Roadway Design Preferences Among Drivers and Bicyclists in the Bay Area

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Paper submitted for presentation at the 93rd Annual Meeting of the Transportation Research Board, Washington D.C., January 2014

Word Count: 6150 + 1250 (2 tables + 3 figures) = 7400 words
ABSTRACT

Two trends in the United States—increased bicycling and growing enthusiasm for complete streets—suggest that practitioners need a better understanding of how roadway users view roadway designs meant to accommodate multiple users. Studies that have examined bicyclists’ preferences for roadway design have not always included non-cyclists’ opinions—even those who would consider bicycling in the future. Moreover, little research has investigated the preferences of the motorists who share the road with cyclists—despite the fact that motorists are still the vast majority of roadway users in the U.S.

This paper presents results from a recent internet survey examining perceived comfort while driving and bicycling on various roadways among 263 non-bicycling drivers, bicycling drivers, and non-driving bicyclists in the Bay Area. Analysis of variance tests revealed that drivers and bicyclists are more comfortable on roadways with separated bicycling facilities than on roadways with shared space. In particular, roadway designs with barrier-separated bicycle lanes were the most popular among all groups, regardless of bicycling frequency. Striped bicycle lanes, a common treatment in the U.S., received mixed reviews: a majority of the sample believed that they benefit cyclists and drivers through predictability and legitimacy on the roadway, but the lanes were rated significantly less comfortable than barrier-separated treatments—particularly among potential bicyclists.

These findings corroborate research on bicyclists’ preferences for roadway design and contribute a new understanding of motorists’ preferences. They also provide further evidence of the disconnect between roadway users’ preferences and the designs encouraged by current engineering guidelines.

INTRODUCTION

Increasing bicycling trips has been national policy since the US DOT set its 1994 goal to double the rate in the US (1). Nearly twenty years later, data from recent national transportation surveys show that bike commuting has increased an average of 47% in major U.S. cities over the last decade (2). In some cities, such as Lexington, Kentucky, and Portland, Oregon, the percentage of bike commuters has grown over 300% since 2000, while many other U.S. cities have seen growth in excess of 100-200% (2). Given this trend toward increased cycling and potentially commensurate increased conflict over limited roadway space, efforts to design and build roadways that accommodate multiple roadway users—also known as “complete streets”—are likely in the best interest of all parties. In fact, nearly 500 regional and local jurisdictions, as well as almost 60% of states, have already adopted complete streets policies or made a written commitment to do so (3).

To complement the movement toward complete streets, practitioners need an understanding of roadway designs that maximize comfort and safety for all roadway users. This paper presents findings from research examining the roadway design preferences of motorists and bicyclists when sharing multi-lane, commercial streets. The findings are based on results from a recent survey exploring perceptions of adult bicycling risk and experiences bicycling among bicycling drivers, non-bicycling drivers, and non-driving bicyclists in the San Francisco Bay Area (4). The results corroborate past research findings on bicyclists’ roadway design preferences and contribute a new understanding of design preferences for drivers. Furthermore, these findings suggest an alignment between roadway users for design preferences, with both
drivers and cyclists—regardless of cycling frequency or type of bicycling—preferring greater separation on the roadway.

LITERATURE REVIEW

Research examining preferences for roadway design has been conducted in several ways, including: 1) surveys examining general trends in preferences for bicycle facilities, 2) stated preference techniques that present survey participants with a range of facilities to choose from and adapt the survey around their preferences as it progresses, and 3) revealed preference research that examines route choice and makes inferences about the value of route characteristics.

Descriptive Statistics

Several surveys have asked respondents their preferences for roadways, but without necessarily requiring the trade-offs that generally accompany stated preference studies. These surveys are helpful for understanding a baseline of what is popular or unpopular among certain cyclist types, and can be used as the basis for future stated or revealed preference work. For example, in their online survey of Texas cyclists, Sener, Uluru, and Bhat found that nearly 80% of respondents characterized the overall quality of bicycle facilities in their communities as “inadequate” or “very inadequate.” In their telephone survey of Portland residents, Dill and Voros found that 37% of those who wanted to bicycle more reported that there were not enough bike lanes or trails near where they wanted to go.

Winters and Teschke conducted a mixed-methods survey using phone and visual aids over the internet to evaluate the roadway design preferences of 1,402 cyclists of all experience levels (including potential cyclists). Of the sixteen road types shown to survey participants, off-street paths were the most preferred by all cyclist types, while major city streets without bicycle facilities were the least preferred. As expected, the presence of on-street parking reduced the attractiveness of any particular route type, and the presence of bicycle facilities increased the attractiveness. One benefit of this study is that it asked about bicycle facilities not common in North America, finding that barrier-separated cycle paths next to major streets were the fourth-ranked option for potential and occasional cyclists, and ranked second and third, respectively, for regular and frequent cyclists. A comparison of the preference rankings to the respondents’ current riding patterns suggests that cyclists do not have the full range of options they would like for cycling. A recent telephone survey from Portland, Oregon, found similarly strong preferences—particularly among potential cyclists and women—for separated bicycle facilities.

Stated Preference

In their adaptive stated preference survey of 167 members of a convenience sample from the University of Minnesota, Minneapolis, Tilahun, Levinson, et al. presented participants with ten-second videos featuring routes along two roadways with different bicycle facilities, as well as an associated amount of travel time. As the respondents chose between the two roadways, a computer program presented them with different options until a final value for the facility was reached (four iterations total). A utility model of the data revealed that, on average, the respondents were willing to travel the farthest to avoid a street with on-street parking but no bike lane. In general, the presence of a bicycle lane had a much greater impact on the odds of...
choosing the higher quality facility than did the elimination of on-street parking or the presence of an off-road facility. The tendency to choose the higher quality facility was magnified among women, and cycling experience did not significantly influence the rankings.

Parkin, Wardman, et al. also used video to present their 144 survey participants with various route options for bicycling in Bolton, United Kingdom (10). Models created from user ratings of the facilities, although resulting in a relatively low R² (maximum of 0.275), suggested that the presence of on-street parking increased perceived risk along residential roads, while the presence of a bicycle lane on any road type decreased perceived risk. However, the effect of a bicycle lane was less powerful for busy roads due to the increased perceived risk from traffic. Overall, users clearly felt safer bicycling on off-street and adjacent paths than they did on the roadway with traffic.

Revealed Preference

Landis, Vattikuti, et al. conducted one of the first revealed preference studies by recruiting volunteers to ride and grade sections of a set route in Orlando, Florida (11). The participants’ grades were then used to model preferences for facility design. The model results showed that the presence of a bicycle lane significantly improved the perceived level-of-service (LOS) of the street segment, irrespective of other street characteristics (including traffic volume and posted speed limit). As with all of the studies in this section, this one was limited to the facilities on the ground and the participants, who all bicycle currently and therefore do not necessarily represent the preferences of a potential bicyclist.

Winters, Teschke, et al. used reported routes from 74 of the participants in their Vancouver bicycling study to examine the distance people detour from the shortest path to use a bicycle facility (12). The researchers found that bike trips were significantly more likely to occur along routes with enhanced bicycle facilities including traffic calming, stencils, and signage; while only 21% of trips would be along designated bike routes in a shortest path scenario, on average, 49% of actual trip distance took place along a bike route. The researchers also found that participants who reported that the risk of injury from car-bike crashes deterred them from cycling were more likely to detour, although the small sample size limits the generalizability of the results.

Broach, Dill, et al used GPS monitors to gather data on the routes of 164 cyclists over several days in Portland, Oregon (13). They were then able to build a model based on revealed, real-time preferences that could account for trade-offs in topography, traffic volumes, and street network characteristics. They found that cyclists travel out of their way to reach bicycle infrastructure, particularly bicycle boulevards, which comprised 1% of the network, but carried 10% of all utilitarian bicycle travel.

Gap in the literature

Knowing current cyclists’ preferences for roadway design is critical to encouraging more cycling, but research has not always examined the preferences of potential cyclists. Furthermore, given the needs of practitioners to balance safety and throughput, they also need to know how drivers view various design options. There is little research on the design preferences of the drivers who share the road with bicyclists—perhaps because, until recently in the vast majority of cities, there were too few cyclists to change the status quo of roadway design. The research presented in this paper contributes to this gap in the literature by examining the roadway design preferences of drivers in addition to potential and current cyclists.
METHODOLOGY

Survey Construction and Recruitment

This survey was conducted as part of a larger study on perceptions of bicycling risk among bicyclists and motorists in the Bay Area (4). The survey was developed based on gaps in the literature as well as the results of focus groups conducted with Bay Area bicyclists and motorists for the project in February and March of 2011. The survey questions covered a variety of aspects of bicycling risk, including experiences bicycling and/or driving near bicyclists; beliefs about bicycling in general; safe and unsafe practices of bicyclists and drivers; attitudes towards cycling in one’s city; opinions about potential cycling laws; knowledge of current cycling laws; and demographics. The survey focused on driver-bicyclist interactions and did not ask questions about pedestrian-bicyclist interactions. Answer choices were always randomized to mitigate response bias. Drawing from the survey, this paper focuses on perceptions of comfort while driving a car near bicyclists or bicycling near drivers on various multi-lane roadways.

The survey was conducted via an online survey tool. In July 2011, the survey link was emailed to a convenience sample of 1,176 people who had previously participated in research on the Bay Area FasTRAK toll tag and “casual carpooling” across the Bay Bridge, and who had agreed to participate in future research. Respondents were offered an incentive of a $5 gift card to a location of the respondent’s choosing upon completion of the survey. Because the gift card form required an email address, the response rate could be calculated despite the anonymity of the survey. A total of 463 valid, completed surveys were received from email list respondents, resulting in a known response rate of 39%.

The roadway design preference aspect of the survey was optional, resulting in a subsample of 225 cycling respondents and a subsample of 263 driving respondents. For this aspect of the survey, respondents were asked to indicate their comfort or discomfort on a series of multi-lane, commercial roadway designs while 1) driving near bicyclists, and 2) bicycling near motorized traffic. They were told to “assume that the car traffic is traveling 25-30 mph” (40-48 kph). Comfort was rated on a seven-part Likert scale, with a neutral option and the modifiers “somewhat”, “moderately”, and “very” comfortable or uncomfortable. The respondents were presented with eight photos of a multi-lane, commercial street, seven of which had been manipulated through Adobe Photoshop to show a variation on the original roadway design. The photos were randomized within each survey to control for ordering effects. The eight photos are shown in Figure 1.
Survey Population

Table 1 shows a breakdown of the survey population, categorized by bicycling frequency. Based loosely on a survey by Dill and Voros (6), these categories were determined by asking people how often, weather permitting, they bicycled for “work/school or errands” and how often they bicycled for recreation. The categories equated to the following:

- **Non-cyclist**: a respondent who reported never bicycling, or bicycling less than once per year for either utilitarian or recreational purposes, and who would not consider bicycling for any purpose in the future
  - **Potential cyclist**: a “non-cyclist” who indicated a willingness to consider bicycling for any purpose in the future
- **Occasional cyclist**: a respondent who bicycled at least a few times per year, but less than several times per month, for any purpose
  - **Yearly cyclist**: a respondent who bicycled at least a few times per year for any purpose, but less than several times per month
  - **Monthly cyclist**: a respondent who bicycled at least several times per month for any purpose, but less than several times a week
• **Regular cyclist:** a respondent who bicycled at least several times per week for any purpose
  - **Weekly cyclist:** a respondent who reported bicycling at least several times per week for any purpose, but not daily
  - **Daily cyclist:** a respondent who reported bicycling every day for any purpose
### TABLE 1 Survey Population Characteristics

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<th>Yearly cyclists (n=100)</th>
<th>Monthly cyclists (n=71)</th>
<th>Weekly cyclists (n=76)</th>
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Note: Spearman’s rho significant ($p ≤ 0.01$)
Chi-square significant ($p ≤ 0.001$)
Fisher’s exact not significant
Spearman’s rho significant ($p ≤ 0.000$)
Spearman’s rho not significant
Chi-square significant ($p ≤ 0.05$)
The data in Table 1 describe the survey population. Not surprisingly, weekly and daily cyclists are significantly younger than non-cyclists, and there are significantly fewer female yearly, monthly, and daily cyclists. There were more female weekly cyclists than male, a split almost certainly affected by response bias given Census data from the Bay Area that indicate that men bicycle for work from 1.75 to 5 times more than women (14). The overall trend of more women responders than men could reflect the tendency of women to participate more than men in surveys (15). The cycling groups also varied according to the distribution of races and ethnicities, with weekly cyclists having the highest percentage of Caucasian respondents. While this seems to fit with most research on bicycling, which tends to have a high percentage of Caucasian respondents, it is not clear how much this proportion reflects who bicycles versus who responds to surveys about bicycling. Regardless, the large percentage of Caucasian bicyclists in this study suggests that the survey responses cannot be assumed to apply to other races without further research.

In terms of driving frequency, the distribution between cycling groups follows the expected direction, with the driving frequency significantly \((p \leq 0.000)\) negatively associated with the bicycling frequency. However, over 90% of the sample drives at least once a week, irrespective of bicycling frequency. There was no significant difference between groups regarding income. Finally, a significantly \((p \leq 0.01)\) smaller percentage of weekly cyclists had children than any other group. Of the respondents who had children, marginally significantly more \((p < 0.10)\) yearly and monthly cyclists than others had children who rode bicycles on the sidewalk or on the street.

Compared to the larger Bay Area population, the survey population is disproportionately weighted toward 25-34 year-olds, females, and Caucasian respondents, and includes fewer respondents from both the very low and very high ends of the income spectrum. In addition, fewer of the survey respondents have children under age 18 than would be expected from the general population. Additional information about the survey and methodology can be found in the dissertation in which these findings are based (4).

The data presented in this paper were analyzed for variance using Chi Square and correlation tests in Microsoft Excel (Microsoft, Redmond, WA) and STATA 12 (StataCorp, College Station, TX).

**FINDINGS**

**Perceptions of Comfort for Roadway Design**

The findings from the survey indicate a surprising alignment in preferences both between cyclists of differing experience levels, regardless of whether one bicycles recreationally or for utilitarian purposes, and cyclists and drivers. Figure 2 displays the percentage of drivers feeling “moderately” or “very” comfortable driving near cyclists in each scenario. Figure 3 displays the percentage of cyclists feeling “moderately” or “very” comfortable bicycling in each scenario. Recreational and utilitarian cyclists are combined for Figure 3, given that the ratings and significant differences between groups followed the same pattern for both types of cyclists. Both figures show combined ratings for “moderately” and “very” comfortable in recognition of the fact that some people, particularly those with little to no cycling experience, may not feel “very” comfortable on any treatment.
Figure 2. Survey Respondents who Drive Feel More Comfortable with Greater Separation from Bicyclists (N=263)

Spearman’s rho indicated significant correlation between cycling frequency and perceptions of comfort at the following levels: * = $p \leq 0.05$; ** = $p \leq 0.01$, *** = $p \leq 0.001$
Figure 3. Survey Respondents who Bicycle Feel Overwhelmingly More Comfortable with Greater Separation from Drivers (N=225)

Non-cyclists who would not consider bicycling again did not rate designs for bicycling. Spearman’s rho indicated significant correlation between cycling frequency and perceptions of comfort at the following levels: # = $p \leq 0.10$, * = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$

There are several points to note from these figures. First, there are only two roadway designs for bicycling that evenly appeal to all groups, regardless of cycling frequency: the two barrier-separated bicycle lane designs, shown in the left column of Figure 1. These two designs also have the most overall appeal for both cyclists and drivers, although there is a marginal significant difference ($p \leq 0.05$) between driver ratings according to bicycling frequency. Second, more current cyclists than potential cyclists felt at least moderately comfortable bicycling on all roadway designs, with the exception of the barrier-separated bicycle lane without parking (left
column, middle row in Figure 1); this treatment, ranked at least moderately comfortable by a high percentage of all groups, appealed to even more potential cyclists than occasional cyclists. This corroborates past research on cycling experience and preference for separation from traffic and parking (7, 8). Third, a higher percentage of respondents ranked each treatment at least moderately comfortable as a driver than as a cyclist, again with the exception of the barrier-separated lanes, which were rated at least moderately comfortable by approximately the same percentage of respondents for both scenarios.

The comfort ratings seem to indicate the following order of preference regarding roadway design for bicyclists:

1) Barrier-separation between moving non-motorized and motorized traffic
2) Separation from parked cars
3) Visual demarcation of space using paint (e.g., the green painted bicycle lane)
4) Visual demarcation of legitimacy using paint (e.g., the shared green lane or sharrow)

This order seems particularly pronounced for potential cyclists. While comfort levels for current cyclists remain close for the barrier-separated treatments and the bicycle lane without on-street parking, potential cyclists’ comfort levels clearly drop once barriers are no longer part of the design. They drop once again when parking is introduced without a barrier—even in the case of the green painted bicycle lane shown on the bottom row of Figure 1 (a design for which only 41% of potential cyclists feel at least moderately comfortable). Beyond the green bicycle lane, the percentage of potential cyclists who feel at least moderately comfortable is very low. In contrast, a majority of current cyclists still feel at least moderately comfortable using the green painted bicycle lane. However, comfort for these groups clearly drops in the case of a striped bicycle lane next to parking, as shown in the right column of Figure 1, and declines dramatically for all options that lack a separated, marked space for cyclists.

The first three priorities for roadway design for cyclists also seem to reflect drivers’ preferences. A large majority of all groups rated the separated (by barrier or paint) designs as at least moderately comfortable for driving near bicyclists. However, only 41% of non-cycling drivers (including drivers who are potential cyclists) rated the shared lane markings (middle photo in Figure 1) as at least moderately comfortable, and, with the exception of those who bicycle daily, less than 43% of all groups rated the green painted shared lane (top photo in middle column on Figure 1) as such. Comments from the focus group participants suggest that these low ratings reflect uncertainty about how to behave—and how bicyclists will behave—in situations with shared space, particularly regarding the green shared lane. A higher percentage of daily bicyclists rated these last two treatments as at least moderately comfortable while driving, perhaps because they were able to picture themselves cycling and imagine how to behave—and how they would want the car driver to behave—in such a circumstance.

These preferences for comfort result in a hierarchy of roadway designs: some are clearly low in the list for drivers and cyclists (sharrows and painted shared lanes), and some are clearly preferable for drivers and cyclists (barrier-separated bike lanes, lanes on streets without parallel parking, painted bike lanes). The complication seems to be what to do when there is not enough room for a separated facility. In that case, bicyclists prefer more treatment, rather than less, while drivers prefer the opposite.

The perceptions of comfort were also examined by gender, with the results following a similar pattern to those above. Female respondents were significantly less comfortable ($p \leq 0.001$) bicycling on any of the shared space designs, as well as driving on roadways with
shared lane markings and the painted shared lane. They were also significantly \((p \leq 0.01)\) less comfortable driving on roadways with a striped or painted bicycle lane next to on-street parking.

**Bike lane beliefs**

Respondents were also asked to rate their level of agreement or disagreement with several statements about bicycle lanes in particular. The percentage of respondents who agreed or strongly agreed with each of the statements is shown in Table 2. For most of these statements, there was no significant difference between groups according to bicycling frequency. Note that the trend is general agreement with the more positive aspects of bicycle lanes, and disagreement with the more negative aspects. For example, nearly 100% of respondents agree or strongly agree that bicycle lanes tell drivers to expect bicyclists on the roadway. A supermajority of respondents also believes that bicycle lanes give bicyclists their own space. These two statements likely underlie some of the comfort ratings for bicycle facilities seen in Figures 2 and 3.

Table 2. Respondents Believe Bicycle Lanes are Beneficial, with Few Drawbacks (N=262)

<table>
<thead>
<tr>
<th>(+) Bicycle lanes…</th>
<th>Non-cyclists (n=36) %</th>
<th>Potential cyclists (n=73) %</th>
<th>Yearly cyclists (n=52) %</th>
<th>Monthly cyclists (n=37) %</th>
<th>Weekly cyclists (n=48) %</th>
<th>Daily cyclists (n=18) %</th>
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</thead>
<tbody>
<tr>
<td>...tell drivers to expect bicyclists</td>
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<td>90</td>
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</tr>
<tr>
<td>...give cyclists their own space</td>
<td>86</td>
<td>89</td>
<td>92</td>
<td>95</td>
<td>96</td>
<td>89</td>
</tr>
<tr>
<td>...make cyclists more predictable on the roadway</td>
<td>83</td>
<td>86</td>
<td>75</td>
<td>81</td>
<td>85</td>
<td>88</td>
</tr>
<tr>
<td>...allow cyclists to ride at their own pace</td>
<td>75</td>
<td>68</td>
<td>73</td>
<td>75</td>
<td>75</td>
<td>67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(-) Bicycle lanes…</th>
<th>Non-cyclists (n=36) %</th>
<th>Potential cyclists (n=73) %</th>
<th>Yearly cyclists (n=52) %</th>
<th>Monthly cyclists (n=37) %</th>
<th>Weekly cyclists (n=48) %</th>
<th>Daily cyclists (n=18) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>...tell drivers that cyclists don’t belong on non-bicycle routes*</td>
<td>36</td>
<td>40</td>
<td>24</td>
<td>19</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>...make it more difficult for cyclists to turn left</td>
<td>36</td>
<td>32</td>
<td>31</td>
<td>30</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>...increase the chance of being doored**</td>
<td>22</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>...encourage drivers to drive closer to cyclists</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>11</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>...unnecessarily restrict fast cyclists</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Significant differences between non-cyclists, occasional cyclists, and regular cyclists at the following levels:

* \(= p \leq 0.05\); ** \(= p \leq 0.01\)
A supermajority also agree that bicycle lanes make bicyclists more predictable on the roadway—a potential benefit for drivers (indeed, 85% of non- and potential cyclists agreed with this statement) that runs counter to the idea that bicycle lanes benefit only bicyclists. This agreement may help explain recent findings that drivers in the San Francisco East Bay and Los Angeles metropolitan area named bicycle lanes as a top requested traffic safety improvement along two major arterial roadways (16, 17).

The significant difference between cycling groups in terms of the belief that bicycle lanes increase the chance of being hit by a car door is likely influenced by experience. Despite the fact that the majority of the sample did not agree with this statement, evidence from the focus groups suggests that this fear may have played some role in the relatively low comfort ratings the striped bike lane received in comparison to other treatment options (4).

Bicycling advocates may find it troubling that nearly 40% of non- and potential cyclists agree that bicycle lanes tell drivers that cyclists don’t belong on non-bicycle routes. This belief may mitigate some of the perceived benefits of bicycle lanes by creating confusion in drivers and cyclists and contributing to an unwelcoming atmosphere for cyclists—particularly in areas with limited bicycle facilities. Future research should further investigate this finding. Despite this finding, however, there is no significant correlation between driving frequency and the belief that cyclists do not belong on non-cycling routes. The belief that cyclists do not belong on non-bicycle routes may therefore reflect ignorance of roadway rules in California (i.e., that bicyclists are allowed on all roadways except where expressly prohibited) and it may also reflect the contrasting legitimacy that pavement markings give to bicyclists on roadways that were originally designed for automobiles rather than bicyclists.

The potential of bicycle lanes to communicate that bicyclists only belong on certain streets has long been used as an argument against bicycle lanes by vehicular cyclists, who fear that their roadway rights and freedom will be taken away if bicycle lanes proliferate (18). However, as seen in Figure 3, the vast majority of cyclists of all types feel more comfortable with bicycle-specific facilities than without them, suggesting that avoiding the use of on-road bicycle treatments contradicts efforts to attract more people to bicycle. Instead, driver education and training might be a more appropriate way to address the misconceptions arriving from non-uniform bicycle facilities. Another option would be for roadways to uniformly have bicycle facilities and/or markings. In European cities with a high bicycling mode share (e.g., Copenhagen, Denmark; Amsterdam, Netherlands; Paris, France), major roadways typically have some type of separated bicycle facility, while minor, residential roadways often have signage and markings. These findings provide a foundation for further research in this area.

**DISCUSSION**

The findings presented in this paper corroborate research on design roadway design preferences among current and potential cyclists, and contribute knowledge about roadway design preferences among motorists driving near cyclists. The findings suggest several key take-aways for practice.

First, regardless of bicycling experience, roadway designs with barrier-separated bicycle lanes were popular among bicyclists and drivers. More drivers and cyclists reported feeling at least moderately comfortable on multi-lane streets with barrier-separated bicycle lanes than any other treatment. The barrier-separated lane without parking was slightly preferred to the barrier-
separated lane next to on-street parking, but in both cases a large majority of the respondents were at least moderately comfortable.

Second, roadway designs with shared space (e.g., options with sharrows, no treatment, or a green shared lane) were relatively unpopular with both cyclists and drivers. Between the three shared-space options, drivers preferred no treatment over minimal treatment. Comments from the focus groups suggest that this is based on a lack of understanding about how drivers and cyclists are supposed to behave when there are shared space markings (4). In contrast, cyclists prefer some type of marking to none at all, but only a small portion reported feeling comfortable in any of the shared spaces. Potential cyclists, in particular, were averse to any shared space: only 10% of potential cyclists indicated they would feel comfortable on a commercial street with sharrows, and only 3% would feel comfortable on a street with no bicycle markings at all. This is a particularly “wicked problem” for the U.S., in which urban areas have typically given priority to cars through travel and parking lanes. When city officials choose not to reduce the parking or travel lanes for cars, there is often not space available for a separated cycling facility.

Third, perceptions of striped bicycle lanes—the most common on-road, marked bicycle facility in the United States—were mixed. On the one hand, a large majority of the sample thought that bicycle lanes communicated that drivers should expect cyclists on the roadway, and increased drivers’ perceptions of predictability when driving near cyclists. On the other, bicycle lanes were seen by some respondents—particularly non- and potential cyclists—as communicating that drivers should not expect cyclists on non-bicycle routes. In addition, some focus group and survey participants commented that a striped bicycle lane in the “door zone” of a car may actually increase, rather than mitigate, traffic risk. Striped bicycle lanes were considered at least moderately comfortable for driving by about two-thirds of the sample, and moderately comfortable for cycling by half the sample—and only 20% of potential cyclists.

The findings for roadway design preferences suggest a disconnect between what people desire and what is allowed to be built. While no comprehensive roadway database exists to determine exactly how prevalent each of these treatments is in the United States, only a few cities have built barrier-separated bicycle lanes (e.g., Portland, Oregon; New York City; San Francisco; Washington, D.C.; Chicago). In addition, at least initially, these cities had to seek approval from the Federal Highway Administration (FHWA) to install the barrier-separated lanes as experiments because these treatments, although seemingly universally appealing, are still not in the American Association of State Highway and Transportation Officials (AASHTO) Bike Guide—the “official” roadway design guide dealing with bicycles (19). Partly in response to the lagging of AASHTO guidelines, the National Association of City Transportation Officials (NACTO) published its own Urban Bikeway Design Guide in 2011 in order to provide guidance on separated bicycle facilities to interested parties (20). Green (or other colors of) painted lanes have only been in the design guide since 2009, although a few cities have had painted lanes for over a decade years (21, 22)—again often as part of an FHWA exemption or study.

The bicycle treatments that have been sanctioned long enough to be prevalent are among the least popular options in Figures 2 and 3; the striped bicycle lane next to parking (given that on-street parking has been a staple of street design for decades), the shared lane marking, and the no-treatment option (occasionally coupled with bicycle route/share the road signage). So few potential cyclists feel comfortable with shared space designs on commercial streets—including sharrows—that they may be essentially useless in attracting new riders. Overall, just a small minority of current cyclists feel comfortable riding on commercial roadways where cyclists and drivers share space.
Therefore, while the U.S. Department of Transportation (USDOT), Centers for Disease Control and Prevention (CDC), American Academy of Pediatrics (AAP) and other prominent organizations have urged people to bicycle more to improve health, reduce emissions, and increase livability, most cities have installed few, if any, bicycle treatments—and the ones they have installed are among those deemed least comfortable. That cities have seen an increase in bicycling despite this mismatch between preferences and the built environment could be taken as a sign that there is serious latent bicycling demand.

Limitations
The data presented in this paper is subject to some limitations. First, the survey data may be biased toward people who care about bicycling or driving near bicyclists and were therefore more likely to participate not only in the overall survey, but also in the optional design preference section. Second, due to funding and time constraints, the survey was conducted with a convenience sample that, while intended to be representative of the Bay Area population, cannot be said to have ultimately been so. Third, conducting the survey via the internet, while facilitating data collection and reducing the possibility of data entry error, also meant that people without regular internet access, in particular the elderly and the very poor, were less likely to have a chance to participate. Fourth, the roadway design ratings were not based on a stated preference framework, and thus cannot be said to represent ratings that have fully considered trade-offs between features (for example, the loss of parking in some cases). In addition, these roadway designs were based on one multi-lane, commercial roadway in the Bay Area with certain base features. Although these findings corroborated those of similar research studies, it is possible that the priority of features could change under different circumstances. Finally, it cannot be guaranteed that all respondents held the same definition of “comfort” when answering the questions.

These limitations are overcome in part by some of the study’s strengths. First, this portion of the online survey received 225 and 263 responses (for bicyclists’ preferences and drivers’ preferences, respectively)—a large enough sample size to mitigate some of the concerns about population and response bias. In addition, the findings presented in this dissertation corroborate findings from earlier studies, suggesting that the limitations of the study are not extraordinary.

CONCLUSIONS
This study is one of the first to examine the roadway design preferences of motorists. The findings presented in this article suggest alignment between drivers and cyclists for roadway designs to maximize comfort while sharing the road, with both groups preferring greater separation on multi-lane roadways. These findings corroborate past research on bicyclists’ preferences.

This evidence urges the reconsideration of design standards for multi-lane roadways—particularly for jurisdictions seeking to attract new cyclists. Despite studies showing that barrier-separated bike lanes are no more hazardous (and may be less so) than other approved bicycle facilities (23, 24), and in seeming disregard of their apparent appeal, barrier-separated bicycle lanes—the single bicycle facility that several studies (this one included) have documented as overwhelmingly popular among potential and current cyclists, irrespective of gender, age, and cycling frequencies—are still not in the official AASHTO Bikeway Design Guide. Arguably,
this could and should be remedied through a special edition of the AASHTO guidelines, or perhaps AASHTO’s recognition of the guidance provided through the NACTO design guidance. The findings presented here also suggest areas for future research. For example, practitioners need a better understanding of the risk of injury from collisions or near misses sustained while bicycling in the bicycle lanes painted in the “door zone” of the roadway. While the data presented here suggest that bicycle lanes convey benefits in the form of increased comfort for cyclists, increased awareness for drivers, and possibly even increased numbers of cyclists, related data from the survey indicate that the risk of being hit by a car door is a consistent worry for weekly and daily cyclists, many of whom have been hit or almost hit in the situation (4).

REFERENCES


