THE EFFECT OF BIKELANE SYSTEM DESIGN UPON CYCLISTS' TRAFFIC ERRORS

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INTRODUCTION

Various attempts have been reported to describe cyclists' behavior, sometimes in quantitative terms, for purposes of driver qualification, highway design, traffic law enforcement, and athletic coaching. Aside from athletic coaching and the informal evaluation of one cyclist by one or more others during many club rides, which are usually done accurately and comprehensively, all reported systems of cyclist evaluation are seriously deficient. This paper first describes, in the context of present practice, a cyclist behavior recording system suitable for evaluating either individual cyclists for proficiency or a population of cyclists for cycling behavior. It then discusses the results of evaluating the behavior of 4 different cyclist populations in cities with 3 different types of bikeway system, showing that cyclist behavior varies according to the type of bikeway system. Specifically, when comparing the behaviors of populations of cyclists from different cities whose bikeway systems have different design characteristics, each population shows a higher proportion of those traffic errors which the particular system design would be presumed to encourage, even though those errors are known to be significant causes of car-bike collisions.

EARLY CYCLIST-BEHAVIOR EVALUATION SYSTEMS

The type of evaluation most commonly used in the U.S. is the stationary, single observer, who observes the behavior of cyclists passing a point, generally according to a very restricted set of variables, part of which may be a classification system based on a few immediately-understandable visual cycling characteristics, such as general type of bicycle and age or sex of cyclist. This system is both defective and limited. It is defective in that the critical portions of many cyclist maneuvers, and many maneuvers themselves, do not occur in front of the observer. For example, an observer stationed to observe an intersection often cannot see whether a cyclist properly performed the intersection approach maneuvers, and these are critical to the safety and acceptability of the cyclist's actions. Also, only the most obvious cyclist characteristics can be observed as the cyclist goes by. The system is limited in many ways. Many maneuvers do not occur at predictable locations, so their observation cannot be planned. It is commonly believed that different types of cyclist exhibit distinctly different patterns of behavior, but this system does not permit the multiple observations of a single cyclist required to validate this hypothesis. The system cannot evaluate the performance of a single cyclist to serve as a competence test. Even though the observations may be made at many locations according to an elaborate plan, there is no assurance that the maneuvers or situations observed constitute an unbiased estimate of the actual proportions of all types of maneuver that are performed by the population of interest. These defects are equally detrimental whether the observer records contemporaneously or at some later time through a visual recording system, be it electronic [what is now called video], photographic, or any other.

Cycling proficiency tests are given to a large proportion of the adolescent population of cycling-oriented European nations using the multiple, stationary observer technique. A fixed course is laid out, observers are stationed at presumably critical points, the cyclists are each identified by a conspicuous number, and are dispatched at intervals to ride the course. The observers evaluate each cyclist in turn, recording the evaluation by cyclist number. Common though this system is, it is not ideal even for evaluating individual cyclists because the specific traffic situation necessary for evaluation may not occur during the single pass through the observing location, and in any case it cannot serve the scientific purpose of evaluating populations of cyclists in their actual maneuver proportions.

Several American investigators have trailed cyclists with a car, recording the results. This is unsatisfactory because the slowly-moving car blocks the overtaking motor traffic with which the cyclist should be interacting, thus destroying the normal traffic pattern.

IMPROVED CYCLIST-BEHAVIOR EVALUATION SYSTEM

The observer who follows by bicycle, however, does not disturb the traffic pattern. Neither does he disturb the typical American cyclist who has not been informed that he is being observed, because the typical American cyclist doesn't look behind in his typical urban trip. (That's one reason for the excessive car-bike collision rate.) In a proficiency testing situation, the observer can direct the course of a small group of cyclists (up to about 8) until he has obtained all the observations that he requires for complete evaluation. In a population evaluation situation, if the observer selects a cyclist, follows him to either his destination or the boundary of the observation area, and then returns toward the center of the area until he sees another cyclist to follow, he will select cyclists in a substantially random pattern and will observe the actual mix of cyclists. The problem is how to record the observations while cycling.

A cyclist cannot write while cycling, and probably cannot accurately push buttons in a digital coder. But he can talk, and a portable tape recorder can record the observations for later tallying. The portable recorder is best carried in a small backpack, with its microphone clipped to the shoulder strap near the cyclist's mouth. (This type of microphone is called a "lapel mike" and is easily available.) The remote control circuit is wired to a pushbutton which is mounted on a thumb stall that is secured to the cyclist's thumb by a bandage-like strip of cloth with hook and pile fasteners. (Pushbutton Electrocraft 35-418, for printed circuit boards, is a comfortable shape. Mount it on the thumb stall with silicone sealing compound.) The observing cyclist then pushes the button whenever he wishes to record, so the tape runs only when he is actually recording. This conserves batteries, tape and subsequent tallying time. I have found that a 30-minute recording (one side of a C-60 cassette) is sufficient for an 8-hour observation period in a college city.

In order to both have a common scoring method and to be able to tally from recorded oral observations it is necessary to have predetermined names for most traffic maneuvers and their errors. The cyclist proficiency score sheet (Figs 1 and 2) lists almost every cyclist traffic maneuver and its typical errors. With these names in mind, the observer merely records the maneuver name, and evaluates it as either "OK" or lists the errors made. Any characteristics not on the score sheet may also be recorded, and the evaluation later adjusted accordingly. Score values are shown on the sheet, but it is not the purpose of this paper to discuss scoring. It considers only the observed proportions of defective maneuvers and the typical errors. The standard of behavior used as the criterion is that described in *Effective Cycling*. (1, §3) Those maneuvers listed on the score sheet that affect other traffic are easily distinguished and observed. Only a few of the deficiencies observed present significant problems of detection or evaluation. All of the maneuvers that showed statistically significant frequency differences in this study present no significant problems of detection or evaluation. The observed cyclist action clearly either does or not exhibit the deficiency in question. This scoring system ignores cyclists who ride on sidepaths or on the wrong side of the road. Their actions are so universally wrong that they cannot be rated against the standard.

OBSERVATIONS USING THE IMPROVED SYSTEM

Using this technique the cycling populations of three California university cities with different bikeway characteristics were evaluated, and were compared with a population of typical club cyclists. All observations discussed herein were made by the author on normal business and academic weekdays in fair weather. The cities are: Berkeley, Davis and Palo Alto. All three cities have universities of high repute, with approximately equally-intelligent students. Their street and traffic situations are different, resulting in different bikeway system designs. Berkeley has relatively narrow streets with moderate to heavy traffic volumes. In some areas it is so hilly that downhill bicycle speeds exceed those of the cars, but few cyclists are seen there. It has no significant bikeway system. Davis has wide streets with low traffic volumes, practically no externally-generated traffic, and an unhurried motorist attitude. Davis has bikelanes on its wide arterials, but not on its normal residential streets. Davis also has its bikelanes positioned between right-turn-only lanes and the curb, at those locations where there are right-turn-only lanes. Palo Alto has a combination of easy, low-volume traffic on its residential streets and moderate to heavy traffic from other areas on its arterial streets, which are nearly all too narrow for bikelanes. It has placed its bikelanes upon its residential streets, where they are obstructed by stop signs at 50% of the intersections. The club cyclists all lived and frequently cycled in the Palo Alto area, and their behavior was evaluated in a ride traversing the cities of Menlo Park, Palo Alto, Mountain View and Los Altos. However, their cycling behavior does not change from place to place, because they ride proficiently wherever they may be, and regardless of the type of bikeway system provided. California, it should be noted, does not have a mandatory bikepath law.

SAMPLE SELECTION

None of these groups is a control group, for it is extremely difficult to obtain and to use control groups in this type of investigation. The difficulties are many. Experiments involving control groups require samples either matched for all relevant characteristics or samples selected without bias from the same population. The experimental factor must be applied to only the specified groups in a logical manner. All groups must then be subjected to the same procedure and test. In this investigation one postulated effect of bikeways is to develop a new, larger and less competent cycling population. (At least, that is the effect that is claimed and desired by bikeway advocates, and the lower proficiency was observed herein.) While important knowledge may be gained by observing, as reported herein, that the behavior of a population of competent club cyclists is unaffected by the presence or absence of bikelanes, it is also mandatory to observe the behavior of the population that actually uses the bikelane system. Matching the cycling populations for experience or for other factors would invalidate the investigations of the cycling behaviors of the populations that are actually attracted by the particular facility types. Even if matching were desirable, the appropriate match would probably be between those portions of the total populations in the areas of interest which are reasonably equally susceptible to using cycling transportation, a condition which is substantially impossible to achieve, even in these areas which are probably much more similar than areas randomly selected from the entire U.S. Furthermore, the experimental factors cannot be applied to each group in a systematic way, because the factors are not under the experimenter's control. He must accept them as they are applied by entirely unassociated entities. The experimental populations could be placed under the experimenter's control, so he could move them to locations where the different experimental factors exist, but that would invalidate the experiment by destroying normal transportation habits, as discussed below. Lastly, the test conditions are different for each group. The scoring system is the same, but the operating conditions are not. They are unique to each area. Suppose a standardized test were developed, for example by requiring each cycling population to travel to another city in which none of the test populations normally rode. While something might be learned through such a test, it would not and could not be a measurement of the behavior in the actual conditions. Transportation is largely an habitual activity. Were an experimenter to move groups of subjects around to different areas in accordance with an experimental plan, the subjects would behave differently than they do in their normal transportational activity. In short, despite the scientific ambiguities produced, the investigator must accept the composition, location, and environment of the subject groups as they exist.

The groups were selected not in accordance with an experimental plan, but as exemplifications of different situations which have been deemed significant in the bikeway controversy, with as much similarity in other conditions as could be reasonably attained. Davis is universally accepted as the bikeway capital of the United States, and, like many such places, serves a university clientele. Palo Alto is widely considered to exemplify bikeway systems for employed adults, with some university participation. Furthermore, these two exemplify two different bikelane system design concepts: arterial street bikelanes contrasted with residential street bikelanes, but each is in a suburban setting in which bikeways were easy to install. Berkeley exemplifies the metropolitan university situation in which traffic is heavy but bikeways are difficult to install and are practically insignificant. All these areas have high cycling volumes by U.S. norms. The population of club cyclists was selected as exemplifying the normative standard of safe, legal and proper cycling, and the safety standard of being the group with the lowest known accident rate. That these groups are all in Northern California is not entirely due to the fact that the investigator lives there. Had Gainesville, Florida, been selected to exemplify university sidewalk cycling, the enormous difference in cyclists' social status and training between Northern California and Florida would have been injected into the investigation. In my opinion, California, particularly the north central portion, presents the best investigative location in American cycling, because the combination of intense cycling activity (by U.S. norms) and widespread governmental involvement has exposed a relatively homogenous (again, by U.S. norms) cycling population to practically every type of facility, stimulating both cycling and engineering competence to an unusual degree.

The city cyclists were selected by a random process that selected cyclists with a probability proportional to the time that they spent cycling in their area on the days of observation, which were normal business and academic weekdays in fair weather selected by the happenstance of the observer's convenience. In all substantial respects this is a random sampling of the cycling activity within each area.

The club cyclists were arbitrarily selected by the process of observing all those that showed up at the start of a regularly scheduled weekday urban touring ride with a scheduled duration of 2.5 hours. There is no reason to suppose that they are not representative of club cyclists in general, and observation shows no characteristic in which they are unusual. They were told that the observer, who is a frequent cycling companion of theirs, would observe their riding events and record his observations on voice tape. The leaders were asked to take a route to their destination that had more traffic and more difficult spots than the normal route, and the observer rode at the rear and for less than 4 minutes in a 2-hour ride spoke into his lapel microphone in a tone that very few of the riders ever heard. The club cyclists rode much of their route in far more difficult traffic conditions than were observed for any of the city cyclist populations.

CRITICAL CONCERNS IN SAMPLE SELECTION

These differences in test conditions may suggest to some that the club cyclists' performance is therefore not comparable to the performances of the others, an objection that is obviously appealing to those who think that their performance is too good. This objection is pertinent only on the interpretation that the club cyclist performance represents an estimate of the average performance of a trained population. If it is taken simply as a demonstration that the normative standard assumed by the rating system can be met and maintained under difficult conditions for substantial periods of time, it doesn't matter whether the club cyclists knew they were being observed or not. Observation cannot make the impossible possible.

If, however, the club cyclist performance is taken as an estimate of the performance that would be achieved by a trained population in normal cycling transportation, then the significance of the bias introduced by the three known differences must be estimated. Since the only behavioral differences between populations that were detected and are discussed in this paper are those associated with left turns and lane changes by cyclists, positioning of cyclists with respect to right-turning cars, and the behavior of cyclists at stop signs, the estimation of bias need cover only these maneuvers. In this case, bias can only exist in one way: the club cyclist performance could not get significantly better. Thus the assumption of bias requires the additional assumption that in the absence of observation the club cyclists usually turn left or change lanes leftwards from the curb lane without looking, position themselves on the right-hand side of right-turning cars, and run stop signs without slowing or looking. This assumption is highly improbable. Since the club cyclists were riding and talking about other matters, they were riding by habit, without conscious notice of the observer. Not only was this obvious to the observer, but the cyclists volunteered this information during discussion at the end of the ride. If their habitual cycling styles were different from that observed, these habits would have betrayed them at least some of the time, something that did not occur. I, the observer, had spent at least several hundred hours riding with club cyclists, singly and in groups, in urban traffic, before consciously deciding to record their behavior, and I noticed no significant difference between observed and unobserved behavior. Since the greater part of the behavioral differences are merely the action of looking for the traffic pattern and conforming to it, so the cyclist can preserve his life at no cost to himself, it is irrational to expect that cyclists who have learned how to do this would largely forgo the opportunity to do so merely because they are unobserved.

The assumption of less competent, more dangerous behavior when unobserved is also denied when considering the source of the putative more competent behavior. The cyclists observed had no advance knowledge that they would be observed, and therefore had no opportunity to specially learn good technique. Nearly all had had no formal cycling training of any type. (One had participated in an Effective Cycling class; he did not lead the group, nor did he behave differently from the others.) There is no possibility that they could have learned the skills that they displayed from any of the bicycle safety campaigns to which they undoubtedly had been exposed, because no such campaigns consider the necessary skills that are displayed and are discussed herein. The only possible source for their skills is the practice of club cycling. Therefore, they must have been exhibiting normal club cycling behavior, which contradicts the premise that they were exhibiting better-than-club-cycling behavior.

The car-bike collision statistics also contradict the assumption that the club cyclists behaved unusually well because they knew that they were being observed. Cross's car-bike collision statistics, as analyzed by Forester (2, 56 ff) show that cyclists learn how to avoid car-bike collisions that are caused by not looking and not conforming to traffic, because these constitute a decreasing proportion of car-bike collisions as the ages of the cyclists increase. Without observation, cyclists improve with experience; there is therefore reason to believe that these experienced cyclists would be better than average, which is what the data show.

CALCULATIONS

The number of cyclists in each location and the extent of the evaluation, as shown by the number of earned points, are given in Table 1. The points lost and average score are given for rough comparison. Note that the number of earned points per cyclist varies. Only 8 club cyclists were evaluated, but their total earned points exceed those of the 71 Davis cyclists. The earned points per cyclists varies with the length and complexity of the trip, which in the random sampling situation is entirely controlled by the observed cyclist.

For each cyclist each traffic maneuver and its errors, if applicable, were tallied on a proficiency score sheet. These tallies were then summarized onto a sheet for each group which listed, for each traffic maneuver, the number of performances and the number of times it was done incorrectly. Seven types of maneuver showed a sufficient number of instances with sufficiently different proportions defective to indicate statistically valid differences in behavior between populations. The statistic used to determine significance is the formula for the normal distribution of differences in proportions:

z= { p1 - p2 } / SQRT { p(1-p)({ 1/ n1 } + 1/ n2) }

STATISTICALLY SIGNIFICANT DIFFERENCES IN BEHAVIOR

The data for those maneuvers that have statistically different proportions defective between the various locations are shown in Table 2. The types of errors in these maneuvers are shown in Table 3. The differences that are statistically significant in proportion defective between locations are shown in Table 4, listed as showing either 95% or 99% probability that the populations indeed behaved differently.

The maneuvers may be grouped as:

1 Yielding to traffic at an intersection that is controlled by a stop sign or a traffic signal.

2 Cyclist making a left turn, including the lane change and the turn.

3 When motorist may turn right, including the cyclist avoiding the right-turn-only lane, approaching the intersection, and getting on the right-hand side of a moving car.

These are very important maneuvers. According to Cross's urban data (1, urban data only), cyclists running stop signs or signals cause 14% of urban car-bike collisions; cyclists turning left cause 9%; motorists turning right cause 7%.

For traffic signals, Berkeley cyclists are statistically the worst, but this is because of one traffic signal at a main campus entrance at which cyclists proceed on a 4-way WALK signal. Considering the American situation, they should not have been considered deficient, because 4-way walks are often intended for cyclists even though this is against the law.

At stop signs, Palo Alto cyclists are significantly much worse than all the others, and the typical error is proceeding without slowing or looking. As the observer behind, usually less than 50 feet behind, I have seen them go through one stop sign after another without the slightest variation in pedal speed and without the slightest head motion to indicate sideways watchfulness. See Table 3.

For cyclists making left turns and lane changes, both Palo Alto and Davis cyclists are much worse than club cyclists, with Berkeley cyclists approximately in the middle. The typical error in turning left is turning from the curb lane without looking behind, and in lane changing is doing so without looking behind. See Table 3.

The situations in which the motorist may or does turn right run from the very general one of selecting the incorrect approach path for a major intersection, through the specific error of riding straight through in or on the right of a right-turn-only lane, to the specifically dangerous error of riding through an intersection on the right-hand side of a car that may turn right. In the general positioning situation, all non-club cyclists are significantly worse than the club cyclists. In my experience, the general precautionary technique of always approaching every major intersection just to the right of the straight-through cars, and no further right, lest some motorist arrive in the wrong position, is one of the last standard habits the American cyclist learns. Advancing to a specifically incorrect procedure, riding on the right of right-turn-only lanes, Davis cyclists have as high a deficiency rate as in general positioning, but Berkeley cyclists become as good as club cyclists. Palo Alto doesn't score on this because Palo Alto cyclists traverse very few intersections with right-turn-only lanes. This relationship is retained for the specifically dangerous maneuver of traversing a major intersection on the right of a car that may turn right. The rate for Davis is twice that of Palo Alto, and is more than 10 times that for Berkeley. Club cyclists show no errors of this type - they've learned what not to do.

The deficiencies listed on the score sheet for these maneuvers, which are those that have statistically different deficiency rates between the populations, are clearly highly related to safety. Actions like changing lanes without looking, or running a stop sign too fast to yield to traffic, cannot be considered safe behavior, and have been demonstrated to be significant causes of car-bike collisions. Even more significant are the typical patterns of deficiencies, in which two complementary deficiencies, such as excessive speed and not looking, are combined into one instance.

OBSERVED RELATIONSHIP BETWEEN CYCLIST BEHAVIOR AND BIKELANE SYSTEM DESIGN

Previous analysis of the traffic patterns associated with bikeways (2, chap 8) shows that urban transportational bikeways of any type contradict the normal rules of the road in three situations: cyclist overtaking motorist, cyclist turning left, and motorist turning right. This analysis clearly shows that the bikelane maneuvers for these situations are far more dangerous than the corresponding normal maneuvers. This is supported by the car-bike collisions statistics that are quoted above. The cyclist overtaking motorist situation causes a car-bike collision if the motorist turns right, as when the cyclist approaches the right-hand side of a motorist who is turning right, so that these observations cover the three situations in which previous analysis had shown that the bikelane principle contradicted the normal rules of the road.

Bikeway advocates argue that this analysis is incorrect because the traffic laws require otherwise. Indeed they do, but this study is concerned with how people believe bikelane traffic should operate, as exemplified by how they behave around bikelanes, rather than with legal niceties that road users do not understand. In California at the time these observations were made the state statutes had long superseded the local statutes and specifically required (as they still do) both cyclists and motorists in these three situations to disobey the bikelane principle and to obey the normal rules of the road instead. This legal requirement is not merely implied by the absence of contrary instruction, but since the bikelane statute specifically allows the normal maneuvers, and none others, the requirement to follow the normal rules of the road is legally clear. Not only was the law clear, but the bikelanes had been in place for a sufficiently long time for initial disturbances to settle out. The Davis system had been in effect for 10 years, the Palo Alto system for 5 years. Therefore, the effects that were observed must be considered the long-term effects of any bikelane program on the understanding and behavior of both motorists and cyclists.

The depths of misunderstanding are shown by three associated investigations. I observed Davis motorists turning right at a bikelaned intersection directly across the street from police headquarters. 20

out of 20 right-turning motorists made wide right turns across the bikelane instead of first merging to the curb as the law required. In Mountain View, the installation of bikelanes on Middlefield Road (which I used frequently) was observed to raise the proportion of motorist wide right turns from 10% to 70%. In Davis, I drove a car repeatedly through right turns at an intersection at which all motorists had to turn either left or right, while most cyclists proceeded straight across into the campus area. On each circuit I approached the intersection slowly, with my right-turn flashers operating and my right-hand wheels in the bikelane. Despite these obvious clues to my intention, 10 Davis cyclists out of 11 overtook in the narrow space between my car and the curb.

These investigations show that bikelane systems are associated with larger proportions of dangerously defective cyclist and motorist behavior than occur in similar cycling populations who ride where there are no bikelane systems, and that the typical dangerous errors are those that are most likely to be encouraged by the design of the bikelane system.

Because of the emotional nature of the bikeway controversy, many objections will be raised to this conclusion. There is certainly some validity in arguing that while the Berkeley, Davis and Palo Alto student populations are comparable, neither those who cycle in each city nor the cities themselves are comparable. Furthermore, there is always the question of the causal relationship - do bikeways cause dangerous cycling or does dangerous cycling cause bikeways? Or is there some other relationship - contemporaneity without causality, or a more complex causal relationship?

To summarize the traffic patterns, Davis has easy traffic on very wide streets, Palo Alto has easy traffic on residential streets but moderate traffic on arterial streets that are too narrow for bikelanes but ample for cycling, while Berkeley has moderate to heavy traffic on all streets, nearly all of which are too narrow for bikelanes but ample for cycling. Davis and Palo Alto are flat, Berkeley is moderately hilly where most cyclists ride and very hilly elsewhere. Certainly the cities are different, and these differences constrained both the cyclists and the bikelane systems. Davis streets are so wide that it got its bikelane system without losing any parking. To have extended it beyond the arterials would have removed parking from one side of the residential streets, and the residents evidently didn't think that that was desirable. After all, their original interest in bikelanes was to prevent student cyclists from blocking the arterials, and their original move, which proved unlawful, was to prohibit cycling on the arterials. Palo Alto got its system at the price of removing parking from one side of a few of the bikelane streets, in a city in which overnight parking is prohibited and in which parking and motor traffic are discouraged. Berkeley could get bikelanes only by taking parking in a city in which there are insufficient off-street parking places for its residents' cars, and in which the cars of students fill all parking spaces for much of the downtown area every working day. Palo Alto attempted to overcome its political problems by decreeing that its arterial sidewalks were mandatory bikeways, but a 54% increase in car-bike collisions per bike-mile scotched that plan. If you believe that urban transportational bikeways are needed (which I consider a false postulate) these three cities well illustrate the paradox that bikeways are only provided where unnecessary and can never be provided where the need is greatest. The situation is certainly not ideal for scientific elucidation, but it does represent the mix of situations that are likely to occur in the real world.

Another objection is that behaviors on bikelane and non-bikelane streets should have been compared within each city, thus eliminating the effects of skill differences produced by, for example, the refusal of many persons to cycle where heavy traffic exists without bikeways. This approach had been considered but was rejected because differences between cities were clearly obvious before organized data collection was started, while differences between streets were not. Quite obviously, the major difference to be explained is between cities, not between the streets of one city, and the categories which are differentiated determine the type of explanation that will be deduced. This investigation does not demonstrate that the presence or absence of a bikelane on any particular street has any effect on cyclist behavior, and I believe that such effects are generally insignificant, with certain specific exceptions at particular locations. This investigation does show that the predominant effect is that the type of bikelane system to which cyclists are predominantly exposed (since few American bicycle riders travel sufficiently far to be exposed to more than one system at any one period of their lives) determines their cycling habits, which are then used on both bikelane and non-bikelane streets, and presumably are transferred to other types of bikeway also.

However, other differences may be significant - particularly the differences in traffic intensity (volume and speed, relative to capacity). Berkeley has more intense traffic than either Palo Alto or Davis, but better cycling behavior from a small cycling proportion of the population. It is at this point that the ambiguities concerning causation enter.

POSSIBLE CAUSAL RELATIONSHIPS BETWEEN CYCLIST BEHAVIOR AND BIKELANE SYSTEM DESIGN

I asked above whether bikelanes cause dangerous behavior or vice versa. I consider that, although the effects travel in both directions, considering behavior as the cause is often more fruitful than considering behavior as the result. This is not an absurd question, because undoubtedly dangerous cycling behavior is one cause of bikeways. The prime advocates for bikeways expect most cyclists to ride improperly. Whether this is because they don't themselves know how to ride properly or because they hope to attract a cycling population from those who don't, or because they simply want to get incompetent 'nuisance' cyclists off the roads, is immaterial. Contrariwise, persons who advocate competent cyclist behavior are not numbered among bikeway advocates. Bikeways are caused by bikeway advocates; they are clearly not provided by highway departments on the excuse that they would prefer providing better roads but haven't the money to do so. Since there is clearly a causal relationship between one's perception of the prevalence, acceptability, and even the desirability, of incompetent cycling behavior and whether one becomes a bikeway advocate, deficient cyclist behavior is a cause of bikeways.

Bikeway systems are frequently claimed to have three beneficial effects. They are said to make cycling safe by substantially reducing car-bike collisions. They are said to teach inexperienced cyclists how to ride properly. They are said to attract many persons to cycling.

What evidence does this study show for the hypothesis that bikelanes substantially reduce car-bike collisions? Bikelanes could accomplish this result by reducing two kinds of behavior: dangerous motorist actions and dangerous cyclist actions. Quite clearly, the data show no lower proportions of dangerous cyclist behavior in bikelane cities; rather the data show high proportions of 6 types of dangerous cyclists' behavior in bikelane cities.

The data show no lower proportions of dangerous motorist behavior in bikelane cities; if anything, the data show the reverse, with larger proportions of right-turning motorists turning from the left-hand side of straight-through cyclists. No car-bike collisions were observed during the study, which is the statistical expectation. The observational technique did not specifically observe dangerous motorist behavior, but it recorded the cyclist's reaction to such behavior whenever that occurred. Only one type of dangerous motorist behavior was observed to be statistically significant: motorists turning right from the left-hand side of straight-through cyclists were frequent in the bikelane cities but were absent in the non-bikelane city of Berkeley, and for club cyclists. Three evasive maneuvers to avoid motorist errors were observed: 2 Avoid Motorist Right Turns and 1 Avoid Motorist Exiting Stop Sign, all in Palo Alto. Despite the prevalence of motorist right turn situations in Davis, no cyclist was observed to take the appropriate evasive action of turning right inside the motorist's turn; the very low traffic speed made this unnecessary. The data show that motorist actions that are dangerous to cyclist are quite rare except for motorist right turns in bikelane cities.

The argument has been made by bikeway advocates that the Davis bikelane system must be satisfactory because of the long absence of fatal car-bike collisions. This absence is probably due more to the Davis conditions than to the bikelane system. Fatal injuries are rare in car-bike collisions, occurring in less than 1% of car-bike collisions, and are generally associated with high impact speeds. Davis motor traffic is low volume and low speed, and Davis motorists are both very easy-going and very considerate of dangerous cyclist behavior, all factors that reduce car-bike collisions, particularly fatal ones. These factors would exist and would protect cyclists whether or not Davis had bikelanes. The important point to make is that if Davis cyclists were to ride in other cities with their same lack of competence, their car-bike collision rate would be very high. The fact that it is the conditions and not the bikelanes that permit this dangerous cycling is demonstrated by the fact that the dangerous cyclist errors observed in bikelane cities were those against which bikelanes offer no protection at all. The argument that Davis cyclists are only as competent as the conditions demand (which has been made by bikeway advocates) merely emphasizes that bikelanes in Davis are more useless than anywhere else, because the considerate motorist behavior compensates for extreme cyclist carelessness.

Equally trenchant is the refutation of the argument that the Davis bikelanes protect cyclists against dangerous motorist errors. The only motorist error against which bikelanes are intended to protect is the motorist overtaking cyclist car-bike collision that is caused by the motorist who either doesn't see the cyclist or doesn't know the width of his own vehicle. The Cross data show that this type of car-bike collision is rare in cities (2% of urban daylight car-bike collisions) and the most prevalent conditions are narrow 2-lane rural-type roads without street lighting during darkness. With its wide, well-illuminated streets and slow traffic, and with its motorists who very obviously (as demonstrated herein) take extreme care for cyclist safety, Davis presents the least motorist danger to cyclists of almost any city in America. Those who argue that the Davis bikelane system is necessary to protect cyclists from motorist errors do not argue from facts.

Furthermore, it is improper to consider the absence of reported fatal car-bike collisions as indicative of general cyclist safety; the UC Davis hospital emergency room averages several severe cyclist injuries per week. Cycling is not safe in Davis; this observer found it necessary to ride with extreme caution to avoid the incompetent cyclists, just as Davis motorists have found.

The data of this study therefore oppose the hypothesis that bikelane systems significantly reduce car-bike collisions and support the contrary hypothesis that bikelane systems at least increase the probability of car-bike collisions by increasing the proportion of actions that cause car-bike collisions.

What evidence does this study show for the hypothesis that bikelanes teach inexperienced cyclists how to ride properly? Since the bikelane cities had the significantly higher proportions of dangerously defective cyclist behavior, and since at least the Berkeley and Davis cycling populations had very similar origins, it appears that bikelanes do not teach their users proper cycling technique as rapidly as does cycling on the normal roadway. The greater cyclist volume in Davis does not justify the contrary argument, because greater cyclist volume would be expected to make cyclist learning proceed more rapidly, not less rapidly, both because of the greater prevalence of correct cyclist models to learn from and because of the more frequently observed consequences of incorrect behavior. One might argue that the Davis bikelanes have a more difficult teaching task because Davis conditions (not necessarily only the presence of bikelanes) attract less competent persons to cycling. If so, then the most favorable evaluation possible is that bikelanes possess insufficient instructional power to train the large number of cyclists that bikeway advocates hope to develop. One must conclude that bikelane systems show no signs of teaching proper cycling technique, but rather of hindering the learning of proper cycling technique.

This study contains no evidence concerning whether bikelane systems are significant creators of new cyclists. The well-accepted differences in proportions of cyclists in the total populations of the three cities are probably due to causes other than the bikelanes. However, bikeway advocates argue that the Davis bikeway system created the Davis cycling population. Well, if their argument is considered to be correct, then it is reasonable to conclude that the dangerous cyclist behavior that was observed in bikelane cities has been caused, at least in part, by those persons who, but for the bikelane system, would not have been cycling.

Bikelanes have been criticized for creating car-bike collision situations, for making it harder to learn proper cycling technique, and for enticing new cyclists into a dangerous activity with false promises of safety. These are of course the opposite of the claims of bikeway advocates that have been discussed above. As was concluded above, the data support each of these anti-bikelane hypotheses better than they support the pro-bikelane hypotheses.

However, there remains the question of whether these observed differences could have been caused by some other agency. The most serious criticism is that the differences between the cycling conditions of the cities caused different cycling populations to be selected from the geographical populations. The most pertinent criticism is that Berkeley conditions select the few competent cyclists from the population, whereas Davis conditions attract most of the population, thus creating a cycling population that naturally exhibits a higher proportion of dangerous deficiencies. One's approach to this question depends greatly upon one's view of the origin of cycling competence.

Bikeway advocates appear to assume that the ability to cycle competently is a rare and innate attribute, because they argue that bikeways are intended for the great majority of cyclists, not for those whom they claim are the elite few competent cyclists who oppose bikeways. If indeed the potential ability to cycle competently in traffic is rare, and since, as this study shows, bikelanes do not correct for the absence of that ability, then bikelanes are an entirely inappropriate social response to transportation problems. It is unethical to use false promises of safety to entice persons into an activity which, by the bikeway advocates' own theory, they cannot perform safely.

Bikeway opponents adopt the opposite view of traffic-cycling ability. They claim that the potential ability to cycle competently in traffic exists in almost all people, but must be developed by training. Quite obviously, if one believes in this view one must support training under normal road conditions, both because normal road conditions are the actual operating conditions and because learning is easier and quicker under normal road conditions than under bikeway conditions. Equally, one must oppose bikelanes for the corresponding reasons: they cause average cyclists to operate dangerously, they cause average motorists to operate dangerously, and by complicating both cyclist and motorist training they so effectively delay learning proper operating technique that only expert cyclists learn to operate safely.

In other words, whether one adopts the bikeway advocates' view that traffic-cycling ability is inherited, or the effective cycling view that traffic-cycling ability is a generally-possessed, trainable function, one is compelled to conclude that bikelanes are an inappropriate social response to current transportational problems.

REFERENCES

1 Forester, John: *Effective Cycling*: 1975: Now fifth ed, 1984, The M.I.T. Press, Cambridge MA 02142

2 Cross, Kenneth D., & Gary Fisher: *A Study Of Bicycle/Motor-Vehicle Accidents: Identification of Problem Types and Countermeasure Approaches*: 1978: National Highway Transportation Safety Administration: avail able from the National Technical Information Service, Springfield VA 22151

3 Forester, John: *Cycling Transportation Engineering*: 1977: Now superseded by *Bicycle Transportation*: 1983: The M.I.T. Press, Cambridge MA 02142

4 Kaplan, Jerrold A.: *Characteristics of the Regular Adult Bicycle User*: 1975: Univ. of Maryland Master's Thesis; available from the National Technical Information Service, Springfield VA 22151

Table 1: Cyclist Sample Sizes

Location	No. of Cyclists	Earned Points	Points Lost	Avg. %
Berkeley	28	1300	208	84
Davis	71	2995	1018	66
Palo Alto	50	2385	1002	58
Club	8	4935	93	98

Table 2: Traffic Maneuvers With Statistically-Significant Differences in Percent Defective Between Cities

Maneuver	Population											
	Club			Palo Alto			Berkeley			Davis		
	n	d	%d	n	d	%d	n	d	%d	n	d	%d
Traffic Signal	80	2	2.5	97	9	9.3	55	9	16.4	105	5	0.5
Stop Sign	119	5	4.2	95	39	41.0	18	3	16.7	59	6	10.2
Right Turn Only	14	1	7.1	0	0	-	7	1	14.3	30	29	96.7
Intersection Approach	26	4	15.4	3	2	66.7	10	5	50.0	12	11	91.7
Left Turn	93	5	5.4	41	26	63.4	22	6	27.3	59	28	47.5
Lane Change	18	0	0.0	14	8	57.1	13	4	30.8	38	17	44.7
Right Side of Moving Car	80	0	0.0	97	5	5.3	55	1	1.8	105	11	11.4

Table 3: Types of Errors, by Percent

Maneuver	Palo Alto	Berkeley	Davis
STOP SIGN			
Neither slowing nor looking	59		
Too fast	12		
Not looking	22		
Others	7		
LEFT TURN			
Wrong start position & not looking	65	19	31
Wrong start position	27	67	56
Not looking	8	0	6
Others	0	14	7
LANE CHANGE			
Not looking	95	100	93
Others	5	0	7

Table 4: Percent Defective and Statistical Significance of the Differences

Maneuver	Club	P.A.	Berk.	Davis	P(Diff)
Traffic Signal			16.4	0.5	>95%
	2.5		16.4		>99%
Stop Sign	4.2		16.7		>95%
		41.0	16.7		>95%
		41.0		10.2	>99%
	4.2	41.0			>99%
Left Turn	5.4			47.5	>99%
	5.4		27.3		>99%
		63.4	27.3		>99%
	5.4	63.4			>99%
Lane Change	0.0		30.8		>95%
	0.0			44.7	>99%
	0.0	57.1			>99%
Avoid Right-Turn-Only Lane	7.1			96.7	>99%
			14.3	96.7	>99%
Intersection Approach	15.4	66.7			>95%
	15.4		60.0		>99%
	15.4			92.3	>99%
Right-hand Side of Moving Car	0.0	5.3			>95%
			1.8	11.4	>95%
	0.0			11.4	>99%
		5.3		11.4	>99%

Fig 1: FORESTER CYCLING PROFICIENCY SCORE SHEET

GROUP # ________________ CYCLIST # _________________

NAME _____________________________ DATE ______________________

ADDRESS _____________________________ TEST PLACE ___________________________

_____________________________ EXAMINER ____________SCORER ___________

Total Possible _________ Total Lost _________ Score (100(P - L)/P _____________

TRAFFIC SIGNAL ....+5____________

Wrong Action........ -5____________

STOP SIGN.............. +5____________

Too Fast ....-2____________

Not Looking ....-4____________

Not Yielding ....-5____________

EXIT DRIVEWAY ....+5____________

Too Fast ....-4____________

Not Looking ....-4____________

Not Yielding ....-4____________

RIGHT TURN ONLY ....+10___________

Straight from RTOL ..-8____________

Swerving Out ....-8____________

INTERSECTION APPR'CH ..+10___________

R-Side R-Turn Car ...-8____________

R-Side Moving Car ...-4____________

Too Far Right ....-4____________

Too Far Left ....-4____________

PARKED CAR ....+10___________

Swerving ....-8___________

Too Far Out ....-2___________

Too Close ....-4___________

No Return When Req ..-2___________

Return When Not Req .-4___________

BEING OVERTAKEN......... +10 ___________

Too Far Left........... -8___________

Too Far Right.......... -4___________

OVERTAKING ....+10__________

Swerving ....-4___________

No Look B4 Swerve ......-8___________

Cut Off Slow Driver ....-5___________

RIGHT TURN ....+5___________

Wrong Lane ....-2___________

Not Yielding ....-5___________

Not Looking Left ....-4___________

LEFT TURN ....+15___________

Wrong Start Posit .....-12___________

Not Looking ....-10___________

Not Yielding ....-15___________

No Stop in Ped Turn ...-15___________

End in Wrong Lane ......-5___________

MULTIPLE L-TURN LANES ....+10___________

Wrong Lane Choice ....-7___________

Wrong Side Of Lane ......-4___________

CHANGING LANES ....+15___________

Not Looking ....-8___________

Not Yielding ....-12___________

Too Many Lanes ....-5___________

Fig 2: FORESTER CYCLING PROFICIENCY SCORE SHEET

GROUP # ___________________ CYCLIST # __________________

MERGE ....+15___________

Incorrect Path ......-8___________

Not Yielding ....-12___________

DIVERGE ....+15___________

Incorrect Path ......-8___________

Not Looking ....-8___________

Not Yielding ....-12___________

GROUP RIDING ....+15___________

Overlap ....-5___________

Too Far Behind ......-2___________

Not Indicating Rock .-2___________

Not Indicating Slow .-5___________

Swerving ....-8___________

WIDE TO NARROW ....+5___________

Swerving ....-6___________

No Look or Yield ....-4___________

OFF-ON ROADWAY ....+15___________

Bad Choice of Place .-2___________

Too Fast Return .....-8___________

Not Looking ....-8___________

Not Yielding ....-8___________

Not Perpendicular ...-8___________

DIAGONAL RR TRACKS ....+15___________

Not Looking ....-12___________

Not Yielding ....-12___________

Not Perpendicular ..-10___________

POSTURE ....+5___________

Incorrect Saddle Ht .-2___________

Incorrect Foot Pos ..-2___________

PEDALLING ....+5___________

Slow Cadence ....-2___________

Stiff Ankling ....-2___________

SHIFTING ....+5___________

Too Slow on Hills .....-2___________

Too Slow in Traffic ...-2___________

PANIC STOP ....+20___________

Rear Wheel Skid ....-5___________

Lift Rear Wheel ....-15___________

Skid & Fall ....-15___________

INSTANT TURN ....+20___________

Too Wide ....-5___________

Too Slow ....-10___________

ROAD DEFECT ....+20___________

Incorrect Action ......-10___________

WIND BLAST ....+20___________

Too Much Wobble ....-10___________

AVOID MOT. @ STOP SIGN ...+20___________

Incorrect ....-10___________

AVOID MOTORIST MERGE .....+20___________

Incorrect ....-10___________

AVOID MOT. RIGHT TURN ....+20___________

Incorrect ....-10___________

AVOID MOT. LEFT TURN .....+20___________

Incorrect Action ......-10___________