV, Equation 2). Cycling experience and other road characteristics such as wide shoulders could raise these thresholds. Given our observations and data, however, we still conclude that mass cycling in the U.S. probably requires access either on low SV roads or separate bike paths and lanes. If speeds are very low, around 20 mph, mass cycling may tolerate moderate volumes of 200 to 300 cars per hour. Or if volumes are low (under 150 cars per hour) moderate speeds around 30 mph may allow mass cycling (Table IV and equation 2). Obviously these hypothesized levels and thresholds need testing in a number of other communities.

Finally, the existence of such access and even short distances and relative high speeds for bikes will not assure mass cycling. The model only gives average percent cycling, and numerous individual areas deviate substantially from these averages. Thus, if an area has potential for fitting these theoretical conditions, planners should also make low cost surveys, like the ones described above (Table IV and equation 2), to estimate the probability for actual and potential cyclists to use the system. Such surveys might also indicate any other barriers to mass cycling and help avoid the fallacy of applying average outcomes to specific locations.

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ENDNOTES

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1. Mass cycling involves enough persons cycling to generate perceptible social benefits such as reductions in congestion, air pollution, and transportation costs. The designation of 10 percent or more of trips in an area as "mass cycling" remains somewhat arbitrary. Only a few cyclists, however, may actually impose more costs than benefits on society by slowing traffic without perceptibly reducing air pollution, space, devoted to parking, and other social costs of driving.

2. Universities of Wisconsin at Eau Claire, Kansas at Lawrence, Indiana at Bloomington, Kentucky at Lexington, and Bowling Green State University in Bowling Green, Ohio.

3. Auburn University and University of Southern California at Los Angeles.

4. Logit or probit models express the weights as elasticities which provide a more accurate weight over a wider range of values for product and transportation mode characteristics. These models, however, remain difficult and often expensive to use. Regression provides a much easier-to-use, first-cut approximation to the weights even for qualitative variables (Amemiya, 1981).