Constructing Improved Bicycle Maps: User Preferences and Comparative Analysis

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Submission Date: 10/29/13
Number of Words: 5,178+ references
Number of Tables/Figures: 10 (2500 words)
ABSTRACT

Efforts to promote bicycling, particularly in urban areas, have often included the provision of bicycle-focused maps or mapping tools to reduce information barriers. The range of methods employed for these maps has varied greatly, to the point that a comparative analysis may help provide some guidance for future map generation. Using a custom created survey of cyclists’ preferences in both map and route choice, this paper identifies features that should be included in an optimal map for the City of Atlanta. A critical review of common mapping methods, specifically stakeholder-based maps, infrastructure-based maps, Bicycle Level-of-Service (BLOS) maps, and crowd-sourced information-based maps is presented, as well as suggestions are provided on how an improved map might be generated using a combination of existing methods.
INTRODUCTION

Bicycling is a low-cost mode of transportation that promotes a healthy lifestyle with limited environmental impacts, reduced road congestion, and reduced fuel dependency of the transportation system (1). However, despite support for bicycling in many communities, and cycling's numerous advantages, the National Household Travel Survey reveals that only 1.8 percent of all trips in the United States are bike trips, and more than half of such trips are for recreation (far below similar numbers in European nations like Germany and the Netherlands) (2).

One of the major reasons cited for the low biking rate in the United States is the absence of safe bicycling facilities (3). Roadway design in the U.S. has been traditionally geared towards fulfilling motorized travel needs that differ, in many cases, from the needs of bicyclists, and are often in direct conflict with the requirements of safe biking. A concerted and growing effort to promote non-motorized transportation has arisen at both local and federal scales and steady growth in biking has followed across the country. For example, in Atlanta, which is not a traditionally bicycle-friendly area, cycling as a mode to commute to work increased 417% between 2000 and 2011 (4). Though this growth may be attributable to a low baseline, it is nonetheless suggestive of a meaningful increase in local bicycling.

Over the past decade, research as well as considerable funding has been dedicated towards improving bike and pedestrian facilities and promoting safe and convenient bike/pedestrian commutes. These efforts are not restricted to infrastructure only, but also include associated projects such as providing better cycling maps, real time information, and promotional campaigns to encourage new cyclists. Maps in particular have been a popular tool for advocacy groups and local governments to bridge the information gap that may keep many “interested but concerned” individuals from cycling (5). However, the volume of literature dedicated to understanding user preferences for such maps, as well as how maps can better capture route preferences, is quite limited.

As local stakeholders such as planning departments and advocacy groups have expanded their efforts to support bicycling, the need for research on bike maps and mapping tool preferences has grown. Being able to provide mapping tools that better match the needs of cyclists, and provide them with superior information, can help maximize the value of other investments supporting bicycling. The need for better maps and mapping tools is the impetus for this project, and its practical value is in its potential contribution to such mapping efforts. Using a review of prominent tools and methods for creating and providing maps, as well as a survey of cyclists within the Atlanta metropolitan area, the intent of the study is to provide practical recommendations and guidance for an improved bicycle mapping tool that is not only current in its use of technology, but that is also valid in its methodology relative to alternative options.

LITERATURE REVIEW

Mode and Route Choice Factors
Maps are only as useful as the information that they provide to users. As such, a discussion of maps and mapping technologies cannot be conducted without a brief overview of the factors that influence bicycling. Starting with the premise that the goal of map provision is to encourage and support the use of bicycles, maps and mapping tools can be used to provide information about those factors that are the most influential in mode and route decision-making. It is vital that any
mapping effort be actively aware of what factors influence route and mode choice, and
incorporate those components into the map.

With regard to mode and route choice factors, travel time and distance are identified as
significant factors influencing both mode choice (6, 7, 8) and route choice (9). Safety is also
emphasized in the research literature as a factor affecting mode choice (10, 11), though
perceptions of safety may be more relevant than actual risk as revealed by number of incidents
and crash rates (12, 13). Travel speeds and traffic volumes are associated with both actual and
perceived safety, and have been found to be significant disincentives to cycling (11, 14). In
addition, weather is a larger factor than climate (12).

Both mode and route choice studies devote a great deal of attention to the provision of
infrastructure. Studies indicate that the presence of bike paths is strongly associated with cycling
and route preferences (12, 9, 11), though this preference may be higher amongst recreational
cyclists (15). Additionally, data on preference for bike lanes is more mixed, with evidence that
bike lanes are preferred over roads without lanes (10, 15), but that bike lanes may provide less
relative incentive than other treatments (separated used paths) or alternative routes (9, 16).
Furthermore, demographic factors or personal preferences have been shown to be potentially
more important than external conditions (16). Despite these mixed results, facility quality seems
to be overall an important factor in travel behavior decision-making with respect to bicycling
mode choice (17, 18, 11).

Bike Maps and Mapping Tools
Maps serve to provide information about a place to tourists and new members of the community,
as well as to guide both newcomers and long-time residents. Given the range of maps and
mapping tools employed around the world, a review of the diversity of methods and assessment
of some prominent examples of each method was required to better understand their relative
strengths, weaknesses, and applicability. This paper examines four prominent types of bicycle-
specific maps: stakeholder-based maps, infrastructure-based maps, Bicycle Level-of-Service
(BLOS) maps, and crowd-sourced information-based maps. Infrastructure and stakeholder-based
maps focus on providing specific information about the location of certain bicycle-related
amenities, such as bike lanes or paths, repair facilities, and tourist attractions. Bicycle Level of
Service (BLOS) maps use a multivariate function to estimate the comparative quality of roadway
segments and displays these ratings, while crowd-sourcing relies on iterative community input to
evaluate segments. Each method is presented in the context of current literature and an existing
application of that method.

Stakeholder-Based Maps
Public agencies, often in conjunction with bike share programs or local advocacy organizations,
produce many of today’s bicycle maps around the world. Yet other stakeholders may play a
significant role in development and dissemination of maps by providing funding, determining the
features/locations marked on maps, and distributing the maps. For example, bike shops often
adopt a role in the funding and distribution of maps; at the same time, bike shop locations are of
interest to map users for emergency repair or maintenance of bicycles. This mutually beneficial
relationship can make stakeholder-based maps attractive from the perspective of the map
developer.

Because cycling can diminish the first mile-last mile problem in transit use (the challenge
of bridging the physical gap between nearest transit stops and actual residences), connections to
public transit are appealing features to include in bicycle maps. However, while transit train stations are typically a standard element in bicycle maps, bus stations are more often excluded or shown as an optional layer in digital maps. Tourist attractions and landmarks are also a staple in many maps. Because landmarks are useful markers for locals as well and do not generally clutter up a map, the need for separate tourist bike maps generally does not warrant the extra cost of creating a separate product geared towards transit users and/or tourists.

*Example Map: Barcelona*

Bike share programs are sprouting and growing in cities around the world. As mentioned earlier, these programs can also play a large stakeholder role in maps, leading cities to publish maps focused around the bike share program such as Barcelona’s *Pocket Bicycle Map of Barcelona* (19). The map produced by the city marks every station in the public-operated bike share program with a red circle. It also shows selected locations for bicycle tours and bike rentals, but not bike shops, which would be helpful. The visual prominence of bike share and bike tour locations makes the Barcelona map a clear example of stakeholders playing a large role in what is and is not graphically represented in the map. This advertising element for both public and private stakeholders leads to wide distribution of the map through public and private circuits, and interests from multiple sides to keep the map updated.

![Figure 1. Selection from Pocket Bicycle Map of Barcelona](image)

*Infrastructure-Based Maps*

The presence of bicycle infrastructure often plays a central role in the design of a bicycle map. However, whether these features are implicitly or explicitly represented depends on the map. Some maps mark the bikeability, or bicycle-friendliness, of the area, as assessed by physical infrastructure combined with other road characteristics. In other cases, the map will explicitly...
identify the presence of particular types of infrastructure, often at the exclusion of other qualities of the road. In the case of the Atlanta Midtown/Downtown Bicycle Suitability Map (20), infrastructure elements are incorporated into a rating function. Other maps, such as that produced by the city of Flagstaff (21), chose to focus exclusively on displaying bicycle infrastructure. Due to the strong positive correlation between infrastructure and ridership comfort levels, one cannot underestimate the importance of the provision and visibility of bicycle infrastructure in a map (18). At the same time, the focus on specific infrastructure makes it important that maps are updated regularly in accordance with infrastructure changes.

**Example Map: Portland**

Portland, Oregon has developed and continues to expand an extensive bicycle infrastructure network. However, the city takes a more nuanced approach to the role of infrastructure in the production of their bicycle maps, incorporating both markers for roads with dedicated infrastructure and bikeability ratings for roads lacking it. Additionally, Portland sought to cater to two different types of trips: work-based and non-work based. The city produced two types of bicycle maps that differed in scale, ratings, and purpose; this allows Portland to accommodate both commuters and casual riders.

The Portland Citywide Bicycle Map as seen in Figure 2 is scaled significantly smaller than the alternative district maps, and assumes that the rider is comfortable riding in traffic (22). Therefore, identification of infrastructure is not explicit, but rather included in a broader spectrum of characteristics. The district based bike/walk maps cater to a much broader audience that includes both seasoned commuters and those who are uncomfortable riding in traffic (23). Therefore, infrastructure plays a more prominent role as bicycle lanes are explicitly delineated with different colors from other routes. However, as there is a smaller network of dedicated bike facilities outside the city core, alternative bikeability ratings for roads lacking bicycle lanes are included, and are set to higher standards than the commuter-focused citywide map. Commercial, educational, and entertainment destinations are also identified with icons on the map.

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**Figure 2. Selection from Portland’s Citywide Bike Map**
Bicycle Level of Service Based Maps

In the 1990s, efforts to quantify route preferences among cyclists led to the development of Bicycle Level of Service (BLOS) ratings. These rating systems use stated preference methods to develop a rating function which can be used to tag road segments with a BLOS rating value corresponding to a BLOS grade (ranging from A-F). Methods for developing this actual function have varied somewhat, but generally include having participants rate segments after viewing video footage of roadway segments (24, 14), riding through them (25, 26), or a combination of both (27). After participants rate each segment, the data are used to create a regression function that captures the impact of various factors on the respondents’ overall ratings. This function can then be used to generate BLOS ratings for other roadway segments simply by inputting values for each of the independent variables.

While BLOS as a methodology was developed primarily to help prioritize bicycle infrastructure improvements in the planning process, it also provides an approachable, quantitative method for generating bike network visualizations and/or prioritizing route options. For some cities, BLOS ratings have formed the basis of bicycle-specific maps. Maps often employ a color-coding strategy to visually display the BLOS rating, and supplement the rating with public input and review to ensure accuracy in particular contexts.

Example Map: Atlanta
The Atlanta Bicycle Coalition (ABC) Midtown/Downtown Bike Suitability Map was a joint venture between ABC, the City of Atlanta, and Sprinkle Consulting (20). The process began with previous subjective-preference maps and the location of bicycle-specific infrastructure. Priority street segments were then re-evaluated using a BLOS rating function drawn from Landis and colleagues (25). This formula generates a BLOS rating as a function of the volume of directional traffic (V), the speed limit (SP), volume of heavy vehicles (HV), FHWA surface condition rating (R), and the width of the outside most traffic lane (W), as well as an error term to account for unobserved factors:

$$BLOS = 0.507 \ln(V) + 0.199 \ SP(1+10.38HV)^2 + 7.066(1/R)^2 - 0.005W^2 + 0.760$$

For the purposes of this function, BLOS results of less than 1.5 are considered grade A, between 1.51 and 2.5 are grade B, etc.

Data were gathered for each independent variable for the roadway segments included within the purview of the map and input into the function to generate a raw BLOS score and the associated grade for each segment (which could be converted to a color-code). The process was supplemented with stakeholder review. By focusing on a smaller, central area of the city, this map allows for a greater level of detail. In addition to identifying quality of individual road segments, the map included heavy rail transit stations, freeway under and overpasses, one-way streets, bicycle shops, and areas of steep grade. Figure 3 displays a central section of the Atlanta Bike Suitability Map, including the color-coded roadway segments and selected stakeholder features.
Crowd-sourced Information Based Maps

Crowd-sourced maps are a step towards development of user-defined maps where diverse interest groups can contribute and participate. Traditionally, bicyclists have remained interested and enthusiastic about sharing information, but there has been little structured effort or ability to harness user enthusiasm to create a reliable bike suitability map until recently. While maintaining coordination and uniformity in crowd-sourcing is a significant challenge, this voluntary coming together of a mass of people for a purpose is particularly useful for large tasks like mapping. Crowd-sourcing is most successful when a platform provides open access for incorporation, alteration, and modification of data. Therefore the popularity of crowd-sourcing is intimately related to the development of advanced Web or Smartphone App technologies.

Some research argues that crowd-sourced maps and geo-wikis are particularly suitable for developing bicycle maps because developing and showcasing bicycle maps is not commercially attractive and hence, fairly rare (28). In addition, cyclists express a need for updated information about byways and local landmarks for their trips, along with preferred and suggested routes between travel points (29); local residents who are familiar with the area can best provide this information. The greatest advantage of crowd-sourced bike suitability maps is that an active community will regularly provide timely updates to maps and include accurate local information that is often difficult for others to find.

Example Maps: OSM and Cyclopath

The popularity of crowd-sourced maps can be seen in OpenStreetMap (OSM). OSM users are able to edit existing content, view all past history of user contributions, and dynamically change the view of the map. Cyclopath, another crowd-sourced geo-wiki-based bicycle map developed by the University of Minnesota, maintains an active database on the bicycle routes and trails within the Minneapolis – St. Paul metropolitan area that is contributed to by the users of the site.
Cyclopath.org). The users of Cyclopath can add, modify, and delete roads and bike trails, or segments thereof. They can also modify points of interest or parks and neighborhoods that may be relevant. In addition, Cyclopath allows users to add public notes and tags describing any feature on the map, which are tagged to their login. According to Masli (28), since Cyclopath’s release, the user community has made more than 13,000 revisions. Cyclopath also allows a user to somewhat personalize the map by allowing them to rate the biking routes on a five-level qualitative scale (ranging from Impassable to Excellent). Figure 4 below shows a mapped route with routing directions and options on the left side of the screen.

![Figure 4. Screenshot from Cyclopath website, December 2012](image)

Crowd-sourced Information from Smartphone Data Collection

With limited funding, transportation agencies are constantly searching for cheaper, more accurate methods to collect bicycle route choice data. One innovative approach to collecting revealed preference data is employing smartphone GPS data collection methods. With the prevalence of smartphones ownership at 46 percent of the U.S. adult population (30), volunteer participants can download a smartphone application and are able to record bicycle trip information such as trip time, trip purpose, distance, average speed, and route map. Examples of such methods being used in practice are CycleTracks in San Francisco (31) and Cycle Atlanta in Atlanta (5). The advantage of smartphone based data collection is that by allowing participants to use their own smartphones, capital costs associated with bicycle route data collection are dramatically reduced, even eliminated. Smartphone GPS methods provide a critical advantage as they are less costly and prone to error than non-GPS methods (31). Ultimately, the collected data can be used to generate route maps and to better understand the factors that influence cyclist route choice.
BIKE MAP PREFERENCES SURVEY

Data Collection
While some recommendations can be made solely on the basis of the strengths and weaknesses of the methodologies themselves, in the end, users’ preferences are critical to the adoption and success of maps. To that end, a survey was constructed and administered to Atlanta-area bicyclists to gather quantitative evidence of user preferences that might provide additional insight into desired features, content, and map forms. Given the exploratory nature of this work, the study team elected not to test any particular hypotheses with respect to map formulation, but rather to allow the survey data and descriptive statistical test results help guide future map development efforts and develop hypotheses that could be tested with maps developed in the future.

The Bicycle Map Survey was developed in partnership with the Atlanta Bicycle Coalition (ABC), a local membership-based advocacy group with access to an e-mail list comprised of cyclists of different levels of experience in the Atlanta region. One survey goal was to solicit a high response rate from dedicated bicycle users with a reasonable cross-section. It was not designed to assess why people do not currently bicycle, but rather what dedicated cyclists want from a map. As such, the sampling strategy was targeted at reaching a sample of dedicated cyclists. To facilitate responses, the survey instrument emphasized brevity and clarity while still covering all of the primary areas of interest. These areas of interest include:

- Mode and route choice preferences
- Preferences for functionality and features of maps/mapping tools
- Motor vehicle traffic characteristics and conditions
- Cycle experience

Survey Implementation Methodology
The survey was distributed in January 2013 to the approximately 1,000 current members of the Atlanta Bicycle Coalition (ABC) newsletter e-mail list. The survey instrument was made available to potential participants via an electronic mailing from ABC with no direct incentives. The online survey was open for a period of two months (with one follow-up email delivered midway through the survey period) during which 199 completed responses were received yielding a 19.9% response rate.

Survey Results
Beginning with basic behavioral questions, the survey found that 64% of the 199 respondents ride primarily for transportation, the other 36% for recreation. The average weekly cycling mileage across all respondents was 44.2 miles with a slightly higher average among recreational riders (51.7 miles) compared to those who rode for transportation (40.8 miles). A t-test on the average miles biked by purpose showed no significant difference between the two groups, although distance travelled was related to the comfort/confidence level of the respondents (value of p=0.0001). When asked about their level of comfort/confidence, 23% of respondents self-identified as “Strong and Fearless”, 64% as “Enthused and Confident”, and 12% as “Interested but Concerned”. Despite specifically sampling for cyclists, researchers also gathered 1% of respondents who identified as “No Way No How” or “I Don’t Know”.

Table 1 displays a break down on miles bikes per week, level of comfort and confidence, and recreational vs. transportation riding across respondents’ characteristics. Recreational
cyclists appear to ride more miles than their transportation counterparts, and are slightly more confident. Put another way, more confident cyclists rode further per week (unclear direction of causality; it may be that riding further makes you a more confident cyclist, or that being more confident encourages you to ride further), but in these subsamples the standard deviation is fairly high due to large variation in average weekly mileage.

**TABLE 1 Respondent Characteristics.**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall</th>
<th>Recreational Rider</th>
<th>Transportation Cyclist</th>
<th>Enthused and Confident</th>
<th>Strong and Fearless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles per week</td>
<td>44.2</td>
<td>42.7</td>
<td>51.7</td>
<td>40.8</td>
<td>43</td>
</tr>
<tr>
<td>Recreation (0) or Transportation (1)</td>
<td>0.6</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>Level of comfort and confidence*</td>
<td>1.9</td>
<td>0.7</td>
<td>2.0</td>
<td>1.8</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*A lower number equates to a higher perception of confidence and comfort

**Route Choice Decisions**

To better understand the decision-making process of participants, the survey asked respondents how important different factors were in selecting their routes while bicycling. The survey included 11 different factors, and asked respondents to rate them on a scale from 1 (not at all important) to 7 (critically important). The resulting ratings of route choice factors, as well as the most common score and the standard deviation across scores are displayed in Table 2.

**TABLE 2 Route Choice Factor Rating.**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean*</th>
<th>Mode</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separated bicycle infrastructure</td>
<td>4.8</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>6.0</td>
<td>5.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Traffic Speed</td>
<td>6.2</td>
<td>6.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Traffic Safety</td>
<td>6.3</td>
<td>6.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Distance</td>
<td>4.4</td>
<td>4.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Road Condition</td>
<td>4.8</td>
<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Elevation/Grade</td>
<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Bike Parking at Destination</td>
<td>3.9</td>
<td>3.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Transit Stations</td>
<td>3.1</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Speed Bumps</td>
<td>2.6</td>
<td>2.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Bike Repair Locations</td>
<td>2.3</td>
<td>2.1</td>
<td>2.7</td>
</tr>
</tbody>
</table>

*On a score from 1 to 7, with 7 being critically important when selecting a route/mode

Overall: N=199                Transportation Riders: N=130     Recreational Riders: N=69

*On a score from 1 to 7, with 7 being critically important when selecting a route/mode
Some interesting findings from Table 2 include:

- The highest rated factor in route choice was perceived traffic safety (score of 6.3 out of 7).
- Traffic speed and traffic volume were closest behind (6.2 and 6.0).
- A noticeable gap existed between the three traffic characteristics and the next factors of separated bicycle infrastructure (4.8), road conditions (4.8), distance (4.3), and grade (4.3).

Chi-square tests were performed on route characteristics and the comfort level of the riders – other than presence of bike repair locations (p=0.007) and speed bumps (p=0.001), the chosen route characteristics were not significantly related to rider type. Therefore, the importance of factors such as traffic safety, traffic volume, and traffic speed were not significantly different across these comfort level groups. For bike repair locations and speed bumps, the Chi-square results were influenced by the significantly high frequency of Strong and Fearless and Enthused and Confident rider types assigning these two factors a low score. This may suggest that bike maps designed for less intense cyclists might wish to include these factors, although this cannot be confidently concluded on the basis of this data alone.

Recreational riders were far more concerned with traffic characteristics, particularly traffic volumes, and cared much less about distance as may be expected, given the decrease of importance in origins and destinations for recreational rides. A t-test on miles biked and rider type (recreational or transportation) showed an insignificant relationship with p=0.1142. Rider type was found to be significantly related to preferring a route with separate facility or not (p=0.027) – a larger proportion of non-recreational riders scored separated facilities higher than did the recreational riders.

**Map Usage**

The study team found that 81% of respondents owned a smart phone, and 5% planned to own one in the next two years. In addition, electronic access was the most highly rated function in terms of importance in a bike map or mapping tool, with an average score of 5.8 out of 7, eclipsing point-to-point directions (the next most important feature) by half a point. Having a map that is electronically accessible is also related to the rider comfort level (p=0.035); such access was most popular among the Enthused and Confident riders, and relatively less important for the others. As expected, given the popularity of electronic access, the most popular map tools were Google Maps bike route feature and the non-bike-specific Google Maps tools, followed by the local Atlanta Bicycle Coalition printed map, Map My Ride, and Ride the City. About 7% of respondents did not use a map tool at all when selecting a route. Table 3 shows the number of responses associated with each mapping tool.
TABLE 3 Usage of Mapping Tools.

<table>
<thead>
<tr>
<th>Stated primarily tool used when selecting a route</th>
<th>Frequency (out of 199 respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Maps</td>
<td>48</td>
</tr>
<tr>
<td>Google Maps Bike Route</td>
<td>96</td>
</tr>
<tr>
<td>Atlanta Bicycle Coalition Map</td>
<td>10</td>
</tr>
<tr>
<td>Campus Bike Map</td>
<td>1</td>
</tr>
<tr>
<td>MapMyRide</td>
<td>8</td>
</tr>
<tr>
<td>RidetheCity</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>19</td>
</tr>
<tr>
<td>None</td>
<td>14</td>
</tr>
</tbody>
</table>

Map Priorities

When asked to rank content features on a scale of one to ten, where one is the most important and ten is least important for bike map inclusion, responses were consistent with cyclists’ ratings of important factors in choosing a route. The results are summarized in priority order Table 4.

TABLE 4 Priority of Features in a Map.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mean**</th>
<th>Mode**</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Safety</td>
<td>3.1</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>3.2</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>Traffic Speed</td>
<td>3.4</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Separated bicycle infrastructure</td>
<td>3.6</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Distance</td>
<td>5.0</td>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td>Road Condition</td>
<td>5.8</td>
<td>7</td>
<td>1.8</td>
</tr>
<tr>
<td>Elevation/Grade</td>
<td>5.9</td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>Bike Parking</td>
<td>7.7</td>
<td>8</td>
<td>1.7</td>
</tr>
<tr>
<td>Transit Stations</td>
<td>8.1</td>
<td>9</td>
<td>1.8</td>
</tr>
<tr>
<td>Bike Repair</td>
<td>9.3</td>
<td>10</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**1 is ranked most important, 10 is least important

The survey also asked respondents about their preferences for particular functionality in a map or mapping tool, and found that electronic access was most popular, but not by a significant margin over the alternative options, all of which appear to have some appeal (see Table 5).
**TABLE 5 Importance of Functions in a Map Tool**

<table>
<thead>
<tr>
<th>Function</th>
<th>Mean**</th>
<th>Mode**</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being able to access electronically</td>
<td>5.8</td>
<td>7</td>
<td>1.7</td>
</tr>
<tr>
<td>Ability to provide input on the map content</td>
<td>4.0</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>Ability to customize the content selected on the map</td>
<td>4.6</td>
<td>5</td>
<td>1.7</td>
</tr>
<tr>
<td>The map provides point-to-point route suggestions</td>
<td>5.2</td>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>The map shows potential hazards</td>
<td>4.6</td>
<td>5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**On a score from 1 to 7, with 7 being critically important in a map tool**

**Discussion**

The high-level of smartphone usage among the survey respondents suggests that maps may be less effective for bicycle enthusiasts if only made available in print form. In addition, electronic access and turn-by-turn directions were more highly ranked as user features (5.8/7.0 and 5.3/7.0 respectively) and may be an expected norm for maps used by bicycle enthusiasts. Customization and crowd-sourcing are appealing but less critical, suggesting that making these tools available through open-sourcing or a crowd-sourced review period may be sufficient to appeal to those who value them.

In terms of map content, respondents prioritized traffic speed, volume, and safety, and separated bicycle facilities. A BLOS-style function that emphasizes traffic speed, safety, and volumes, as well as the presence of dedicated infrastructure, might be able to take the most important factors into account and present results that users can readily interpret. Any route suggestions provided by the map should favor highly rated corridors on the preferred variables, more than simply minimizing distance and grade.

Interestingly, bicycle infrastructure was not valued as highly by the respondents as might have been expected, though it was valued more highly by those who identified themselves as less confident - as were most other factors, which might suggest that confident cyclists are truly less concerned with conditions. Infrastructure was also more important for maps than it was in route choices; one might conclude from this that bicyclists accept the reality of limited dedicated bicycle infrastructure when choosing a route, but prefer a map which provides information about where such infrastructure exists so that they can use it when given the choice. It should be noted, though, that generalization of the results of this survey may not hold for less avid cyclists or new cyclists as the sampling population is biased towards frequent and confident cyclists. In addition, it’s not entirely clear whether the population of cyclists (particularly their preferences) is meaningfully different from one city to another. Future research will be necessary to explore this further.

**Future Research and Applicability**

Atlanta was selected on the basis of research convenience and resource limitations, but many of the recommendations might be generalized to other cities on the basis of a meaningful sample.
size if we assume that there is reasonable commonality of cyclist preferences across comparable
cities (further research regarding this is needed). While not guaranteed to be an ideal cross-
section of the region’s cyclists, the sample size is large enough to suggest some general trends in
the population of current cyclists. In selecting this sample, a much smaller representation for
non-cyclists and non-residents is accepted (as well as those without access to e-mail or
involvement in ABC). These groups may be populations with unique preferences for bicycle
maps, which are not captured in this survey (a limitation that may warrant improvements in
sampling methods for future research or even a survey targeted at non-cyclists). In addition to
methodological improvements and expanded sampling, future efforts should consider expanding
the size of the survey to include an array of demographic questions, as well as consider
supplementary interviews to explore the qualitative experience of map use and its relationship to
route/mode choice.

CONCLUSIONS

The review of mapping methods presented in this paper indicates that an improved mapping tool
could be generated through the combination of the most effective components of each mapping
method. This general suggestion is supplemented by a selection of major findings and
recommendations, highlighted in Table 6. Survey results revealed a lower prioritization of
bicycle infrastructure than might have been expected based upon the literature reviewed
previously. The results also challenged the importance of including stakeholder features such as
bike repair shops and transit stops. These features should be added if possible, but stakeholders
should be mindful of cyclists’ priorities for map features. BLOS methods might offer a platform
for incorporating traffic speed, volume, and safety (which were the most prioritized factors
among survey respondents), but BLOS has historically been used to generate static print maps,
which were less utilized and favored than electronic maps among respondents. That said, there is
the potential to use more precise and current data to provide a fluid and evolving BLOS-based
online map. It may also be feasible to incorporate additional data as selectable layers or inputs
for an existing online map tool such as that provided by OSM or Google Maps. Table 6 below
outlines the finds and recommendations from the paper.

TABLE 6 Findings and Recommendations

<table>
<thead>
<tr>
<th>Findings</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle-specific infrastructure is less important than traffic conditions</td>
<td>• Expand methodologies to focus on conditions • Update existing methods to include wider array of features</td>
</tr>
<tr>
<td>Respondent concern for real-time conditions of traffic volume, speed, and safety hazards</td>
<td>• Incorporate updated and current data on conditions</td>
</tr>
<tr>
<td>Electronic maps favored over static print maps</td>
<td>• Improve accessibility of electronic maps</td>
</tr>
<tr>
<td>User input and local knowledge are appealing to some respondents and may be useful to map developers</td>
<td>• Supplement map development with user input measures • Encourage user relationship with product</td>
</tr>
<tr>
<td>Stakeholder features (transit stops, bicycle repair facilities) are less prioritized</td>
<td>• Include when possible • Do not include too much to compromise other features or functionality</td>
</tr>
</tbody>
</table>

Crowd-sourcing has a lot of merit as a process for data collection, and the results support
that it has appeal for some respondents. Local public involvement in map creation is invaluable,
and crowd-sourcing is an easy way to use local knowledge. The prevalence of smartphones among respondents, and the high percentage of participants who have used a related app suggest that smartphone data collection may be a useful tool for identifying favored corridors and validating conditions. In considering the different features that each respondent preferred and the distributions of ratings and rankings, layering of service information may be a useful option. This would allow users of the map to select the factors of increasing personal relevance and importance, or even to input their comfort and experience level, and receive route information that captures a perspective potentially more similar to their own (this could also be incorporated into an existing tool such as OSM or Google Maps).

Provision of online and printed maps for the bicycle user community may require simplifying the presentation of data to make the information more useful to users. Electronic maps provide a platform for expansive route maps containing relevant information associated with each roadway segment. Electronic maps also constitute a sizable undertaking, but could integrate the most comprehensive and appealing mapping tools developed to date.

Future efforts to develop and implement the recommendations from this study may identify as-yet-unknown challenges and/or preferences in the pursuit of a superior mapping tool for municipalities and advocacy organizations. Such efforts may also aim to assess the needs of those who currently bicycle infrequently or not at all, as their map preferences and route decisions may vary from the sample used in this research. Thus, as bicycling continues to grow in the United States, the value of generating improved maps will also grow.

SOURCES


8. Heinen, E., Maat, K., & van Wee, B. Day-to-Day Choice to Commute or Not by Bicycle. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2230,


