A Sight Distance for Edge Lane Roads

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ABSTRACT

An edge lane road (ELR) is a class of roadway which includes Advisory Bike Lanes and Advisory Shoulders. ELRs support two-way motor vehicle traffic within a single center lane and vulnerable road users (VRUs) such as bicyclists or pedestrians in the edge lanes on either side. Motorists may use the edge lanes, after yielding to any VRUs there, to pass approaching vehicles.

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

This paper concludes that passing sight distance, the sight distance criterion currently specified in American guidance, is inappropriate for ELRs and that two new sight distance models specific to edge lane roads are appropriate for their design. The first model called Head On Sight Distance allows drivers to stop before colliding with an approaching vehicle. The second model called Avoidance Sight Distance allows drivers to maneuver around an approaching vehicle without coming to a complete stop. Sight distance values were created for each model by utilizing findings from other guidance. Values produced in this work are intended to be used for future ELR installations. Further research is recommended to refine these models.

Keywords: Edge Lane Roads, Advisory Bike Lane, Advisory Bicycle Lane, Advisory Shoulder, Sight Distance, Head On Sight Distance, Avoidance Sight Distance

INTRODUCTION

An edge lane road (ELR) is a class of roadway which includes examples known as Advisory Bike Lanes and Advisory Shoulders. ELRs support two-way motor vehicle traffic within a single center lane and vulnerable road users (VRUs) such as bicyclists or pedestrians in the edge lanes on either side. Motorists may use the edge lanes, after yielding to any VRUs there, to pass approaching vehicles.

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

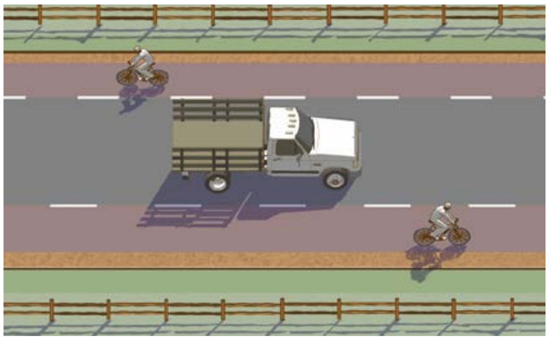

FIGURE 2 Motorists travel in the two-way center travel lane. When passing a bicyclist, no lane change is necessary.

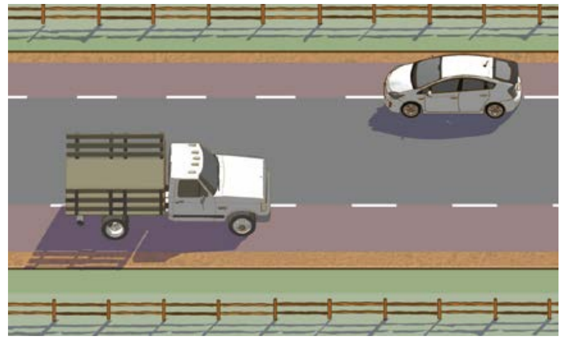

FIGURE 1 When two motor vehicles meet, motorists may need to encroach into the advisory shoulder space.

An ELR has no center line. The center lane is separated from the edge lanes with broken lines. The broken line indicates a permissive condition allowing motorists to move into the edge lanes after yielding to any VRUs there.

ELRs have enormous potential. They can inexpensively provide VRU facilities on millions of miles of local and collector roads in the U.S. This can be useful where roads are too narrow or lack the right-of-way for the addition of standard bicycle lanes or sidewalks. Further, ELRs can provide more distance between VRUs and traffic than standard bicycle lanes in some situations and are an excellent striping treatment for bicycle boulevards *(2)*.

Their use in the U.S. and Canada has grown since the first installation in 2011 *(2)*; almost 40 installations were known as of July 1, 2020 *(3)*. Given the millions of road-miles which are potential candidates for an ELR installation and its low cost, continued growth seems likely.

ELRs have been popular in other countries for several decades. A report from the 2013 International Transport Forum lists ten countries using this treatment with three countries reporting use predating 1970 *(4)*. The Netherlands, the originator of the concept, has approximately a thousand kilometers of ELRs in their country *(5)*.

The most common application of ELRs is as a means to provide VRU facilities. Another potential application is on low-volume, high-speed two-lane roads as a means for reducing the rate of single-vehicle, roadway departure crashes *(6)*. Higher speed ELRs are known in Australia and Great Britain but are not used in the U.S. or Canada.

LITERATURE REVIEW

Due to its short history in the U.S. and Canada, ELR literature in these countries is sparse. The first mentions of ELRs are in the 2009 Fundamentals of Bicycle Boulevard Planning & Design Guide *(7)* and in the 2010 City of Portland Bicycle Plan for 2030, Appendix D Bikeway Facility Design: Survey of Best Practices *(8)*.

Federal guidance includes the 2016 FHWA Small Towns and Rural Multimodal Networks Guide *(1)*, where they are known as Advisory Shoulders and the 2019 FHWA Bikeway Selection Guide *(9)*, where they are called Advisory Bike Lanes. Some design guidance exists on the FHWA webpage *(10)* that details requirements for Request to Experiment applications with this treatment; this webpage refers to the treatment as Dashed Bicycle Lanes but predates the Small Towns and Rural Multimodal Networks Guide and is considered less authoritative. The current draft of the 5th Edition AASHTO Guide for the Development of Bicycle Facilities (Jeremy Chrzan, June 5, 2020 email) includes ELRs and uses both the Advisory Bike Lanes and Advisory Shoulders terms. Canada has at least one published guide which includes the treatment, the 2019 British Columbia Active Transportation Design Guide *(11)*.

An early review of existing installations and current knowledge was published in 2017 *(12)*. Two ITE Journal articles *(2, 13)* discuss the growth of the treatment, its safety performance, and alternative uses. A private website, www.advisorybikelanes.com, provides an extensive body of information on the treatment including the lessons learned about ELRs by other countries with more experience *(3)*.

Of the official guidance listed, the Small Town and Rural Multimodal Networks Guide *(1)* is the only one that makes a recommendation on sight distance. Despite identical operating characteristics, ELR sight distance recommendations vary between countries. Danish guidance recommends twice the stopping sight distance *(14)*, the 2016 Dutch CROW manual *(15)* makes no mention of sight distance, and American guidance recommends passing sight distance *(1)*.

NEED FOR AN ELR-SPECIFIC SIGHT DISTANCE

The most notable feature of ELRs is the use of one lane to support two-way vehicular traffic and the need for vehicles to 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.

The aim of this paper is to explore sight distance criteria which are applicable to ELRs and explore the development of ELR-specific sight distance models.

ELR-SPECIFIC SIGHT DISTANCE REQUIREMENTS

It is assumed that Stopping Sight Distance (SSD) is sufficient to prevent motor vehicle collisions with stationary objects and VRUs in the edge lane. What is needed is a sight distance which prevents collisions between two motor vehicles approaching one another. This will typically be longer than SSD since SSD assumes one object is stationary.

Two scenarios for approaching vehicles exist. The first scenario involves the edge lanes being unavailable for maneuvering. This requires that both vehicles be able to stop before reaching the other. The second scenario involves the edge lanes being available for maneuvering. This allows drivers to move to the side for a pass without stopping. The scenario in which an edge lane is immediately available but is occupied by a VRU some distance ahead is assumed to be equivalent to the first scenario if the VRU is nearby and equivalent to the second scenario if the VRU is farther ahead.

Before exploring new sight distance models for ELRs, it is useful to investigate existing sight distance models for aspects which might be useful in an ELR-specific sight distance model.

DISCUSSION OF EXISTING SIGHT DISTANCE CRITERIA

Passing Sight Distance (PSD)

Passing sight distance is cited in the Small Town and Rural Multimodal Networks Guide (1) as an ELR sight distance criterion. PSD is the sight distance needed by a motorist to safely pass another vehicle. No other country is known to use PSD for ELRs.

Per the 2011 Green Book *(16)*, 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.

Examination of the PSD model shows at least three problems when applied to ELRs.

PSD assumes the roadway operates as a two lane road on which successive vehicle-bicycle passing maneuvers occur. PSD assumes that a motor vehicle belongs on the right until a passing opportunity is detected and a passing maneuver is initiated. On an ELR, a vehicle belongs in the center until a maneuver is necessary to avoid oncoming traffic.

The second issue is the speed differential assumed by the PSD model. PSD assumes that the average speed of the passing vehicle while in the left lane is 12 MPH higher than the passed vehicle *(16)*. 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, in most cases, 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 *(16)*. The bicycle design dimensions promulgated by AASHTO *(17)* show lengths ranging from seventy inches (5.8 feet) for a normal bicycle to one-hundred-seventeen inches (9.8 feet) for a bicycle with child trailer. These are significantly shorter than the nineteen feet assumed by the PSD calculations.

These three issues demonstrate that PSD is not an appropriate sight distance criterion for ELRs. Fortunately, all of these issues produce overly-conservative sight distance values so this mistaken guidance does not create a safety problem.

PSD aspects which can be of use in an ELR-specific model include object height and perception-reaction time (PRT). PSD assumes that a driver is alerted to the possibility of an approaching vehicle and that an object height of 3.5 feet is adequate for that purpose.

The 2011 Green Book *(16)* states the passing driver's PRT for aborting a passing movement is 1 second. This is the recommendation made by NCHRP Report 605 *(18)*. Because no other published, adopted PRT is shorter, because a passing driver is alert for an oncoming vehicle, and because there is only one decision to be made, this is considered to be the minimum PRT for an ELR.

Stopping Sight Distance (SSD)

As with any other road, an ELR 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. This sight distance is useful to prevent VRU-motor vehicle collisions. The specified object height for SSD is two feet.

However, SSD is insufficient for safe operation of an ELR since approaching vehicles violate the assumption of a stationary object.

Head On Sight Distance (HOSD)

The concept of Head-On Sight Distance was named in the literature by Gattis *(19),* who wrote about the need for a sight distance on crowded residential roads which provided insufficient width for two cars to pass one another. Gattis defined HOSD as twice the SSD. In practice, SSD can differ between opposing directions of traffic as when grades are involved and the sum of the SSDs should be used. For this work, a doubling of the needed sight distance will be used for clarity.

Danish guidance recommends twice the SSD as a sight distance criterion for their ELRs *(14)*. The AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads *(20)* recommends that the sight distance provided for two-way travel on one lane roads should equal twice the SSD.

However, SSD assumes a driver is surprised by an unexpected obstacle and uses a PRT of 2.5 seconds.

Other Sight Distance Criteria

Decision Sight Distance (DSD) and Maneuver Sight Distance (MSD) were also examined for this work. Their concepts are relevant but the specific components of their models were not used in this work.

DSD provides sufficient sight distance for a driver to avoid an unexpected condition in a visually cluttered environment *(21)*. Its PRT is not applicable because of those assumptions. Its lateral shift maneuver time was based on research of a different movement from the early 1940's and was not used.

With the exception of the driver being surprised by an unexpected hazard, the Maneuver Sight Distance (MSD) model mirrors the needs of a driver maneuvering into the edge lane to bypass an approaching vehicle. Data on the time needed for a lateral shift maneuver appeared to be based on only one study and that study was not available for review *(22)*.

AN ELR-SPECIFIC SIGHT DISTANCE MODEL

As described previously, two cases need to be addressed:

1. Drivers must stay in center lane and stop before colliding,
2. Drivers are able to maneuver into the edge lane and avoid colliding without stopping.

Both cases require a PRT. Case 1 requires the stopping distance be added to the PRT distance for a total sight distance. Case 2 requires the distance for a lane change maneuver be added to the PRT distance for a total sight distance.

Using components from established guidance, estimates for these two sight distance models will be created. Without simulator or field work to verify the assumptions made, the intent is to remain conservative so these values can be used in the field until experimental refinement occurs.

Because the driver only needs to detect another vehicle in both cases, the 3.5 foot object height used by PSD is sufficient.

Perception-Reaction Time (PRT)

The time needed to perceive an object, recognize it, and decide upon a course of action is a well-studied subject. Most studies have assessed this time in response to a stimulus which is unexpected by the driver. For an ELR, it is reasonable to assume that the driver is aware that they may have to avoid an oncoming vehicle and that the alerted condition is most applicable.

Findings published in NCHRP Report 270 *(23)* found 95th percentile perception-response times of 1.2 seconds for alerted drivers. Report 270 suggested that a 50% factor be added to account for fatigue and similar issues which extend response time. The 50% value was based on the results of unreferenced studies which assessed the impacts of alcohol. Addition of the 50% factor results in a recommended value of 1.8 seconds.

As reviewed in NCHRP Report 400 *(24)*, Olson *(25)* and Johansson's *(26)* data on perception-reaction times in an alerted condition were similar and consistent. Data from these studies gives a mean perception-reaction time of .73 seconds and a standard deviation of .16 seconds. A 95th percentile value for that data is 1.05 seconds. Adding the 50% factor used in NCHRP Report 270 results in an alerted perception-response time of 1.6 seconds.

The 2011 Green Book recommendation of a 1 second PRT for PSD follows the recommendation made by NCHRP Report 605 *(18)*. It is unknown whether the 1 second PRT recommended by NCHRP 605 includes a 50% safety factor as the other two values do.

Averaging the values from NCHRP 605 (1 second), NCHRP 400 (1.6 seconds) and NCHRP 270 (1.8 seconds), gives 1.5 seconds as an estimated PRT for an alerted driver in a simple setting.

Gattis *(19)* used a similar process and settled upon a 1.2 second PRT for the application of HOSD to local streets. This decision was based on a published reaction time to traffic signal changes (in an unreferenced source) of 1 second and a review of studies performed by Taoka which found a range of average reaction times to signal changes extending from 1.1 to 1.3 seconds *(27)*.

Given these findings, 1.5 seconds appears to be a conservative PRT value. This is reasonable since the driver is assumed to be alert to the possibility of an approaching driver but is engaged in a driving task which lasts longer than a typical passing movement.

Case 1: Complete Stop to Avoid Collision

In the case of a driver needing to come to a complete stop, the HOSD concept with the shorter PRT appears sufficient to prevent a collision. For this work, HOSD is defined with the 1.5 second PRT value.

The SSD equations for level grades in the 2011 Green Book *(16)* are:

$SSD = 0.278Vt + 0.039(V2/a)$ Metric $SSD = 1.47Vt + 1.075(V2/a)$ Customary

where SSD = stopping sight distance in meters or feet, V = vehicle speed in km/h or mph, t = PRT in seconds, and a = deceleration rate of 3.4 m/s^2 or 11.2 ft/s^2, respectively. *(16)*

Using a PRT of 1.5 seconds and multiplying SSD values by 2 produces the results in the HOSD values shown in Tables 1 and 2. Calculated values are rounded up to the nearest value ending in 0 or 5.

Table 1 HOSD - Metric

Speed (km/h)	HOSD (m)
30	50
40	70
50	100
60	135
70	175
80	215
90	265
100	315

Table 2 HOSD - Customary

Speed (MPH)	HOSD (ft)
20	165
25	230
30	305
35	390
40	485
45	590
50	700
55	825
60	960

Case 2: Maneuver to Avoid Collision

In the case of a driver choosing to move into the edge lane to pass an approaching vehicle, the PRT must be added to the time needed to laterally shift toward the edge lane. In some situations, it will be necessary for the driver to scan the edge lane before shifting right. The distance needed by both drivers to accomplish these tasks before meeting is called the Avoidance Sight Distance (ASD).

Two variants of ASD are defined. ASD+scan refers to the ASD with time for an edge lane scan by the driver included and ASD-scan refers to ASD without an edge lane scan. In many cases, a motorist will not need to scan the edge lane before executing a lane change. If the road is lightly traveled by VRUs and the speed differential between VRUs and drivers is significant, the driver will be primarily concerned with VRUs ahead of them.

The distance of the lateral shift is less than a full lane change. Assuming both drivers are in the middle of the center lane, they only need to move over one half of a vehicle width plus a safety margin. The conservative assumption made is that drivers shift six feet, one-half the nominal width of a passenger car plus a safety margin of three feet. The three feet safety margin is based on anecdotal evidence that drivers tend to maintain a greater separation on ELRs than on standard two lane roads. A six foot shift also provides a margin for wider vehicles.

Scan of Edge Lane

Little information was found on the time needed to scan a lane before moving into it. Mourant *(28)* found that drivers took an average of 0.66 seconds to scan the side view mirror. The average was the only value provided by this work and it will be used for this estimate.

Lateral Shift Maneuver

Previous studies exist which produce time estimates for full lane change maneuvers but their data was based on observations of drivers initiating a pass on a two lane rural highway which can take more time in relaxed conditions *(21, 29, 30, 31)*.

For this work, the shifting taper requirement described in Section 6C of the MUTCD is used. Shifting tapers are used when drivers must be shifted away from a work zone or incident area but are not required to merge with another traffic stream. Drivers are alerted to the shift beforehand by signage and a clear line of sight. Tables 6C-3 and 6C-4 in the MUTCD provide the formulas for minimum shifting taper length:

L = WS2/120 for speeds of 40 MPH or less
L = WS/2 for speeds of 45 MPH or more

where L is the length of the taper in feet, W is the width of the offset in feet, and S is the speed in MPH.

The formulas for the ASD variants used to populate Tables 3 and 4 below are:

ASD – scan = 2* (1.5*speed + L) and
ASD + scan = 2 * (1.5*speed + 0.66*speed + L).

where speed is the given speed (in m/sec or ft/sec) and L is the taper length (in m or ft) from the equations immediately above.

Calculated values are rounded up to the nearest value ending in 0 or 5.

Table 3 ASD – Metric

Speed (km/h)	ASD+scan (m)	ASD-scan (m)
30	50	40
40	70	55
50	90	75
60	115	95
70	165	140
80	190	160
90	210	180
100	235	200

Table 4 ASD - Customary

Speed (MPH)	ASD+scan (ft)	ASD-scan (ft)
20	170	130
25	225	175
30	280	225
35	345	280
40	415	340
45	555	470
50	620	520
55	680	575
60	740	625

RESULTS

Three ELR-specific sight distances were calculated: HOSD, ASD+scan, and ASD-scan. Figure 3 plots these sight distances with PSD.

The graph shows that all of the ELR-specific sight distance models produce substantially lower values than PSD. The graph shows ASD-scan produced lower values than ASD+scan. The graph shows that both ASD variants produce lower values than HOSD with the exception of ASD+scan at 20 MPH, where the difference is five feet. These outcomes are expected and reasonable.

For both ASD and HOSD, the sight distance values are the result of doubling a value with a safety margin. This doubles the safety margin and may produce longer sight distances than necessary. Further work is needed to answer this question.

Because HOSD ensures that both drivers have enough time to come to a full stop, it is a more conservative sight distance than ASD and should be provided where possible. If edge lanes are expected to be unavailable then HOSD must be provided.

The time for a scan of the edge lane in ASD will not be needed in all conditions. If a road is expected to exhibit a low VRU-motorist speed differential or is expected to host higher volumes of VRU traffic, ASD+scan should be used. Where the VRU-motorist speed differential is greater and/or VRU traffic is light, ASD-scan may be used.

Data on the time to scan the edge lane before shifting right consisted only of an average of observed data in a different situation. Further research could accurately characterize that task’s duration and the conditions that prompt drivers to perform it.

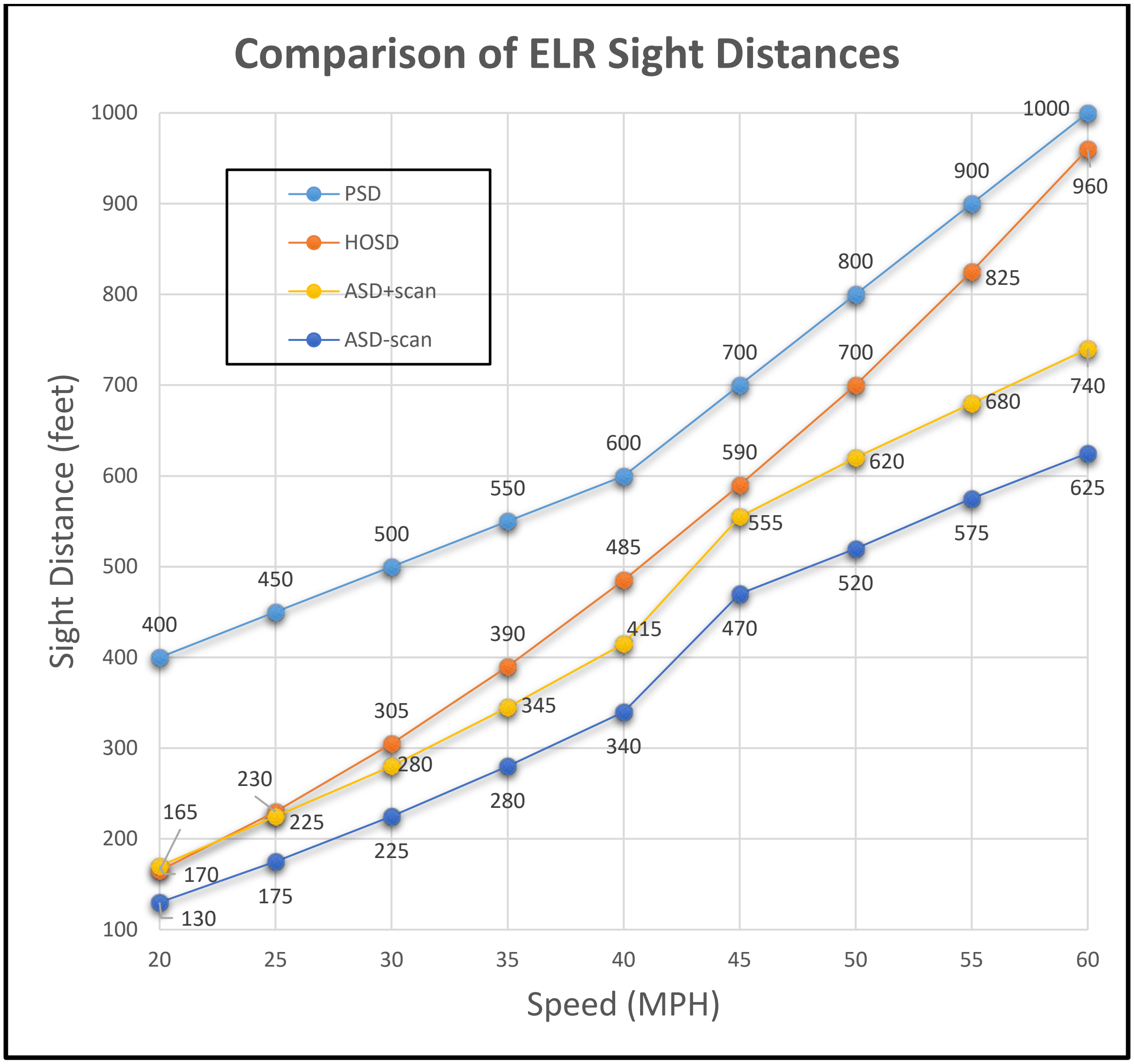

Figure 3 Graph of ELR Sight Distances

CONCLUSION

Sight distances for edge lane roads (ELRs), also known as Advisory Bike Lanes and Advisory Shoulders, are examined. Passing sight distance, the currently specified criterion for ELRs in American guidance is shown to be problematic and produce overly-conservative values. A review of other sight distance models and related guidance allowed the generation of two different sight distance models for ELRs. The first model provides sufficient distance for the oncoming drivers to come to a complete stop before meeting; this is called Head-On Sight Distance (HOSD). The second model provides sufficient distance for the oncoming drivers to maneuver around each other without stopping; this is called Avoidance Sight Distance (ASD).

For both models, an object height of 3.5 feet was chosen because the item of interest was another vehicle.

Figure 3 provides a graph of the PSD, HOSD, and two ASD model values. The ELR-specific sight distance models provide lower values than PSD and provide for safe operation. The choice of which sight distance to use will depend on conditions. As the most conservative value, HOSD should be provided where possible. If edge lanes may be unavailable for motorist use, HOSD must be provided. ASD+scan includes time for drivers to scan the edge lane before shifting right. ASD+scan should be used on roads with low VRU-motorist speed differential or higher VRU volumes. ASD-scan does not include time for drivers to scan the edge lane before shifting right. ASD-scan can be used, if needed, on roads with higher speed differentials or low VRU volumes. The intent of ASD-scan is to provide a fallback sight distance in situations where it is appropriate and it is infeasible to provide ASD+scan.

Further research is needed to refine ELR-specific sight distance models.

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