A Historical Perspective on the <u>AASHTO Guide for the Development of Bicycle Facilities</u> and the Impact of the Vehicular Cycling Movement

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1. ABSTRACT

This paper draws from a literature review and interviews to demonstrate the impact of advocacy, research, and culture on guidance for design users, bike lanes and separated (protected) bike lanes in the American Association of State Highway Transportation Officials (AASHTO) Bicycle Guide content from 1974 to present. In the late 1960s and early 1970s, a bicycle renaissance in America resulted in efforts at the local, state, and federal level to encourage bicycling. After Davis, California, became the first community in the United States to build a network of bike lanes, a new brand of bicycle advocacy – vehicular cycling (VC) – formed to oppose efforts to separate bicyclists from motorized traffic based on fears of losing the right to use public roads. Via positions of power and strong rhetoric, vehicular cyclists influenced design guidance for decades to come.

Through the 1980s, the VC philosophy aligned with a federal view that bicyclists freeloaded from the gas tax, the latter resulting in diminished federal support for guidance and related research throughout the decade. However, the passing of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) led to increased bicycle networks and renewed interest in bicycle facility research. Although vehicular cyclists continue to oppose roadway designs that separate bicyclists from motorized traffic, research from the last decade demonstrates networks of separated bikeways improve bicyclist safety and are necessary to meet the needs of the vast majority of the public who want to bicycle but feel unsafe in many traffic contexts.

2. INTRODUCTION

A transportation design guide does more than just synthesize scientific data and facts—it reflects the values of a culture based on the opinions and political climate of the era, and the knowledge and biases of the people involved in the development of the guidance. From the 1950s through the 1970s, the transportation profession focused almost entirely on expanding motor vehicle mobility, as evidenced by the completion of a 26,000-mile network of interstates in 1971 after only 15 years of effort. It is within this context of suburban expansion, increasing automobile dependence, and worsening air quality that interest in bicycling for transportation emerged.

However, as more adults began to bicycle in the 1970s, bicycle crashes increased (see example from Santa Barbara, CA, in Figure 1) *(1)*. People began to demand safety improvements and political support grew to provide them. For example, in 1971, New York Congressman Ed Koch advocated for a new roadway design approach, saying, “The only way to ensure safety for the many thousands of New Yorkers who want to bicycle is to designate official and exclusive bike lanes” *(2)*.

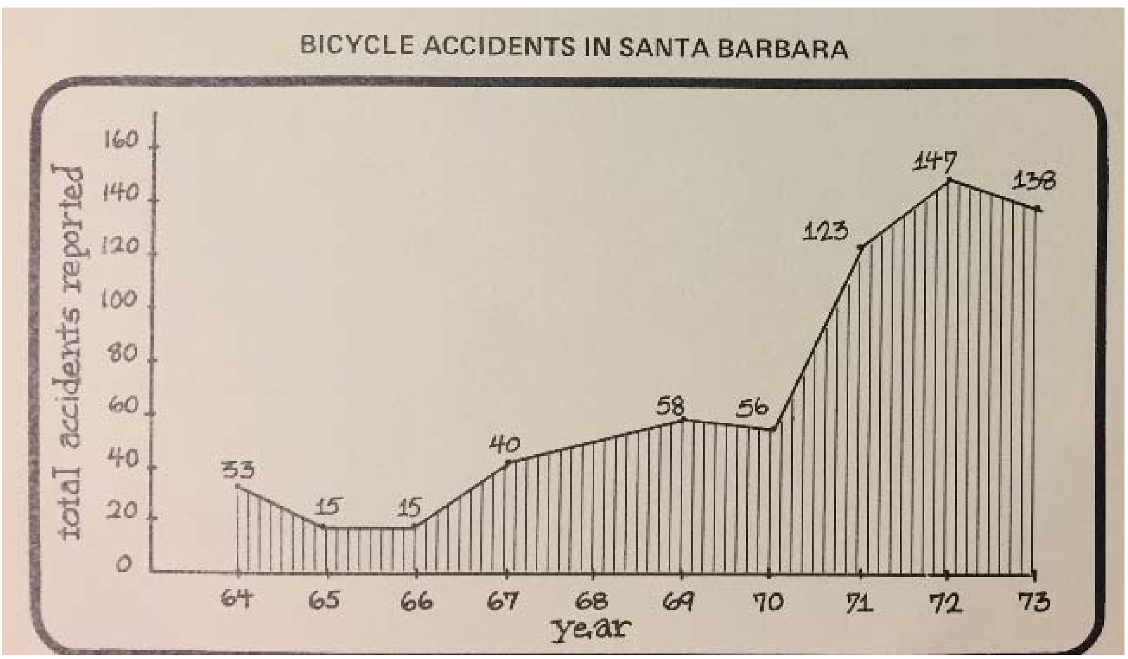

FIGURE 1. Bicycling Trends from 1974 Santa Barbara Bikeway Master Plan *(1)*

As citizens requested bike lanes, transportation officials were put in the uncomfortable position of having no reliable design guidance. To resolve this issue, the U.S. Department of Transportation (USDOT) and some states began to fund bicycle programs and research. This research and experience led to the development of bicycle facility design guidance at the state (notably California) and national level, including the publication of the first edition of the AASHTO Bike Guide in 1974.

This paper reviews the evolution of the AASHTO Bike Guide from 1974 to 2012 as a case study, relying on Guide content, published research, and interviews of key sources to show how advocacy, research, and culture influenced the history of the Bike Guide as it pertained to guidance for design users, bike lanes (unprotected) and separated bike lanes (curb- or parking-protected).

3. METHODOLOGY

3.1 Overview of Methods

As a history paper, this paper focused on a thorough review of the five editions of the AASHTO Bicycle Guide (from 1974 to 2012), along with foundational research documents from the 1970s to the present which have been sources for the design options in the Guide and, more generally, opposition to and support for bikeways into the present day. To understand the historical context of the various Guide editions, the review also included the published writings of known influential people at the time each edition was written, including papers, books, and web archives. To supplement this information, interviews were conducted with key people involved in the development of research or the various guides who did not have published opinions; these sources were chosen either due to their authorship of the guides, their role in funding the development of the guidance, or their name recognition via multiple sources as a major influence on the process. The interviews served to further illuminate the factors influencing the content of the various guides and provided clarity regarding the impact advocacy, research, and culture exerted on the final guide content.

3.2 Limitations

As this paper assessed Guide content and significant relevant influences over time, it was not possible to explore the themes that played a part in the history and deserve to be studied more in depth. These include themes of power, voice, and gender dynamics. Future research further exploring these themes in the context of bicycling history would be welcomed.

4. FINDINGS

4.1 Bicycling Reemerges as a Mode of Transportation: 1960-1974

4.1.1 Davis, California – The First Bike Lane Network in America

In the 1960s and 1970s, Davis emerged as a leader among U.S. cities by providing a bicycle network for its growing population of utilitarian bicyclists who were commuting to work and the UC-Davis campus. While conditions for bicycling were favorable on campus, the bicycling experience deteriorated on shared city streets as motorized traffic volumes grew and conflicts between users increased. In 1963, advocates, informed by visits to the Netherlands, began to lobby the Davis City Council to support the installation of bike lanes to create a bicycle network that was comfortable and appealing for people of all ages and abilities, including women, children, university students, and seniors *(3)*.

While shared use paths had existed in the U.S. for over 60 years, separating bicyclists from motorized traffic within the street was a new concept in the U.S. In 1966, the City adopted a plan for a network of bike lanes. Since bike lanes were a new concept, there was a desire to experiment with a variety of options which were observed in the Netherlands, including a conventional bike lane (unprotected), a street-level parking-separated bike lane (protected), and a sidewalk-level separated bike lane. By 1972, the City had installed a connected bike lane network that connected a majority of the community (*3*).

4.1.2 Relevant Literature and Research

In 1971, the California legislature mandated a research project to "study the most feasible and least expensive methods by which existing and future public streets and thoroughfares can more safely accommodate bicycle riders." This resulted in the publication of the *1972 UCLA Guidelines (4)*, which developed bicycle facility design guidance based on interviews with practitioners and a review of U.S. and international guidance and research. European studies of protected bike lanes all showed similar results: overall bicycle safety improved, and bicycle ridership increased with their implementation, although additional treatments were at times necessary to address increased bicycle crashes at some intersections.

Separately, a 1972 study by DeLeuw Cather evaluated the Davis bicycle network installed between 1966 and 1971 *(5)*. The study reviewed safety performance of the bikeways and provided recommendations for improvement and expansion of the network. Findings included that:

1) Bicyclists and motorists preferred streets with bike lanes to those without, and that separation from motor vehicles and pedestrians increased user comfort;
2) Few bicycle/motor vehicle crashes occurred in bike lanes;
3) Right turn on red was a major source of conflict between bicycles and motor vehicles;
4) Intersection sight distance was an issue on the parking-protected bike lanes at intersections and driveways;
5) Bicyclists operated at speeds between 7-15 mph on flat grades, averaging 10-11 mph;
6) Debris cleaning of protected bike lanes did not occur, creating operational challenges
7) Sidewalk-level protected bike lanes had challenges with pedestrians, trash cans being stored on them, and frequent grade changes at driveways, which discouraged some bicyclists from using them;
8) There were some conflicts with pedestrians exiting cars adjacent to parking protected bike lanes;
9) Some bicyclists did not turn left appropriately from bike lanes; and
10) Motorists illegally entered or parked in unprotected bike lanes.

Of particular interest for later debates was the parking-separated bike lane on Sycamore Street, which was one block in length and serviced over 550 cyclists/hour during peak weekday hours. Despite a lower crash rate/mile than other facilities in the Davis study, as well as clearly high bicycle traffic, this protected bike lane became a poster child for bad design according to Forester, due to its seven collisions over a two-year period.

Additionally, the City of Davis did not prioritize the facility. Despite the study recommending the provision of phase separation with bike signals at Russell Road, the restriction of additional parking at driveways to mitigate sight distance issues, and the installation of additional protected bike lanes and intersections to manage conflicts and clarify bicycle transition and left turn expectations, former city engineer Duane Copley revealed that the City did not make these improvements. He recalled the protected lanes were difficult to maintain and at locations with sidewalk level protected bike lanes or designated sidewalks “at least 50% of bicyclists rode in the street. Bicyclists didn’t like traveling with the pedestrians and they didn’t like riding up and down driveway ramps and meandering around utilities in the lane.” These designs were replaced with on-street bike lanes sometime after 1977 (Copley, personal communication).

4.1.3 The Genesis of Vehicular Cycling as an Advocacy Concept

The implementation of a bicycle network in Davis attracted considerable attention within California and the U.S., inspiring other cities to develop bicycle networks. The development of bike lanes and separated bike lanes, in addition to the designation of sidewalks as bike routes, concerned some club bicyclists that they would lose their right to the road and have to bicycle at slower speeds on “inferior” facilities. These fears were exacerbated when local ordinances were passed to require bicyclists to use bikeways – some of which were nothing more than narrow sidewalks. Additionally, a 1944 Uniform Vehicle Code (UVC) provision was popularized: “Wherever a usable path for bicycles has been provided adjacent to a roadway, bicycle riders shall use such path and shall not use the roadway”; this became known as the mandatory sidepath law. The UVC also included a provision known as the ‘ride to the right rule” which requires bicyclists to ride “as close as practicable to the right-hand curb or edge of the roadway;” this became known as the “mandatory bike lane law.”

In 1972, the City of Palo Alto, CA, began to implement a bicycle network by installing unprotected bike lanes and signed bicycle routes – including sidewalk bike routes, and created an ordinance requiring the use of bike lanes. This attracted the attention of John Forester, a local engineer and amateur bicycle racer. Concerned about the mandatory use ordinance and the potential to be required to bicycle on narrow sidewalks with pedestrians, he became involved with the California Statewide Bicycle Committee, which was tasked with developing proposals to modify legislation and create bikeway standards.

Forester believed bike lanes would increase risks associated with turning motorists, motorists opening doors from parked vehicles, and bicyclists turning left, and, most importantly, delegitimize a bicyclists’ right to operate on a street. To prove protected bike lanes were dangerous, he rode his bicycle at roadway bicycling speed on a sidewalk designated for bicycle use and attempted to turn left across all lanes of traffic from the sidewalk at this speed. He published his account of this ride as “the one valid test of a sidepath system” that proved sidepath style bikeways were “about 1,000 times more dangerous than riding on the same roads” *(6)*. While this account was clearly anecdotal, Forester used this experience—as well as his position as an engineer—to claim sidewalks, sidepaths, and protected bike lanes were dangerous and would increase liability for designers and cities in the event of a crash.

These events inspired him to author a book titled <u>Effective Cycling</u>, which centered on a philosophy that “bicyclists fare best when they act as, and are treated as, drivers of motor vehicles” *(7)*. The book explains his methods for driving his bicycle in a manner similar to a motorized vehicle, a concept he later popularized through articles in *Bicycling Magazine*.

4.1.4 1974 AASHTO Bicycle Guide

The 1974 Guide was prepared by the Standing Committee on Engineering Operations by the American Association of State Highway and Transportation Officials (AASHTO) *(8)*. It begins with the safety need for guidance: “During the past decade, a bicycle renaissance has occurred in the United States. One area of concern in which the impact is already being felt is the growing conflict between bicycles and motor vehicles in the use of streets and highways. One measure of this growth rate is frequency of accidents involving bicyclists. In 1972, there were over 1,100 fatalities involving bicyclists on public highways, an increase of over 100 percent in a decade." The guide predated the vehicular cycling movement and relied heavily upon the 1972 UCLA Guidance and DeLeuw Cather reports *(4,5)*.

The Guide suggested the following criteria to warrant bike lanes designed to serve all bicyclists who were classified as commuter, recreational, or neighborhood bicyclists:

1) motor vehicle volume > 2,000 ADT,
2) bicycle volume > 200 bikes/day, and
3) motor vehicle volume > speed > 30 mph.

The Guide also provided information regarding the design and tradeoff considerations for three types of bike lanes:

1) parking protected bike lane (separated with wheel stop curb)
2) unprotected bike lane adjacent to parking located at the curb
3) unprotected bike lane on a street with no parking

The Guide recommends unprotected bike lanes as the preferred option based on challenges identified in 1972 DeLeuw Cather study *(5)*. While it recognized "some form of curb or bumper block provides a more positive means of controlling motor vehicle encroachment," it recommended against barriers, stating that they "tend to be hazardous to bicycle operation and obstruct maintenance operations, particularly snow removal."

The Guide recommended the following intersection treatments "to minimize the number of possible conflict points between bicycles, motor vehicles, and pedestrians within the intersection" including:

1) Continue bike lanes to the intersection
2) Provide marked bicycle crossings adjacent to and parallel with pedestrian crosswalks
3) Provide a designated space to execute a two-stage turn
4) Use an offset approach (10-20 feet) to reduce conflicts between right-turning motorists and straight-through bicyclists where there is a heavy vehicular right-turn movement across the bicycle crossing (now known as a protected intersection)

Appendix A contains a table comparing key AASHTO Bike Guide criteria from 1974 through the proposed 2018 Guide to allow comparison between editions.

4.2 Use and Abuse of Power: 1975-1981

4.2.1 Relevant Literature and Research

The late 70s produced literature and research that would influence the field for decades to come. In addition to Effective Cycling, Forester authored the Cycling Traffic Engineering Handbook in 1977, later renamed and reprinted as Bicycle Transportation, which described his vision for creating a profession of cycling transportation engineers. The book explained that the underlying reason for providing bikeways was a government and societal effort to get “cyclists out of motorists’ way” and as a response to “the ignorance and fear of cyclists” operating in motor vehicle traffic. In his opinion, bikeways would do nothing to improve safety and would in many cases worsen safety *(9)*.

Forester also wrote that “every facility for promoting cycling should be designed for 30 mph. It if is not, it will not attract the serious cyclist…and hence it will not be an effective part of the transportation system. A facility that is designed only for childlike and incompetent cyclists encourages the “toy bicycle” attitude and discourages cycling transportation” (*9*). These statements disregarded those who did not share his point of view, and belied reality: research by Lott in 1976 found the addition of bike lanes in Davis attracted people from other routes, and that certain demographics, such as women over 25 years old and middle, high school, and college students, were much more likely to ride on the street after bike lanes were installed. Forester’s reaction was that it was unethical to” appeal to the public superstition that bike lanes make cycling much safer,” claiming there was no proof bike lanes were safer (*42*).

Yet other research of the day also did not support the vehicular cycling premise. The findings from FHWA’s 1975 report on Bicycle Facilities *(10)* were consistent with modern-day research on bicyclists’ preferences and safety: bicyclists preferred separation, there were fewer crashes between bicyclists and motorists on streets with bike lanes compared to streets with shared lanes, and facilities that require bicyclists to move in the contra-flow direction resulted in more crashes. Studies by Cross (1974) and Kaplan (1976) of crash types and crash rates on streets with different types of bikeways, respectively, had similar findings *(11, 12)*.

However, in a misrepresentation of the findings, Forester cited these studies as evidence that *all* methods of separation were unsafe, failing to acknowledge the studies had found that streets with bike lanes were safer than streets without. Additionally, the Cross and Kaplan studies did not include separated bike lanes, but Forester used anecdotal references to problems to claim the protected bike lanes “had been tried in Davis and discarded because of a high accident rate”—even though the DeLeuw Cather Study did not support this claim. This led to other actions to oppose their installation in other cities, including “a bitter fight” over their use on San Francisco’s Upper Market Street *(13)*.

Other bikeway opponents came from a different point of view, as represented by CalTrans engineer Harold Munn. In a 1974 ASCE paper, Munn argued that efforts to separate bicycles from the normal flow of vehicular traffic were not practical in the 20th century, where the priority was to accommodate motorized vehicular traffic. He concluded that “the bicyclist will have no choice but to mix with motorized traffic,” and that it would be necessary to convince adult cyclists “to operate their bicycles as they do vehicles” (*13*).

Adherents to these philosophies would become well known opponents to bike lanes, protected bike lanes, and shared use paths in communities across the U.S. Many cited Forester and the critical accounts of research he published in books and magazine articles that were easily accessible. Without access to the paper copies of 1970s studies Forester critiqued (only recently available via the internet), transportation professionals, public agency staff, and citizens who were unaware of research contradicting Forester's claims had few sources other than his books for bicycle planning. This opposition to bikeways by strong, vocal bicycle advocates led to transportation professionals being confused about what bicyclists wanted, often resulting in agencies taking the path of least resistance – which commonly meant no accommodations for bicyclists on public streets.

4.2.2 1978 Caltrans Bicycle Guide

Under the direction of California Statewide Bicycle Facilities Committee, a new design guide was developed between 1975 and 1978. The work of the committee was heavily influenced by Forester, who was now president of the California Association of Bicycling Organizations. He appointed his colleague, John Finley Scott, as the bicycling representative to the committee to represent the bicyclists point of view. According to Forester, "Cyclists, again under my leadership, continually opposed the dangerous proposals [developed in the committee], although some cyclists expressed desire for safety bikeways to make cycling popular" *(6)*. Additionally, "in my attempts to redirect the committee to making cycling safer rather than discriminating against cyclists, I wrote probably about half of the paperwork produced by the committee." The two primary references for the 1978 CalTrans Guide were Munn's 1974 ASCE paper and Forrester's <u>Cycling Traffic Engineering</u> handbook *(9, 13)*.

This Guide took a remarkably different view of bicycling from the research conducted to date. It codified vehicular cycling as the primary method for accommodating bicyclists, stating: "An effective program is one that is conducted in recognition of the fact that billions of dollars have been spent on a road system to allow people to travel almost any place they wish. Most of these roads are sufficient to accommodate shared use by bicyclists and motorists, and hence, most bicycle trave1 has occurred and will continue to occur on that system" *(14)*. It also de-emphasized the role bikeways could play to address safety concerns stating: "Many of the common problems are related to improper bicyclist and motorist behavior and can only be corrected through effective education and enforcement programs" and recommended against protected bike lanes and sidepaths.

In contrast to the 1974 AASHTO Guide, this guide eliminated any guidance for specific speeds or volumes that would warrant separation from traffic.

4.2.3 1981 AASHTO Bicycle Guide

The next version of the Guide (1981) was prepared by Richard Lemieux, an engineer who was the FHWA bicycle program manager in the late 1970s. He did not recall the 1974 AASHTO Guide, saying he "relied upon the 1978 CalTrans Guide as a starting point for the 1981 Guide," as well as a review of the 1977 *FHWA Safety and Locational Criteria for Bicycle Facilities* for additional guidance. Mr. Forester was noted for persistently contacting the bicycle researchers and program managers, including with Mr. Lemieux during his time at FHWA, When the Guide was put out for public comment, "Mr. Forester provided over half the comments." Mr. Lemieux dutifully considered them all and incorporated many changes into the document as a result (Lemieux, personal communication).

According to Lemieux, the mindset within agency leadership was that accommodating bicycling on the roads was unrealistic. "The people I worked with genuinely believed that highway users pay highway taxes and nobody else has a right to use that money (*13*).” This was underscored when the bicycle program was eliminated in 1983 and Lemieux was reassigned to a pavement design group (Lemieux, personal communication).

Given its basis, this Guide has a similar tone and philosophy to the 1978 CalTrans Guide, emphasizing a Vehicular Cycling approach with higher-speed bike travel as a design objective (design speed increased from 15 mph to 30 mph, see Appendix A), along with education and enforcement support. It also stated Munn’s pessimistic view that society would be unwilling to invest in bike networks stating that the construction of a “separated bikeway system, composed of bicycle paths and lanes” would be too expensive and “not provide for the vast majority of bicycle travel” (*15*).

The bike lane warrant from 1974 was dropped and replaced by a vague reference to consider traffic volumes and speeds, and protected bike lanes were prohibited, stating, “Bicycle lanes should always be placed between the parking lane and the motor vehicle lanes.” The Guide also noted that parking-separated bike lanes “create hazards for bicyclists from opening car doors and poor visibility at intersections and driveways, and they prohibit bicyclists from making left turns.” This Guide also took a vehicular cycling approach to intersection design as well, stating, “Bicycle lanes tend to complicate both bicycle and motor vehicle turning movements at intersections” (*15*).

4.3 Quiet on the Front: 1981-1990

4.3.1 Relevant Literature and Research

A lack of funding and fewer bikeways limited research activity in the 1980s. The most cited study from this decade is a 1988 study by Smith and Walsh that evaluated before and after conditions of two newly-installed striped bike lanes on a one-way street couplet in Madison, WI, one of which was striped on the left side of the street, and the other of which was striped on the right. The study found a significant increase in crashes associated with the new left-side bike lane in the first year, but not with the right-side bike lane. Moreover, the increase associated with the left-side lane became statistically insignificant after one year, which the authors attributed to a familiarity (and thus changed behavior) with the bike lane *(16)*.

4.3.2 1991 AASHTO Bicycle Guide

This Guide included a new section to extend the prohibition of protected bike lanes and to discourage construction of sidepaths, justified by nine design challenges listed in the *1978 CalTrans Bikeway Guide (17)*. It also discouraged construction of wide sidewalks, as they do “not necessarily add to the safety of sidewalk bicycle travel. Wide sidewalks encourage higher speed bicycle use and can increase potential for conflicts with motor vehicles at intersections, as well as with pedestrians and fixed objects” (*17*). The studies by Smith and Walsh *(16)* and Cross *(11)* are cited throughout as evidence that drivers would not be looking for contra-flow riders.

4.4 A Resurgence of Interest and Activity: 1991-1999

4.4.1 Relevant Literature and Research

The 1990's saw an increase in bicycle research, fueled by Federal funding for bicycle and pedestrian facilities resulting from the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which encouraged the development and implementation of bicycle plans.

In 1994, FHWA published the "Effects of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations" (*18*). This document was the first to suggest specific bikeway accommodation treatments based on the skill level of the bicyclists and factors such as speeds, motor vehicles volumes, presence of parking, and sight distances (Figure 2).

Table 5. Group B/C bicyclists, urban section, with parking.

average motor vehicle operating speed	**average annual daily traffic (ADDT) volume**											
	less than 2,000				2,000- 10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv				**truck, bus, rv**				**truck, bus, rv**		
less than 30 mi/h	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**bl 5**	**bl 5**	**bl 5**	**bl 5**
30-40 mi/h	**bl 5**	**bl 5**	**bl 5**	**bl 5**	**bl 5**	**bl 6**	**bl 6**	**bl 5**	**bl 6**	**bl 6**	**bl 6**	**bl 6**
41-50 mi/h	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**
over 50 mi/h	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane **bl** = bike lane **na** = not acceptable

* see page 11 for definitions.

** **WC** numbers represent "usable widths" of outer lanes, measured from left edge of the parkign space (8 to 10 ft [2.4 to 3.0 m] minimum from the curb face) to the left stripe of the travel lane.

FIGURE 2. Group B/C (Basic/Child) bicyclists, urban section, with parking recommendations *(18)*.

This approach, which claimed confident cyclists (Group A) constituted 5% of present cyclists and the B/C group constituted 95% of present cyclists, was vehemently opposed by vehicular cycling advocates. As noted by Forester, this "policy then assumes that the B/C group will continue to be the large majority for whom the entire system must be designed. In effect, the FHWA advocates dumbing down the cycling traffic system to suit the desires of the least competent possible users." The real purpose of this policy is "to promote the highway establishment's major cycling interest, its desire to prevent cyclists from delaying motorists" *(9)*.

In 1994, Wachtel and Lewiston published a study determining crash probabilities on various facilities in Palo Alto, CA *(19)*. The study was widely cited by vehicular cycling advocates for the conclusions that bicyclists were at 1.8 times greater risk of a collision while riding on the sidewalk than riding within the road, and that, regardless of facility type, cyclists were 3.6 times more likely to be involved in a collision if they were riding against traffic as compared to with traffic. The study only included junction-type crashes and did not account for the 26 percent of crashes that occurred on segments.

However, when Lusk et al. *(20)* reanalyzed Wachtel and Lewiston's data in 2011, they drew different conclusions by including all crashes, finding:

- the relative risk of sidewalk riding was *statistically the same as riding in the road*.
- when direction of travel was accounted for, *the relative risk of sidewalk riding dropped to half of the risk of riding in the street* for cyclists riding with traffic.

Another study, Moritz' 1998 survey of North American bicycle commuters, found that streets with bicycle lanes were clearly the safest in terms of crash rates, as compared to major and minor streets without bicycle facilities *(21)*. This study also found higher crash rates on sidewalks and multi-use trails, although it did not distinguish between the two, or separate falls from crashes with motor vehicles. Regardless, both studies *(19, 21)* were promoted by VC advocates as providing evidence against bikeways *(22)*.

In 1997, the first model evaluating real-time perceptions of bicyclists traveling in actual traffic was published *(23)*. The study participants represented a cross section of age, gender, experience, and geography, thereby providing a broader assessment of the general public's perceptions than research geared toward bicycling advocacy groups such as the League of American Wheelmen. Furthermore, the study documented for the first time the strong, positive impact of bicycle lanes on comfort ratings ("level of service") while bicycling.

4.4.2 1999 AASHTO Bicycle Guide

The 1999 AASHTO Bike Guide was the first to be published after ISTEA became law. The law required each State DOT to hire a bicycle and pedestrian coordinator. With this dramatic increase in professional staff, this guide received a higher level of review from people throughout the U.S. than prior versions, resulting in multiple authors and drafts before finalization.

For the first time, the Guide defined different types of bicyclists, using the classification system recommended in the 1994 FHWA Report: A (advanced), B (basic), C (child) bicyclist *(18, 24)*. The draft sought to align bikeway type to design user. For example, a "B" cyclist (casual, novice, recreational) would prefer well-defined separation on arterials. An "A" cyclist (confident, experienced) would be comfortable with a wide outside lane. Ultimately, however, the Guide excluded FHWA's recommended classification system. The vague language regarding speeds and volumes from previous editions remained, with the caveat that rider preferences should be considered *(24)*.

4.5 Increasing Interest in Bicycling: 2000-2009

4.5.1 Relevant Literature and Research

The 2000s saw a large increase in bicycle lane installations, including the first protected bike lanes in over 40 years *(25)*. Research began to focus on interactions between bicyclists and motorists in various street configurations *(26)* and behaviors of bicyclists and motorists in different contexts *(27)*, providing empirical evidence of the effectiveness of various facilities. Dill and Carr documented the connection between bike lanes and ridership in cities *(28)*, showing a positive and significant correlation at the city scale, while others began to explore barriers to bicycling and preferences for bicycle facilities, and to quantify the desire among the general population to have more opportunities to bicycle (e.g., Dill and Voros, *29)*.

4.5.2 2012 AASHTO Bicycle Guide

The 2012 AASHTO Bike Guide was the first guide developed through an NCHRP research contract. This edition contained significant new content, and increased references to support guidance included although the design user still skewed towards the confident cyclist *(30)*.

While the 2012 Guide was being written (2007-2009), jurisdictions began to install protected bike lanes, green-colored lanes, bicycle signals, and bike boxes following the MUTCD's official experimentation process. Due to interest in innovative bikeway design treatments, the first draft of the 2012 Guide included a chapter entitled "Design Issues on the Horizon" which provided some basic information on separated bike lanes, green-colored bike lanes, bike boxes and raised bike lanes. However, the NCHRP panel overseeing the Guide cut the chapter due to the fact these facilities were new and not yet extensively studied. There was also concern that provision of separated bike lanes guidance would conflict with statements that maintained the vehicular cycling philosophy opposing separation.

The A/B/C typology scheme was eliminated in favor of a more nuanced discussion of user skill and comfort to more clearly articulate a person's tolerance for motor vehicle traffic stress based on the 1997 BLOS research *(23)*. For the first time since 1974, a table was added to specify roadway volumes and speed thresholds for different bikeway treatments. The intersection design guidance removed the vehicular cycling premise that "bicycle lanes tend to complicate both bicycle and motor vehicle turning movements at intersections," which was not supported by evidence.

This Guide was the first to label shared-use paths that were parallel to roadways as "sidepaths", in order to distinguish them from shared-use paths (or trails) located in independent rights-of-way. The Guide also articulated for the first time the importance of integrating sidepath operations with the roadway, stating that the path should have the same priority as the parallel roadway—although the text also maintained extensive discouragement for building them.

4.6 Bicycling as a Mainstream Mode: 2010 - Present

4.6.1 Relevant Literature and Research

Recent years have marked a time of significant advances in the understanding of bicyclists' and motorists' preferences and factors that contribute to the safety of bicyclists operating on or near roadways. Importantly, several studies have directly examined the safety of separated bike lanes and found them to be safer than roadways where bicyclists share travel lanes with motor vehicles. For example, multiple studies of separated bike lanes in Canada and the U.S. by Lusk and her colleagues have found that the overall relative risk of cycling on a protected bike lane was lower than cycling on the reference streets *(20, 31)*. (Lusk et al. were also the first to publish a review of the AASHTO guidance from 1974 to 1999, finding, similarly to this study, that the guidelines did not seem to be rigorously research-based *(31)*.) A Dutch study by Schepers et al. found that one-way protected bike lanes are significantly safer than a bicycle lane or no facility *(32)*. Furthermore, multiple studies by Teschke, Harris, and colleagues examining bicycle crashes in Toronto and Vancouver found that protected bike lanes were significantly less likely to be associated with a crash than all other facility types *(33, 34)*.

Separately, studies by Sanders and Dill, McNeil, and colleagues (among others) have documented bicyclists' clear preferences for riding on facilities with greater separation from motorists *(35, 36)* consistent with findings from the 1970s. Dill and McNeil have also worked to characterize people's attitudes toward cycling and roadway design preferences into typologies of traffic tolerance *(37)*.

Research has also documented that the provision of a network of separated bike lanes appears to be key to improving safety and ridership. For example, Buehler and Pucher compare cycling rates and injuries to show that bicycling in the U.S has been and continues to be much less safe than in peer countries where networks of protected bike lanes exist *(38)*. A frequent criticism by VC bikeway opponents is that confounding factors are the source of these safety gains, not the bikeways themselves, and that a safety in numbers effect is therefore unproven (*44*). However, a study by Marques and Hernandez-Herrador evaluated the impact of ridership and bicycle network construction and expansion, and found evidence of a strong safety in numbers correlation *(39)*.

Finally, national and state organizations looking for more advanced guidance have now published their own guidance on how to design separated bike lanes and other bikeway design treatments that are common in other countries, including NACTO's Urban Bikeway Design Guide and Massachusetts Departments of Transportation's Separated Bike Lane Design Guide *(40, 41)*.

5. CONCLUSION

This paper covers the evolution of AASHTO Bike Guide content from 1974 to 2012, providing insight into the dynamics and context for each edition. At the heart of the story is a fundamental question posed by USDOT Assistant Secretary John Hilten in 1973:

> *Should bikeways be designed to accommodate a smaller number of people moving at the maximum rate of speed achievable by the bicyclist over long distances or should they be designed to accommodate the maximum number of people willing to travel for shorter trips?"*

An inability to directly address this question delayed the development of urban bicycle transportation networks in North America for decades. The public officials and engineering professionals of the 1970s showed creativity and courage in experimenting with new ideas to support safe bicycle transportation, as did AASHTO, which published a design guide based on limited US experience but supplemented by international research and best practices. However, the lack of maintenance for bikeways, a reluctance to fully commit to separated bike lanes with protected intersections, and ill-considered sidewalk bike routes gave credence to vehicular cyclist concerns and fueled the rise of the vehicular cycling backlash in the late 1970s. Many of these concerns would worry any frequent cyclist, and should be carefully considered today as new bicycle facilities are being planned and built.

It is also instructive to see how research standards have changed and bicycling knowledge has become more democratic. John Forester had an outsized impact on bicycle planning and facility design during his time. However, his tendency to ignore and even belittle the legitimate concerns and preferences held by the general public who did not enjoy bicycling in high volume or high speed mixed traffic, spurred many a researcher to seek more substantiated truths about facility safety and people's preferences.

Today, this research matters more than one person's experience, and there is a stronger commitment at all levels of government to accommodate and encourage bicycling—and to maintain that commitment. It is also now understood that it is possible to build bicycle networks that are safe and appealing to the general population, and that the delivery of these networks can increase bicycling and improve overall safety outcomes. As the bicycle continues to be seen as a key tool to mitigate the damage wrought by decades of car-centric development: congested roadways, polluted air, inequitable transportation options, chronic disease, and loss of life, it is hoped that the field continues to push forward with innovative designs that are rigorously evaluated, providing the best designs and guidance for professionals seeking to plan and build bicycle facilities.

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APPENDIX A

TABLE 1. Comparison of AASHTO Bike Guide Content in the Various Editions

	AASHTO Bike Guide Edition					
	1974	**1981**	**1991**	**1999**	**2012**	**2018**
Pages of Guidance	50	36	51	86	201	400+
Design User Description	Commuter, Recreational, Neighborhood	Commuter: Fast, Direct Recreational: Pleasure, Comfort	Utilitarian: Fast, Direct Recreational: Pleasure, Comfort	**A**dvanced (5%): Fast, Direct **B**asic/**C**hild (95%): Pleasure, Comfort	Experienced/Confident: Fast, Direct, but appreciate comfort Casual/Less Confident: Majority of Population, Prefer Comfort	Highly Confident (4-7% of public) Somewhat Confident (5-9% of public) Interested but Concerned (51-56% of public)
Minimum Design Speed	10 mph minimum	20 mph minimum	20 mph minimum	20 mph minimum	18 mph minimum	15 mph separated bike lanes & shared use paths
Desirable Design Speed	15 mph normally	30 mph desirable	30 mph desirable	30 mph desirable	30 mph maximum	18 - 30 mph rural areas or low ped volume paths
Bicycle Lane Installation Criteria	vehicle volume > 2,000 ADT vehicle speeds > 30 mph	Inexperienced will avoid high volume & speed roads. Commuters will ride regardless.	Inexperienced will avoid high volume & speed roads. Commuters will ride regardless.	Inexperienced will avoid high volume & speed roads. Commuters will ride regardless.	Experienced/Confident comfortable on most streets, some prefer separation on high volume & speed streets when available. Casual/Less Confident prefer separation or low-volume, low-speed streets.	Experienced/Confident comfortable on most streets, some prefer separation on high volume & speed streets when available. Casual/Less Confident prefer separation or low-volume, low-speed streets.

	1974	1981	1991	1999	2012	2018
Bike Lane Width	4.0 feet min. at curb 5.5 feet min. adj. to parking	4 feet min. at curb 5.0 feet min. adj. to parking > 5 feet where: vehicle speeds > 35 mph or substantial % of trucks	4 feet min. at curb 5.0 feet min. adj. to parking > 5 feet where: vehicle speeds > 35 mph or substantial % of trucks	4 feet min. at curb 5.0 feet min. adj. to parking +1 to 2 feet where parking turnover high > 5 feet where: vehicle speeds > 50 mph or substantial % of trucks	4 feet min. > 5 feet where: vehicle speeds > 35 mph or substantial % of trucks	4 feet min. > 5 feet where: vehicle speeds > 35 mph or substantial % of trucks
Wide Curb Lanes	Not Discussed	preferred where no bike lanes 12-foot minimum 14 feet desirable benefits bicyclists and motorists	preferred where no bike lanes 12-foot minimum 14 feet desirable benefits bicyclists and motorists	preferred where no bike lanes 14-foot minimum 15 feet desirable benefits bicyclists and motorists	last resort where no bike lanes 13-foot minimum 15 feet desirable benefits bicyclists and motorists	last resort where no bike lanes 13-foot minimum 15 feet desirable benefits bicyclists and motorists
Shared Roadways	10-foot lanes light volume traffic 12-foot lanes heavy volume traffic	No Guidance	No Guidance	No Guidance	Lower speed and volume preferred use BLOS to assess	Lower speed and volume preferred use BLOS to assess
Separated Bicycle Lane Guidance	Recommended Treatment	Prohibited Treatment	Prohibited Treatment	Prohibited Treatment	Discussed as one-way bicycle only sideapath	Discussed as one-way bicycle only sideapath
Sidepath Guidance	Shared Use Okay. Ideal separarate from road min. 20 feet, preferable 30 feet	Bike Only Preferred Shared Use Undesirable	wide curb lanes, bike lanes and shared lanes preferable to sidepaths due to 9 separate risk factors	wide curb lanes, bike lanes and shared lanes preferable to sidepaths due to 9 separate risk factors	wide curb lanes, bike lanes and shared lanes preferable to sidepaths due to 14 separate risk factors	wide curb lanes, bike lanes and shared lanes preferable to sidepaths due to 14 separate risk factors
Sidepath Intersection Guidance	Use Protected Intersection	Prefarable: Avoid; No Guidance other than provide good sight lines, consider median	Prefarable: Avoid; No Guidance other than provide good sight lines, consider median	Integrate with intersection; Basic guidance for considerations given to manage conflicts	Integrate with intersection; Basic guidance for considerations given to manage conflicts	Integrate with intersection; Basic guidance for considerations given to manage conflicts

	1974	1981	1991	1999	2012	2018
Intersection Design Elements						
Continue Bike Lanes to Intersection	Encouraged	Drop bike lanes at merge areas with right turn lanes	Drop bike lanes at merge areas with right turn lanes; option to dash if right turn volume low	Dash bike lanes at merge areas with right turn lanes; option to drop	Dash bike lanes at merge areas with right turn lanes; option to drop	Encouraged
Mark Bicycle Crossing	Encouraged	No Guidance	No Guidance	Discouraged, but may be used for complex intersections	may be used for complex intersections	Encouraged
Provide 2-Stage Turn Queue Box	Encouraged	No Guidance	No Guidance	No Guidance	No Guidance	Encouraged
Protected Intersection Geometry	Encouraged	No Guidance	No Guidance	No Guidance	No Guidance	Encouraged