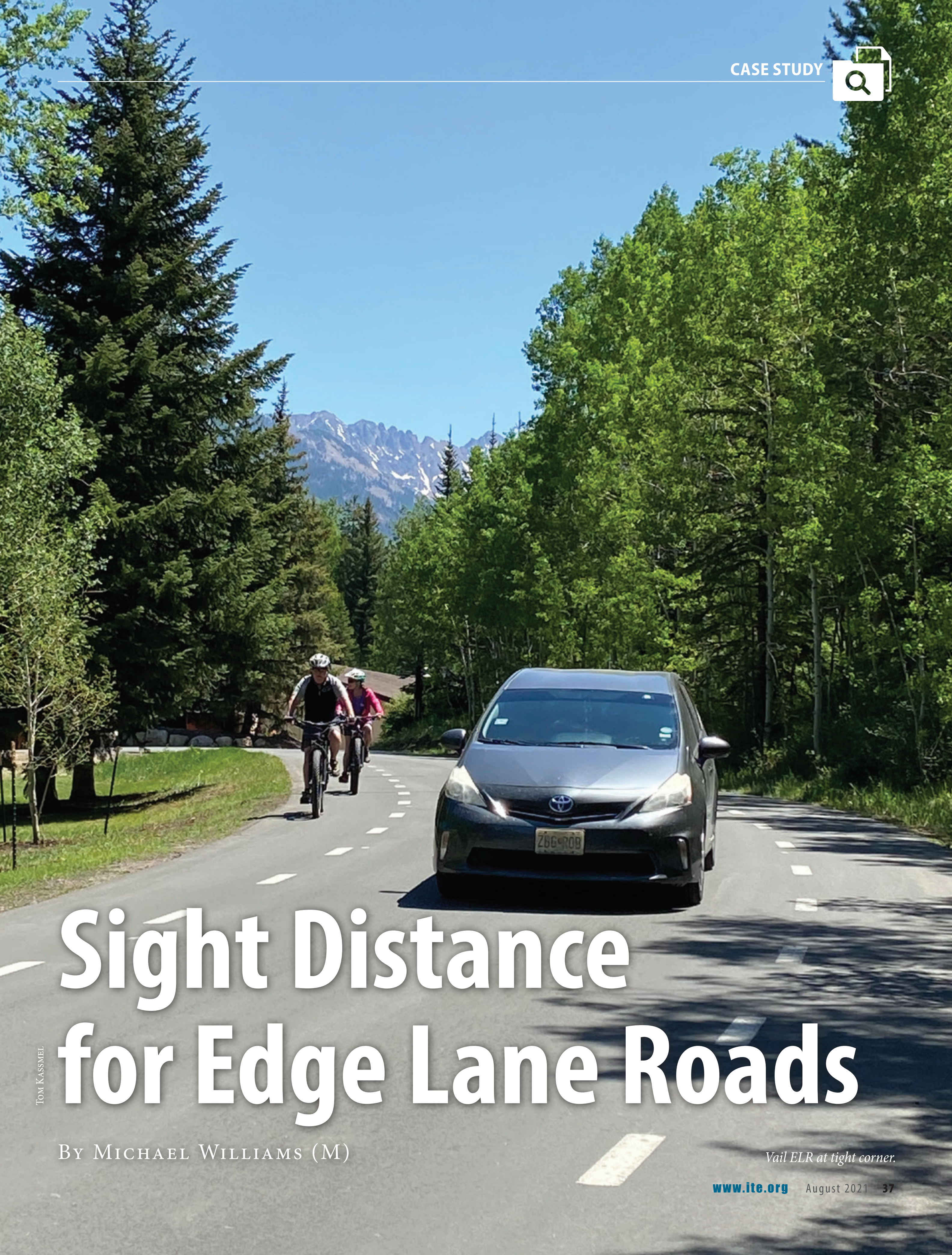

Tom Kassmel

Sight Distance for Edge Lane Roads

By Michael Williams (M)

Vail ELR at tight corner.

The name edge lane road (ELR) refers to a class of treatment that includes advisory bike lanes and advisory shoulders. Edge lane roads (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 from the *FHWA Small Town and Rural Multimodal Networks Guide*.[1]

An ELR has no centerline. 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.

ELR use in the United States and Canada is growing; over 50 installations were known as of March 2021.[2, 3] Given the candidacy of millions of road-miles for this treatment, inclusion in the upcoming release of the *AASHTO Guide for the Development of Bicycle Facilities*, and its low cost, continued growth seems likely.

A notable feature of ELRs is the use of one lane to support two-way vehicular traffic and the need for motorists to maneuver to pass approaching traffic. This requires a sight distance that allows motorists to detect one another and safely avoid collision. But no ongoing or upcoming research on ELR sight distance requirements is known. Additionally, no appropriate American sight distance guidance exists. I was involved in three ELR projects in 2020 that required accurate sight distance guidance.

Given the need for this guidance, this article's aim is to develop conservative, ELR-specific sight distance recommendations that can be used until field research can refine these recommendations.

Existing Guidance and Literature

Despite identical operating characteristics, ELR sight distance recommendations vary between countries. Danish guidance recommends twice the stopping sight distance (SSD).[4] Dutch guidance makes no mention of sight distance.[5] The *Small Town and Rural Multimodal Networks Guide* is the only U.S. guidance that addresses the topic, and it recommends passing sight distance.[1]

The *AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads* recommends that the sight distance provided for two-way travel on one-lane roads should equal twice the SSD.[6] The same guidance is found in the *1984 Park Road Standards* published by the National Park Service.[7]

The concept of Head-On Sight Distance was named in the literature by J.L. Gattis, who wrote about the need for a sight distance greater than SSD on residential roads that provided insufficient width for two cars to pass one another.[8]

The use of twice the SSD, as opposed to SSD, is required because the object to be avoided (the approaching vehicle) is not stationary. The object to be avoided is, for our purposes, moving toward the driver at a similar speed. A driver must be able to stop within a distance that does not overlap with the stopping distance needed by the approaching driver.

SSD assumes a driver unalerted to the potential need to avoid an obstacle in the road and includes a long reaction time as a result. Doubling this long reaction time creates an overly conservative sight distance recommendation.

Problems With Passing Sight Distance

Passing sight distance is the only official American recommendation for this treatment. It is cited in the *Small Town and Rural Multimodal Networks Guide* as an ELR criterion.[1] No other country is known to use PSD for ELRs.

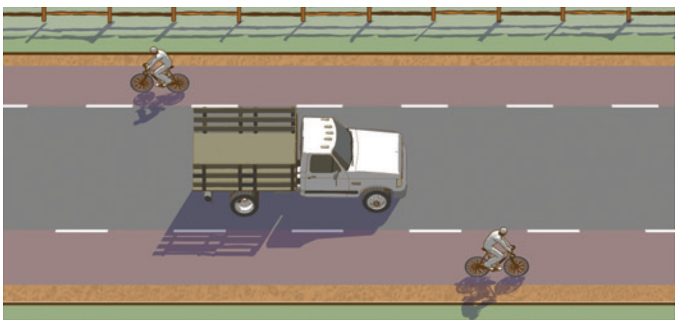

Figure 1. Motorists travel in the two-way center travel lane. When passing a bicyclist, no lane change is necessary.

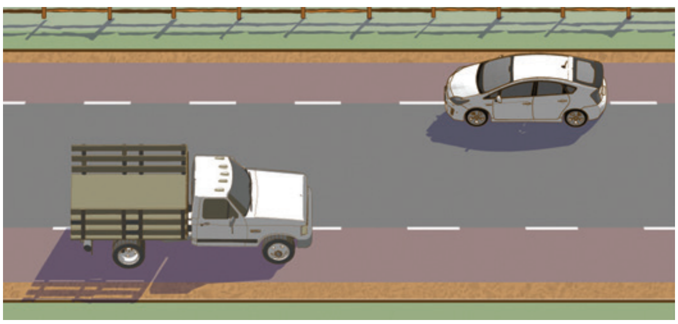

Figure 2. When two motor vehicles meet, motorists may need to encroach into the advisory shoulder space.

Three issues exist with the application of PSD to ELRs.

First, PSD assumes that a vehicle belongs behind another until a passing opportunity is detected and a passing maneuver is initiated. On an ELR, a vehicle is in the center lane until a maneuver is necessary to avoid approaching traffic.

Second, PSD assumes that the average speed of the passing vehicle while in the left lane is 12 mph greater than the passed vehicle.[9] This difference will likely be larger during a vehicle-bicyclist passing maneuver. And in most cases, no acceleration is needed by the passing vehicle. This raises the average speed differential further.

Third, the PSD model assumes that both vehicles are 19 feet long.[9] AASHTO stipulates bicycle lengths ranging from 70 inches (5.8 feet) for a normal bicycle to 117 inches (9.8 feet) for a bicycle with child trailer.[10]

These issues demonstrate that PSD is not appropriate for ELRs. Fortunately, these issues produce overly conservative values so safety problems due to too-short sight distances are avoided. But appropriate American sites for ELRs have been passed over due to sight distance concerns based on this guidance, and the decision to not implement VRU facilities can decrease safety for all road users.

ELR-Specific Sight Distance Requirements

Because PSD and twice the SSD are inappropriate, an appropriate sight distance recommendation is needed that prevents collisions between two motor vehicles approaching one another.

With respect to VRUs, the provision of SSD protects them from drivers approaching from behind. Assuming VRUs are moving at the same or lower speeds as the motor vehicles, they should be protected from drivers approaching from ahead by the sight distance developed in this article. Protection of VRUs that are traveling significantly faster than motor vehicle traffic from drivers approaching from ahead is out of the scope of this article.

For motor vehicles approaching one another, two scenarios must be addressed. The first scenario, shown in Figure 3, involves the edge lanes being unavailable for maneuvering. This requires that both vehicles be able to stop before reaching the other or to slow sufficiently until an opening in the edge lane becomes available. The worst case of coming to a full stop before reaching the approaching vehicle is assumed from this point forward. The second scenario has drivers moving right for a pass without stopping as shown in Figure 4.

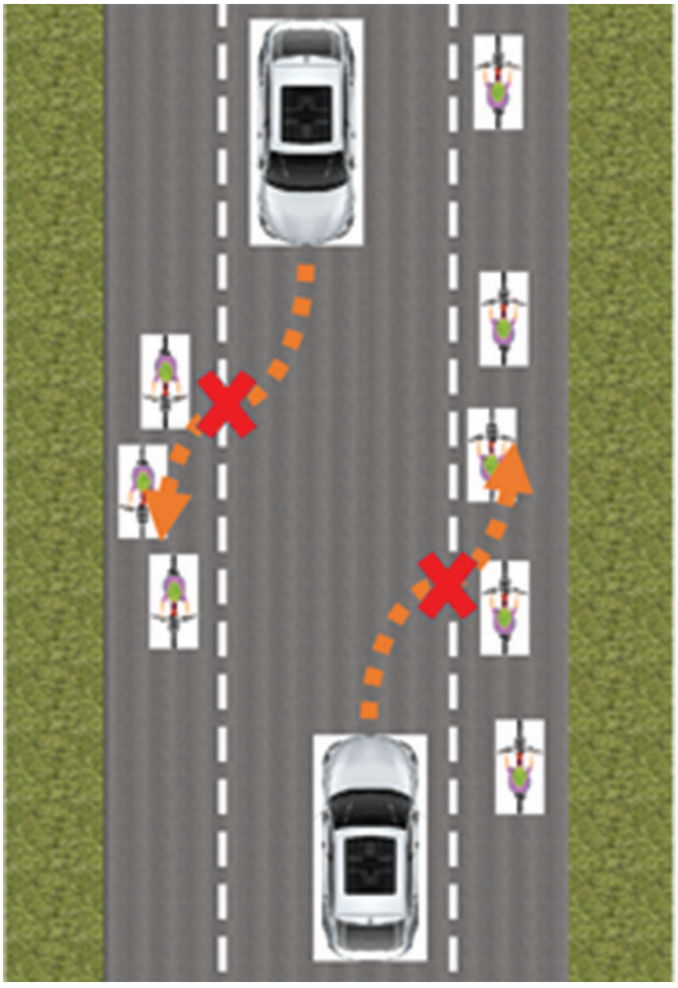

Figure 3. Two vehicles on an ELR with edge lanes unavailable for maneuvering.

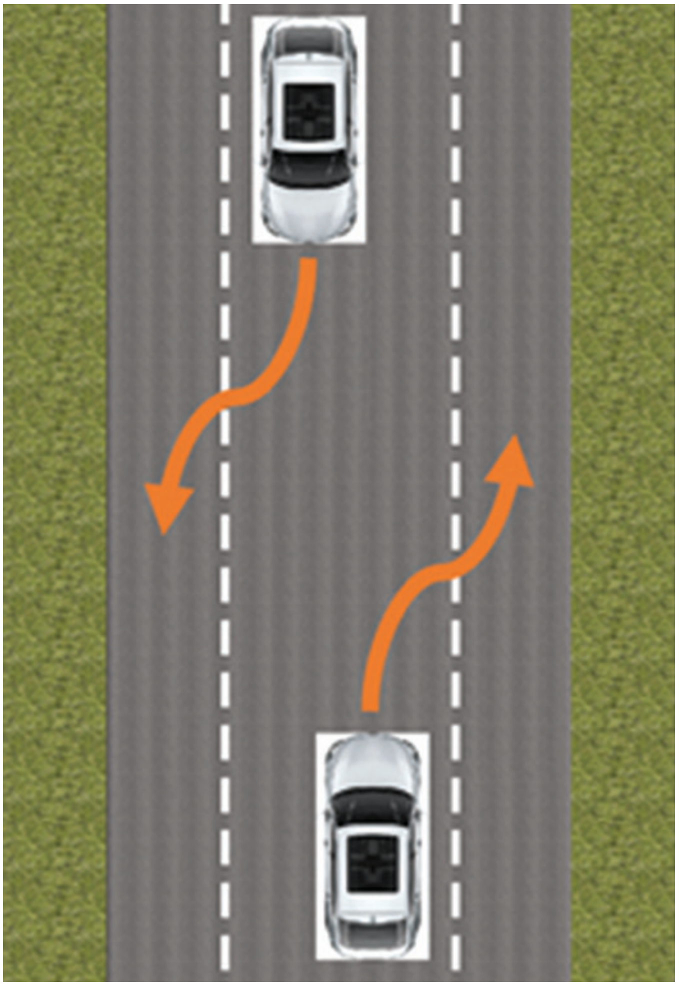

Figure 4. Two vehicles on an ELR with edge lanes available for maneuvering.

An ELR-Specific Sight Distance Model

For both cases, a common perception-reaction time is first estimated. Following that, the time required for actions specific to each case are estimated. These times are combined to create the proposed ELR sight distance models.

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. This work assumes that the driver is alerted, i.e., aware of the possibility of an approaching vehicle.

Where a driver must avoid an approaching motor vehicle, drivers need only detect another vehicle. The 3.5-foot object height used for PSD is assumed for this purpose.

Findings published in *NCHRP Report 270* found 95th percentile perception-response times of 1.2 seconds for alerted drivers.[11] The report added 50 percent to this value to account for other factors such as fatigue resulting in a recommended value of 1.8 seconds. The 50 percent value was sourced from a study that investigated the results of alcohol on driver performance.

As reviewed in *NCHRP Report 400*, Olson and Johansson's data on perception-reaction times in an alerted condition were consistent.[12, 13, 14] These studies produced 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 percent 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*.[8, 15] Because this is well-used, published guidance rather than research findings, this value is not derated by 50 percent.

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

Gattis' research relied on other research and chose a 1.2-second PRT for his HOSD work.[7]

Given these findings, 1.5 seconds appears to be an appropriate and conservative PRT value for ELRs. Because this value approximates a 95th percentile value that is further derated by 50 percent and then used for both drivers, it can be argued that it is overly conservative. Future field research is needed to refine this aspect.

Case 1: Complete Stop to Avoid Collision

In the case of two drivers needing to come to a complete stop, the HOSD concept is adapted. HOSD is defined to be twice the SSD but with the 1.5 second PRT.

The SSD equations in the *2011 Green Book* are:[8]

$SSD = 0.278Vt + 0.039(V^2/a)$ Metric

$SSD = 1.47Vt + 1.075(V^2/a)$ 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.

Using a PRT of 1.5 seconds and multiplying SSD values by two produces 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 drivers choosing to shift laterally to pass, the PRT must be added to the time needed to move right. 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 that includes time for an edge lane scan by the driver 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 rarely traveled by VRUs or the speed differential between VRUs and drivers is significant, the driver need only be 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 assumption made is that each driver shifts 6 feet; this is equal to one-half the nominal width of a passenger car plus a safety margin of 3 feet. The 3-foot safety margin is based on anecdotal evidence that drivers tend to maintain a greater separation on ELRs than on standard two-lane roads. Six feet of distance between the vehicles provides sufficient margin for wider vehicles.

Scan of Edge Lane

The only information found that is relevant to the time needed to scan an edge lane before moving into it is work done by Mourant.[16] Mourant found that drivers took an average of 0.66 seconds to scan the side view mirror; no other values were reported. This time is used as a surrogate for the time needed to scan the edge lane. The 0.66-second value is not derated as the PRT was for this case.

Lateral Shift Maneuver

For this work, the shifting taper requirement found in Section 6C of the *2009 Manual on Uniform Traffic Control Devices* (MUTCD) is used.[17] Shifting tapers are used when drivers must be shifted away from a work zone but are not required to merge with another traffic stream. Drivers are alerted to the shift in advance by signage and have clear sightlines. 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 (6 feet as described earlier), and S is the speed in mph.

The formulas for the ASD variants used to populate Tables 3 and 4 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.

The ASD formulas include the doubling needed to accommodate both vehicles and produce the values shown in Tables 3 and 4. 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

Nighttime ELR Sight Distances

Detection of VRUs and oncoming vehicles is necessary during nighttime driving. The distance at which a driver can detect "a small or low contrast object on an unilluminated roadway" with their headlights is called the Headlight Sight Distance (HSD) and is stated to be 427 feet (130 meters) in *NCHRP Report 400*.[12] The report also notes that large or high-contrast objects can be detected at longer distances under the same conditions.

If the headlights of both vehicles are on, physics dictates that detection at twice the HSD will not be a problem. The only circumstance where this may not be sufficient is the use of HOSD at 60 mph, as shown in Figure 5.

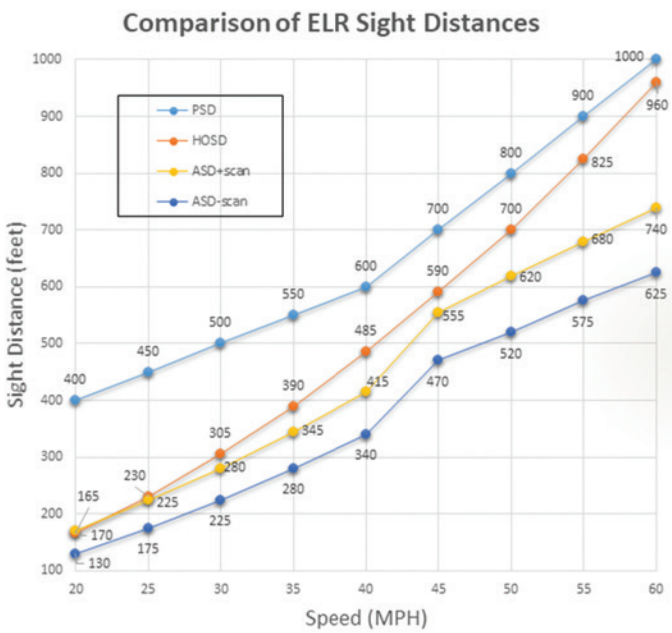

Figure 5. Graph of ELR Sight Distance.

Detection of VRUs may be a problem at higher speeds but an ELR is preferable in these conditions because the vehicles and the VRUs are more likely to be horizontally separated than on a standard two-lane road without bicycle lanes.

Results

Three ELR-specific sight distances were derived and calculated: HOSD, ASD+scan, and ASD-scan. Figure 5 plots these sight distances with PSD.

The ELR-specific sight distance models produce shorter distances than PSD. ASD-scan produced shorter distances than ASD+scan. Both ASD variants produce shorter distances than HOSD with the exception of ASD+scan at 20 mph, where the difference is 5 feet. These outcomes are expected and reasonable.

These sight distance recommendations include the doubling of values with significant safety margins. This may produce longer sight distances than necessary.

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

Conclusion

Passing sight distance (PSD) is the current U.S. recommendation for sight distance on an edge lane road. It has been shown to be inappropriate and overly conservative. Two new sight distance models are proposed. 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).

The choice of which sight distance to use depends on conditions. As the most conservative value, HOSD should be provided whenever 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 may be used, if needed, on roads with higher speed differentials or low VRU volumes. The intent of ASD-scan is to provide a possible fallback where ASD+scan is infeasible or for use on ELRs that are installed with a primary goal of reducing roadway departure crashes rather than provision of VRU facilities.

These models are appropriately conservative and can be used on ELR projects until future research creates more refined ELR-specific sight distance models. **itej**

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