SIGHT DISTANCE FOR ADVISORY BICYCLE LANES

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ABSTRACT

An advisory bicycle lane is a roadway striping configuration which supports two-way motor vehicle and two-way bicycle traffic using a central vehicle travel lane and "advisory" bicycle lanes on either side. The center lane is shared by motorists traveling in both directions. The bicycle lanes on either side are for travel in one direction only. Bicyclists have preference in the bike lanes but motorists can encroach into the bike lanes, after yielding to cyclists, in order to bypass oncoming vehicles.

Advisory bicycle lanes (ABLs) are a new and inexpensive treatment in North America which can provide bicycle facilities on roads too narrow for standard bicycle lanes. Thousands of road-miles are candidates for ABLs. Despite widespread potential, this facility has seen little study in North America.

A notable feature of ABLs is the single lane used to support two-way vehicular travel. This requires sufficient sight distance for motorists to detect oncoming traffic and either maneuver to bypass the oncoming traffic or come to a full stop.

After examining various sight distance criteria, this paper concludes that twice the stopping sight distance, called the collision sight distance, is a minimal sight distance for an ABL. More preferable is a sight distance that supports a sequence comprising detection of oncoming vehicles, scan of the bike lane and a maneuver to bypass oncoming traffic. This sight distance does not exist in the literature. Further research is needed to develop this sight distance and other design guidance for ABLs.

Keywords: Advisory Bike Lane, Advisory Bicycle Lane, Sight Distance

INTRODUCTION

An advisory bicycle lane (ABL) is a roadway striping configuration which provides for two-way motor vehicle and two-way bicycle traffic using a central vehicle travel lane and “advisory” bicycle lanes on either side. The center lane is dedicated to, and shared by, motorists traveling in both directions. The bicycle lanes on either side are for travel in one direction only. Bicyclists are given preference in the bike lanes but motorists can encroach into the bike lanes, after yielding to cyclists, in order to bypass oncoming vehicles.

Operation of an ABL-equipped roadway is demonstrated in the figures below courtesy of the FHWA Small Town and Rural Multimodal Networks Guide *(1)*, in which the bicycle lanes are called the advisory shoulder space.

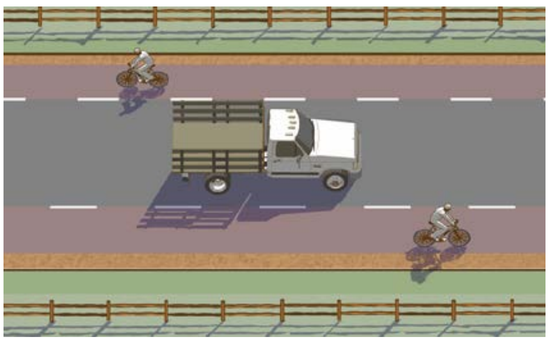

FIGURE 2 Motorists travel in the two-way center travel lane. When passing a bicyclist, no lane change is necessary.

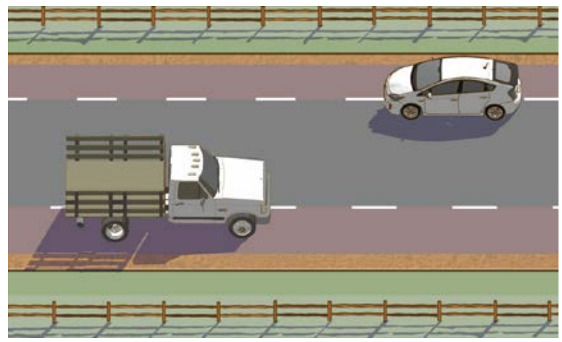

FIGURE 1 When two motor vehicles meet, motorists may need to encroach into the advisory shoulder space.

An ABL-equipped roadway has no center line and differentiates the center lane from the bicycle lanes with broken lines rather than the solid line used for standard bicycle lanes. The broken line indicates a permissive condition allowing motor vehicles to move into the bicycle lanes after yielding to any bicyclists. A variety of treatments are possible at the outside edge of the bicycle lane, e.g. edge line, unmarked edge of pavement, or an on-street parking lane. Current North American installations are dominated by five foot wide bike lanes and center travel lane widths ranging from nine feet to twenty-two feet *(2)*. On roads lacking sidewalks, the bike lanes may serve as pedestrian facilities.

According to the FHWA Small Town and Rural Multimodal Networks Guide *(1)*, ABLs are appropriate for roads with posted speed limits of 35 MPH or less and with volumes of less than 6,000 ADT.

ABLs have the potential to inexpensively provide thousands of miles of pedestrian and bicycle facilities. Rural roads with little chance of widening to support bicycle or pedestrian facilities are candidates. Urban roads on which removal of on-street parking is considered infeasible to allow installation of dedicated bicycle lanes are candidates. Legacy roads of substandard width are candidates. Any two-way roadway which is currently too narrow for dedicated bicycle lanes may be a candidate for an ABL treatment.

ABLs are popular in other countries. The Netherlands have over a thousand kilometers of ABLs in their country *(3)*. They have found them to be safe and attractive to cyclists.

ADVISORY BICYCLE LANES IN NORTH AMERICA

ABLs are being implemented in North America. The first ABL was installed in 2011 in Minneapolis, MN. Twelve installations were known as of June, 2017 with eleven in the United States and one in Canada. More facilities are in the design stage. Given the thousands of road-miles which are potential candidates for an ABL installation, the ABL's ability to inexpensively provide bicycle facilities, and its ability to provide bicycle facilities on roads with too little width for dedicated bicycle lanes, continued expansion of its use seems likely.

LITERATURE REVIEW

Despite their potential, the use of ABLs in North America has received little examination. This is primarily due to the small number of installations and their recency. The only published North American literature found regarding this facility are a high-level design guide published by the FHWA for the rural context *(1)* and a white paper on existing ABL installations in North America *(2)*.

Four of the ten communities interviewed for the white paper *(2)* had conducted studies of their installations. Those communities were: Boulder, CO, Hanover, NH, Minneapolis, MN, and Edina, MN. These studies were, of necessity, based on limited data. The average facility length was 1589 feet, average ADT was 2000, and average facility age was 4 years.

A number of studies assessing the impact of ABLs have been conducted outside North America, primarily in the Netherlands. These studies involve many kilometers of roadway and longer durations. Application of their findings to the North American context may be difficult or controversial.

NEED FOR A SIGHT DISTANCE CRITERION

The most notable feature of ABLs is the use of one lane to support two-way vehicular traffic and the requirement that vehicles maneuver out of the center travel lane to bypass oncoming traffic. This operational feature imposes a minimum sight distance that allows motorists to detect one another and safely avoid collision at a given speed.

The primary question this paper addresses is whether an appropriate sight distance to support safe operation of an ABL-equipped roadway exists or if one needs to be formulated.

EXISTING GUIDANCE ON SIGHT DISTANCE

The 2016 Dutch CROW manual *(4)* provides facility selection and design guidance for ABLs but no guidance on a sight distance criterion.

Existing North American design guidance for this facility comprises three sources: 1) the FWHA Small Town and Rural Multimodal Networks Guide *(1)*, 2) Lessons Learned: Advisory Bicycle Lanes in North America white paper *(2)*, and 3) the FHWA webpage on experimentation with "dashed bicycle lanes" *(5)*. The Small Town and Rural Multimodal Networks Guide *(1)* recommends the use of passing sight distance on page 2-20. The white paper *(2)* defers to the FHWA Small Town Guide *(1)* on this subject. The FHWA website *(5)* provides no direction on sight distance.

The only available guidance for sight distance on an ABL is passing sight distance (PSD).

The primary issue with PSD is that it does not reflect the operation of an ABL. An important assumption of the PSD is that a vehicle belongs in the right hand lane at all times until a passing opportunity is detected and initiated. In an ABL, a vehicle belongs in the center travel lane at all times until a maneuver is necessary to avoid oncoming traffic, after which both vehicles return to the center travel lane.

CONSIDERATIONS FOR SIGHT DISTANCE

The aim of this paper is to examine alternatives to the PSD as an ABL sight distance criterion. If an existing sight distance is appropriate, a new one will not have to be created.

To assess other sight distance criteria for an ABL, two-way vehicular travel in the center lane and posted speed limits of 35 MPH or less are assumed. Alternative sight distances are described below, compared, and discussed.

An appropriate sight distance for an ABL should be based on a reasonable worst-case scenario occurring on the roadway. Two possibilities exist when a motorist must maneuver to bypass an oncoming vehicle. If the bike lanes are unoccupied, the vehicles can move into the bike lanes to accomplish the passing maneuver. The second possibility is that insufficient width exists for a successful passing maneuver and both vehicles must come to a full stop to avoid a collision. This may occur if the bike lanes are not available for use or one vehicle fails to give way.

DISCUSSION OF EXISTING SIGHT DISTANCE CRITERIA

Passing Sight Distance (PSD)

Passing sight distance is included in the Small Town and Rural Multimodal Networks Guide *(1)* as a requirement for sight distance on ABL-equipped roadways.

Per the 2011 Green Book *(6)*, PSD is the sum of four components:

1. the distance traveled during perception and reaction to the passing opportunity as well as the initial acceleration to the point of encroachment on the left lane,
2. the distance traveled while the passing vehicle occupies the left lane,
3. the distance between the passing vehicle and the opposing vehicle at the end of the passing maneuver, and
4. the distance traveled by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane.

With respect to a vehicle-bicycle passing maneuver, PSD provides values which are too conservative due to inapplicability of the first PSD component to this maneuver, the greater speed differential likely between the two parties, and the vehicle lengths assumed.

The primary issue with PSD is its failure to reflect the operation of an ABL. Recommendation of PSD appears to model an ABL as a roadway on which successive vehicle-bicycle passing maneuvers occur. An important assumption of the PSD is that a vehicle belongs in the right hand lane at all times until a passing opportunity is detected and a passing maneuver is initiated. In an ABL, a vehicle belongs in the center travel lane at all times until a maneuver is necessary to avoid oncoming traffic, after which both vehicles return to the center travel lane. This difference in operation renders component #1 of the PSD definition inapplicable to an ABL.

The second issue is the assumption on speed differential underlying the PSD. PSD calculations assume that the average speed of the passing vehicle while in the left lane is 12 MPH higher than the passed vehicle *(6)*. Without data, it is not possible to assess the relevance of this assumption but it seems likely that the speed differential is higher during a vehicle-bicycle passing maneuver due to the generally lower speeds of bicycles. Additionally, no acceleration is needed by the vehicle as described in component 1 of the PSD definition which raises the average speed differential further.

The third issue is the assumption made by the PSD calculations that both vehicles are nineteen feet long *(6)*. The bicycle design dimensions promulgated by AASHTO *(7)* show lengths ranging from seventy inches for a normal bicycle to one-hundred-seventeen inches for a bicycle with child trailer. These are significantly shorter than the nineteen feet assumed by the PSD calculations.

PSD is not reflective of ABL operation and it appears that PSD produces overly-conservative values for its model of an ABL.

Stopping Sight Distance (SSD)

An ABL-equipped road should provide SSD as a minimum requirement. This provides a motorist enough time and distance to detect a stationary object in the road and stop before striking the object. SSD values for various speeds are available in the 2009 Manual on Uniform Traffic Control Devices (MUTCD) *(8)* and the 2011 AASHTO Green Book *(6)*. SSD should be adjusted for grade and may differ based on direction of travel. Object height for SSD is assumed to be 2 feet.

SSD is insufficient for safe operation of an ABL since oncoming vehicles violate the assumption of a stationary object.

Collision Sight Distance (CSD)

If the bicycle lanes are not available for vehicle maneuvers for any reason, oncoming motorists must be able to detect each other and stop before colliding. Per the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads *(9)*, the sight distance for two-way travel on one lane roads should equal twice the SSD. For lack of an existing name, this is termed the Collision Sight Distance (CSD). If a grade is involved, CSD equals the sum of the SSDs for each direction. The SSD calculations assume an object height of 2’ *(6)*.

CSD appears to provide sufficient distance to prevent two oncoming vehicles from colliding when the bike lanes are unavailable for maneuvering. Additional margin may exist due to drivers’ expectations of seeing oncoming traffic and the low object height assumed by the calculations.

Despite providing enough distance to avoid a collision, CSD may not provide enough distance for the preferred action which is a shift to the right to bypass oncoming traffic. For this action, a driver would be required to detect an oncoming vehicle, scan the bike lane to ensure room is available and complete a shift maneuver before reaching the other vehicle. This action would likely take more time and distance than CSD provides.

Decision Sight Distance (DSD)

Assuming the bicycle lanes are available for vehicle use, a distance known as the decision sight distance (DSD) may be applicable. Per the 2011 Green Book *(6)*, DSD “is the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete complex maneuvers”. Object height is assumed to be 2’.

This distance is intended to be used in complicated situations where the perception and recognition of the hazard requires more time. The DSD varies according to the maneuver chosen by the motorist. With respect to a full stop on a rural road, it is only slightly longer than the SSD due to the longer perception time allowed but for other maneuvers, it is much longer. The pre-maneuver time used for a full-stop in a rural setting is 3.0 seconds and 9.1 seconds for a full-stop in an urban setting *(6)*.

DSD is insufficient for safe operation of an ABL since oncoming vehicles violate the assumption of a stationary condition.

Avoidance Sight Distance (ASD)

Use of twice the DSD, called Avoidance Sight Distance (ASD) here, would allow both vehicles to detect and maneuver away in time to avoid a collision. However, some issues exist with ASD.

The first problem with ASD is that the bike lanes may not be available to one or both motor vehicles, eliminating the possibility of maneuvering away from an oncoming vehicle. One must ensure that both vehicles can stop to avoid a collision following one or both drivers’ recognition of this fact.

Another issue is that ASD incorporates the DSD assumption of unexpected or difficult-to-perceive threats. Motorists on an ABL are assumed to be aware of the likelihood of oncoming traffic. Additionally, oncoming traffic is likely to be easily perceived though situations can be envisioned which would challenge that assumption.

If the environment is so complicated that the longer perception time of a DSD is needed, it is likely the wrong environment for an ABL. Instances could arise where a longer perception time is needed but this should be addressed on a case-by-case basis by a qualified engineer rather than incorporating it into the assumptions for ABL sight distance formulation.

While ASD may be a sight distance worth striving for on an ABL, its assumption of unexpected or hard-to-perceive threats may make it inapplicable to an ABL which is only intended for lower-volume, lower-speed roads.

Headlight Sight Distance (HSD)

Detection of cyclists, pedestrians and oncoming vehicles is necessary during nighttime driving on an ABL. When driving at night, sight distance is often constrained by the reach of a vehicle's headlights. This is called the headlight sight distance (HSD). Page 67 of NCHRP Report 400 *(10)* sets HSD at 130 meters (427 feet) for "a small or low contrast object on an unilluminated roadway". It also notes that large or high contrast objects can be detected at longer distances under the same conditions.

HSD is provided for comparison to the other distances in nighttime conditions.

Comparison of Sight Distances

Table 1 lists the discussed sight distances for speeds at which an ABL-equipped roadway would commonly be posted in North America.

TABLE 1 Sight Distances Versus Posted Speed

Speed (MPH)	PSD (ft)	SSD (ft)	CSD (ft)	ASD1 (ft)	ASD2 (ft)	HSD (ft)
20	400	115	230	-	-	427
25	450	155	310	-	-	427
30	500	200	400	440	980	427
35	550	250	500	550	1180	427

TABLE 1 Notes:
PSD is per Table 3-4 of the 2011 Green Book *(6)*.
SSD is per Table 3-1 of the 2011 Green Book *(6)*.
CSD is equal to twice the SSD with no grade per the Green Book *(6)*.
ASD1 is equal to twice the DSD for full stop in a rural setting per the Green Book *(6)*.
ASD2 is equal to twice the DSD for full stop in an urban setting per the Green Book *(6)*.
HSD is per the 1997 NCHRP Report 400 *(10)*.
DSD is not included.
"–" indicates the value was not available in the referenced source.

DISCUSSION

Sight Distance Criteria

Both SSD and DSD are insufficient to prevent a collision between oncoming vehicles on an ABL because the assumption of a stationary threat or condition is violated. The ASD family of sight distances provides enough distance for both vehicles to maneuver away from oncoming traffic but incorporates longer pre-maneuver times than an ABL-equipped roadway may require, especially in an urban setting. PSD does not reflect operation of an ABL and likely produces overly-conservative values for its model. CSD provides sufficient distance for oncoming vehicles to avoid a collision by stopping but may not provide enough distance for the preferred action which is a shifting maneuver to bypass oncoming traffic.

It appears that CSD provides a minimum sight distance for an ABL-equipped roadway since drivers are able to come to a full stop before colliding with oncoming traffic.

A preferred sight distance is one which allows a driver to detect an oncoming vehicle, scan the bike lanes for bicyclists, and either maneuver into the bike lane or come to a full stop prior to arrival of the oncoming vehicle. This sight distance does not appear to exist in the literature.

ASD1 and ASD2 from Table 1 appear to model the preferred sight distance since their longer pre-maneuver times may give drivers sufficient time to scan the bike lanes and decide on a course of action. Without empirical data, this is hard to justify.

Nighttime Driving Conditions

It is only at the 35 MPH speed that CSD exceeds the HSD, by seventy-three feet. This appears to indicate that nighttime driving at 35 MPH on an ABL-equipped roadway could produce dangerous situations. HSD is defined as the distance at which a driver can detect “a small or low contrast object on an unilluminated roadway”. A vehicle with its headlights on would be detectable at distances significantly greater than the HSD. One could easily assume that this would create a safe roadway but additional data would be needed to solidify that assumption.

If one considers the detection of cyclists or pedestrians at night, a comparison of SSD and HSD shows that, at these speeds, SSD is significantly smaller than the HSD. This allows a driver to detect a cyclist or pedestrian and stop before a collision occurs.

Research

Very little study has been performed on this facility in the U.S. or Canada. The lack of a sight distance criterion is just one symptom of this deficiency. Other areas needing study include center lane width, appropriate speeds and volumes for ABL siting, preferred intersection treatments, etc.

CONCLUSION

Collision Sight Distance appears to be a minimal sight distance criterion for an ABL-equipped roadway. Collision Sight Distance is derived from an actual, worst-case road scenario and provides a safety margin for avoiding head-on vehicular collisions on an ABL.

What does not appear to exist is a sight distance criterion which fully supports the preferred operation of a motorist on an ABL. This sight distance should provide time and distance for oncoming drivers to detect each other, scan the bike lane, and choose an appropriate response be it a maneuver into the bike lane, a full stop or to slow until a maneuver can occur. Avoidance Sight Distance may come close to meeting this need but is not based on an actual ABL scenario.

Research into an appropriate sight distance for an ABL is needed.

Given the paucity of study of this facility in the North American context and its potential for widespread application, more discussion and study of this facility is warranted.

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