Geometric Design for Adequate Operational Preview of Road Ahead

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Minimum geometric conditions must exist to provide an ample amount of preview sight distance (PVSD) for comfortable and safe traffic operations. The PVSD concept is based on the assumption that the driver views or previews the roadway surface and other cues that lie ahead to obtain the information needed for vehicular control and guidance. The driver needs a minimum PVSD to perceive and respond to upcoming alignment cues; the roadway geometry affects how much PVSD is available for the driver. A roadway designed with geometric features adequate to the design speed would in many cases provide ample PVSD, but a roadway with constrained design features could have inadequate PVSD. The paper includes a derivation of equations to calculate the available preview sight distance on a crest vertical curve and discusses two applications of the PVSD concept to sharp horizontal curves. When a geometric analysis finds that inadequate PVSD exists, upgraded signing or pavement marking to provide drivers with extra positive guidance may be considered as a means of compensating for inadequate PVSD.

A well-designed roadway should provide the driver with an adequate line-of-sight ahead or along the roadway. The AASHTO "Green Book" (*1*) states that, as a minimum, all roadways should provide the driver with adequate stopping sight distance (SSD). Decision sight distance, passing sight distance, and intersection sight distance are also needed for certain situations. Traffic engineering reference books discuss the sight distance needed to perceive and react to a changing traffic signal. But the driver has other sight distance needs in addition to stopping for hazards ahead, passing slower vehicles, negotiating an intersection, or reacting to a signal. To have a relaxed, comfortable, and safe ride, the driver also needs an adequate view of the roadway alignment ahead. This view of the road surface and other appurtenances ahead provides cues needed for control and guidance, and has been referred to, in a context of pavement marking adequacy, as preview distance (*2*). Herein it is referred to as preview sight distance (PVSD).

The outline and shape of the roadway ahead provide visual cues to help the driver guide the vehicle along and into a proper path. The actual road shape can be defined by pavement edges and curbs, and surface pavement markings may act as surrogates to define roadway outlines and shapes. For instance, the driver's view of upcoming lane lines and curb edges sweeping to the right shows the driver that a horizontal curve to the right is ahead. Other cues, such as traffic control signs or the background environment (i.e., tree lines, guardrails, etc.), may also be present to help guide the driver. Where vehicle densities are high, drivers may rely on the outline of the vehicle stream ahead for guidance.

This study focuses on the minimum crest curvature geometry that must exist to provide an ample amount of PVSD for traffic operations. Two applications of the PVSD concept to sharp horizontal curves are briefly discussed. Where ample PVSD exists, drivers can perceive upcoming alignment cues in advance and respond in order to control and guide the vehicle.

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DESCRIBING INADEQUATE PVSD CONDITIONS

One could assume that horizontal and vertical curvature that is flat enough to provide adequate SSD would automatically provide an adequate PVSD. Even if a roadway with adequate SSD automatically has ample PVSD, the many sections of roadways that do not conform to current geometric design standards may have inadequate PVSD.

Some of today's roads were first trails or wagon roads, and were paved after the automobile age arrived. If such roads ever were designed, it was for a much lower speed than that at which drivers now operate. It would seem that the potential for PVSD deficiencies would be greater on the many miles of older local or secondary roadways, especially those with curved alignments, than on modern primary highways. Certain locations on these subpar roads may be candidates for upgraded signing or pavement marking to provide the driver with positive guidance as a way of compensating for inadequate PVSD.

Scenario Illustrating Inadequate PVSD

A scenario involving inadequate PVSD can easily be envisioned, as in the case of an undivided urban four-lane minor arterial street in rolling terrain. The horizontal and vertical alignments were designed for 48 km/hr (30 mi/hr), but the actual 85th percentile speed on the street is over 65 km/hr (40 mi/hr). There is a 24.4-m (80-ft) omission in the centerline and lane line markings because of an intersecting street at the crest of a vertical curve. A horizontal curve to the right begins near the intersection and crest. A driver who is unfamiliar with the area, traveling in the inside lane, rapidly approaches the crest of the vertical curve. Upon entering the area bounded by the intersecting street, the driver is briefly in a cueless zone (with no lane lines or curb edge). Although now in a horizontal curve, the driver has erroneously assumed that the roadway continues straight ahead. The vehicle is well into the horizontal curve before the driver again sees roadway curvature cues, that is, the curb edge and pavement markings. If the driver cannot correct the mistake and steer into the curve quickly, the vehicle could cross over into the next lane to the left, which is an oncoming traffic lane.

In this example, the combination of a crest vertical curve and omitted pavement markings created a gap in the series of cues being provided to the driver. Fog or overdriving the headlights may create the same effect. If for any reason the flow of cues on which the driver is relying for guidance is inadequate, then there is a greater potential for guidance levels falling below what is needed for safe and comfortable vehicle operation. The inadequate PVSD may result in erratic positioning of the vehicle within a lane, driving outside of the lane boundaries, or an accident. Vehicle control errors have more severe consequences on roads with narrow lanes. For instance, an additional 0.3-m (1-ft) deviation in lane position due to inadequate PVSD in addition to normal lateral variation may not be critical when driving in a wide lane, but the same amount of deviation on a narrow lane could cause the vehicle to encroach on adjacent lanes.

Breaking the Problem Into Components

Analyzing the adequacy of the PVSD along a roadway segment involves a comparison of the available PVSD with the needed PVSD. However, available research does not fully define all of the parameters of such an analysis.

Available PVSD may be constrained by near and far limits. As the driver looks through the front windshield to gather cues for vehicle guidance, the driver's close-up view is obstructed by the front hood. The driver cannot see any closer ahead than this minimum distance. The far limit of the driver's view of roadway surfaces and markings may be governed by the roadway geometry. In the absence of supplementary cues, cues are derived from that length of roadway between the near and far limits of the driver's view of the pavement surface.

The needed PVSD is not so easily defined. Conceptually, it is the length of roadway traveled while the driver perceives and reacts to upcoming roadway guidance cues. It is not easy to measure driver preview time precisely. In order to approximate needed preview time, the author made a number of measurements while driving three winding highways and one city street, all of which appeared to have limited sight distance. In roadway sections that had a preview that seemed uncomfortably small, a stopwatch was used to roughly measure the elapsed time from when the driver (i.e., the author) fixed on a point on the roadway surface ahead for guidance until the vehicle passed that point. The fixed point was located the least distance ahead that allowed the driver to feel marginally comfortable, as he controlled and guided the vehicle. Measurements indicated that a minimum preview time might be on the order of 1.3 to 1.7 sec.

It should be noted that these measurements were made under the following conditions:

1. The driver's only task was to control and guide the vehicle;
2. The driver exercised a very high level of attention;
3. Attention was not diverted to perform other tasks; and
4. Although sight distance was restricted, the roadway had no unexpected gross alignment changes.

It should not be inferred that these values are suitable for design. The amount of preview needed at a given location may depend on the rigor of the required control and guidance efforts at that location. Allowances for driver fatigue, driving task-sharing, and variations among drivers could necessitate greater preview times, if the requirements of a large portion of the driving public are to be comfortably accommodated. Additional information about needed PVSD can be obtained from other studies, including some performed to assess pavement marking adequacy.

Comment

Inadequate PVSD arises when the available viewing distance of the roadway is less than the driver needs to react and make vehicle guidance adjustments. It is assumed that, other elements being equal, a driver would need more guidance on a curved alignment than on a straight alignment. On the basis of the author's driving experience, it was hypothesized that on a horizontal curve, a pavement edge can be a less effective cue on an undivided multilane roadway than it is on a two-lane roadway. This is probably because a driver in the inside lane of an undivided multilane roadway sees a wider pavement and therefore the pavement edges are a less precise "target." In addition, there is no immediately adjacent right pavement edge to help guide the driver and prevent encroachment on the adjacent lane or lanes. Perhaps the driver on an undivided multilane roadway relies more on the lane line markings for guidance through the horizontal curve than does the driver on a two-lane roadway with a well defined edge.

RELATED LITERATURE

Guidance in selecting or evaluating proper PVSD is not contained in the Green Book (*1*) or in many other common geometric design references. But discussions of various topics related to PVSD can be found in human factors literature and geometric design literature.

Tracking and Preview Time

A study on a two-lane road reported by Gordon (*3*) concluded that "On the basis of the driver's fixations, the road edges and the centerline are essential information a driver needs." Gordon noted that the "forward reference distance" of the drivers in the sample and the points they fixed on varied greatly between drivers. Among different drivers, increased forward reference distance did not correlate with increased speed. On curves to the right, drivers' fixation points on average did shift to the left but did not cross over the center line. In a subsequent article (*4*) Gordon wrote, "It is unfortunate that so little is known about the important factor of anticipation in driving. Exploratory studies are needed to determine optimal or minimal anticipation distances applicable to road signs, barriers, [and] curves."

McLean and Hoffman (*2*) reported the preview findings of a number of studies. As Table 1 shows, the findings of the various studies were not consistent. Differences between the various study methods could have contributed to the variation of the findings. Conducting studies of driver steering behavior at 32 km/hr (20 mi/hr) and at 48 km/hr (30 mi/hr), McLean and Hoffman found that for preview times of 2.5 sec or more, steering behavior did not appreciably change. When preview times were less than 2.5 sec, there was an increase in erratic steering behavior. At both 32 km/hr (20 mi/hr) and 48 km/hr (30 mi/hr), about 21 m (70 ft) of far sight distance was needed for drivers to align their cars adequately. At 40 km/hr (25 mi/hr), 21 m (70 ft) is traversed in 1.9 sec. These studies were conducted on a straight road in a traffic-free environment.

When studying the adequacy of pavement markings, Allen et al. (*5*) noted that "the road perspective is determined within the first few hundred feet down the road." They concluded from previous research that sight distances of 30–61 m (100–200 ft) were adequate.

TABLE 1 Preview Times Reported by Various Researchers

Author(s)	Driving situation	Speed m/sec (ft/sec)	Preview time sec.
Gordon	gently meandering	6.1 (20)	7
Hoffman, Joubert	slalom course	7.6 (25)	2
Kondo, Ajimine	straight	3.0-16.8 (10-55)	2-9
Kondo, Ajimine	tight curves	3.0-7.6 (10-25)	2-4
Mourant, Rockwell	open highway	21.3-30.5 (70-100)	≥3
Wierwille, Gagne, Knight	simulated highway	30.5 (100)	~3

Time for Other Tasks

Drivers have to perform other tasks that take time. In a synthesis of studies conducted to determine how much glance time is consumed while performing such tasks as checking vehicle instruments, checking mirrors, or reading street name signs, Taoka (*6*) listed average values ranging from 0.62 sec to well over 1 sec.

Amount of Available Visibility

Allen and O'Hanlon (*7*) discussed the need for roadway markings or delineation to provide the driver with positive guidance. The visibility of a given target is defined by its size and contrast. Steering performance is a function of the configuration of delineation and its contrast. The contrast of the target can be affected by light characteristics and environmental factors such as fog, snow, dust, and rain. At night, apparent contrast drops off more rapidly due to headlight scattering.

Currently, headlights on American cars are not uniform in either position or performance. Fambro et al. (*8*) noted that low-beam headlights should provide 15,000–20,000 candela, and high-beam lights up to 75,000 candela. Headlights do not provide an even pattern of light ahead, but rather are aimed and create "hot" spots. A low-beam light 0.6 m (24 in.) above the pavement (the average headlight height) will hit the pavement 70 m (230 ft) ahead and 1.8 m (6 ft) to the right. Presently, pavement reflectances are not well defined, but tend to be in the ranges of 10–20 percent at distances of 61–122 m (200–400 ft). Objects of 14% reflectance are visible at 119 m (390 ft) when illuminated by a source of 25,000 candela, and are visible to 158 m (520 ft) when illuminated by 75,000 candela. The reduction of light transmitted to the driver due to tinted windshields and the impact of oncoming vehicle glare must be considered. Table 2 presents findings from an older study, which approximate visibility with current low-beam headlights, both with and without glare from oncoming vehicles. Fambro et al. (*8*) noted that accident reports do not often list the accident cause as poor headlight visibility (3 percent in one study, 3–23 percent in a pedestrian accident study). The number of cases in which inadequate headlight illumination contributed to an accident but the police report listed a more easily identified factor, such as driver error or excessive speed, is unknown.

Inferences from Literature Concerning PVSD

A number of authors have recognized the need to relate the available sight distance to the sight distance needed for vehicle control and guidance. Although the reported values of needed preview time vary between research studies, the use of values no less than 2.0–3.0

TABLE 2 Visibility Distances Considering Glare

Target	Distances - m (feet)	
	No Glare	Glare
Large objects	39-88 (127-290)	32-114 (105-375)
Small objects	61-89 (201-291)	46-69 (150-228)

sec seem well supported, especially when the need for the driver to perform other tasks in addition to control and guidance is considered. Further study may show the need for a preview greater than 3.0 sec. The values reported in Table 2 imply that a driver traveling at highway speed [27 m/sec (90 ft/sec)] and dimming the headlights while meeting an oncoming vehicle's headlights would briefly have less than 2.0–3.0 sec of preview time. That is, the PVSD available for the driver could be less than is desirable.

EQUATIONS TO SOLVE FOR AVAILABLE PVSD

The amount of needed PVSD may vary according to the complexity of the driving task ahead. A basic need is to be able to see the roadway alignment cues, specifically the lane lines and pavement edges or curbs, far enough ahead to control and guide the vehicle into the roadway. The following equations can be used to estimate the amount of PVSD provided in certain situations.

Solution for Crest Vertical Curve

Figure 1 shows terms used in the derivation of a solution for a parabolic crest vertical curve of the form $x^2 = -4ay$, with the x coordinate of the vertex being 0. The parameter a is uniquely defined by knowing the slope g at any point (other than at the vertex) of known horizontal distance x from the vertex; $a = x/2g$. Suppose that at a point a horizontal distance (q) to the left of the vertex the slope is $g_1 = \tan\theta$. Taking the first derivative of the equation and substituting yields the following.

$$x^2 = -4ay \quad (1)$$

$$2x = -4ay' \quad (2)$$

$$2q = 4ag_1 \quad (3)$$

$$2q/g_1 = 4a \quad (4)$$

If point x is at the point of vertical curvature (PVC), then $2q$ is the length of the horizontal chord.

Now let the slope of a tangent to the parabola at another point x be $-g_2$ when $x = p$, given $p > 0$. Let L_{qp} be the horizontal distance between the points $x = q$ and $x = p$.

$$2p = 4ag_2 \quad (5)$$

$$L_{qp} = q + p = 2a(g_1 + g_2) \quad (6)$$

$$L_{qp}/[(g_1 + g_2)/2] = 4a \quad (7)$$

$$L_{qp}/[(g_1 + g_2)/2] = 2q/g_1 \quad (8)$$

Note that $(g_1 + g_2)/2$ is the average slope between the pair of points $x = -q$ and $x = p$.

The profile tangent sight distance (PTSD when used as a term, or c when used as a dimension) will be defined as the line of sight from the driver's eye to a point that intercepts and is tangent to the curvature of the pavement surface. If the roadway surface is entirely relied on for guidance cues through a crest vertical curve, the PTSD becomes the available PVSD. In deriving a simple formula, this distance c may be measured horizontally (as is done in the field) without significant error. Similarly, the height h of the driver's eye above the pavement surface may be measured vertically. Assuming that both the driver and the point at which the line of sight intercepts the pavement surface are within the limits of the crest vertical curve, PTSD extends from the driver's position at the coordinates $(x - c, f(x - c) + h)$ to the intercept point $[x, f(x)]$.

A parabola has a constant PTSD in both directions, that is, from left to right or from right to left. (It is an interesting mathematical exercise to show that any twice-differentiable curve with a constant PTSD in both directions, measured horizontally, must be a parabola.) The condition for a constant PTSD is given by

$$f(x) - f(x - c) - h = c\,f'(x) \quad (9)$$

If

$$f(x) = -kx^2 \quad (10)$$

then this delay differential equation becomes

$$-kx^2 + kx^2 - 2kcx + kc^2 - h = -2kcx \quad (11)$$

The PTSD for the parabolic vertical curve is thus found by the following substitutions.

$$x^2 = -4ay \quad (12)$$

$$y = x^2/-4a = -kx^2 \quad (13)$$

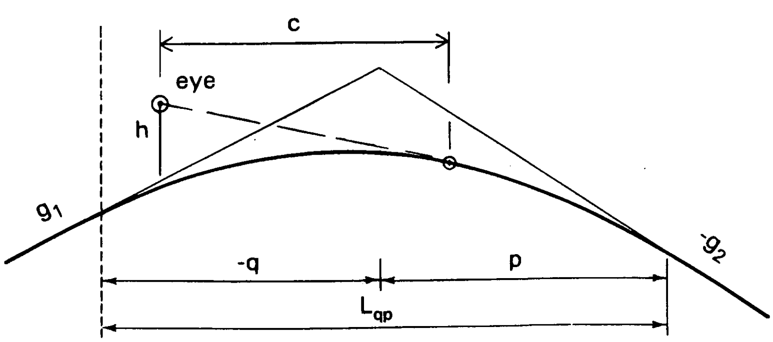

FIGURE 1 Derivation of PTSD for crest vertical curve, driver within curve.

where $k = 1/4a$

$$c^2 = \frac{h}{k} = \frac{h}{1/4a} = 4ah = \frac{2gh}{g_1} \qquad (14)$$

Taking the square root,

$$c = \sqrt{\frac{2gh}{g_1}} = \sqrt{4ah} \qquad (15)$$

for a parabolic vertical curve in which both gradients have an equal absolute value. For a vertical curve in which the two gradients are unequal, further substitution yields the generalized equation

$$c = \sqrt{\frac{L_{qp}h}{(g_1 + g_2)/2}} = \sqrt{\frac{2\,L_{qp}\,h}{g_1 + g_2}} = TSD \qquad (16)$$

The common formula for stopping sight distance when SSD $< L$ is, in effect, a summation of two of these equations to find c. One part calculates c_1 with a driver's eye height (h_1) of 1.07 m (3.5 ft) and the line-of-sight tangent to the vertical curve surface; the other calculates c_2 from the point at which the line of sight touches the curve surface to the point at which an object is a height h_2 of 0.15 m (0.5 ft) above the surface.

$$SSD = c_1 + c_2 = \sqrt{4ah_1} + \sqrt{4ah_2} \qquad (17)$$

Solution for Crest Vertical Curve with Driver in Advance of Curve

The preceding solution assumed that both the driver and the point at which the driver's line of sight intercepted the pavement surface were within the limits of the crest vertical curve (i.e., needed sight distance was less than vertical curve length). When a driver is approaching the beginning PVC but is still a distance b in advance of the PVC (see Figure 2), then a different equation must be derived.

The physical or actual vertical curve commences at the PVC. However, a theoretical vertical curve parabola exists in advance of the actual PVC. There is a vertical distance j between a driver's actual elevation on the tangent grade in advance of the PVC and a point on the theoretical crest vertical curve parabola beneath the driver. For a driver positioned in advance of the PVC, the PTSD now becomes

$$c = \sqrt{\frac{L_{qp}\,(j + h)}{(g_1+g_2)/2}} = \sqrt{\frac{2L_{qp}\,(j + h)}{g_1 + g_2}} \qquad (18)$$

The value of j may be found as follows.

$$b = \sqrt{\frac{L_{qp}\,j}{(g_1 + g_2)/2}} \qquad (19)$$

$$j = \frac{b^2\,(g_1 + g_2)/2}{L_{qp}} \qquad (20)$$

If a value for the PTSD when both the driver and the line-of-sight intercept are within the vertical curve has been determined, then the PTSD for a driver located in advance of the PVC may be simply found by

$$c = \sqrt{\frac{L_{qp}\,h}{(g_1 + g_2)/2} + b^2} \qquad (21)$$

If the vertical curve length is greater than the needed PVSD, the equation implies that the available PTSD for a vehicle in advance of the PVC will be greater than the available PTSD for a vehicle that has passed the PVC but is still within the limits of the vertical curve.

Examining a Horizontal Curve

In a horizontal curve, the driver's view of the roadway ahead may be less than what is needed to give an adequate preview. Restricted PVSD can occur if other vehicles or roadside objects restrict the PVSD, or if the roadway curves out of sight.

A sharp curve to the right can illustrate two possible assumptions. In one approach, it is assumed that even if adjacent vehicles in the right lane limit the distance ahead that the driver can view his own lane, the absence of oncoming traffic allows the driver to receive cues from the opposing lane's pavement edge or lane lines. In a more conservative approach, it is assumed that the driver must obtain advance cues from the driver's own lane.

Using the more conservative assumption, the distance ahead over which the driver must preview the road surface will not be adequate if the needed line of sight is blocked by a roadside object or another vehicle on the inside of the curve. The available PVSD may be approximated by the common Green Book (*1*) formula for an obstruction blocking the view around a horizontal curve.

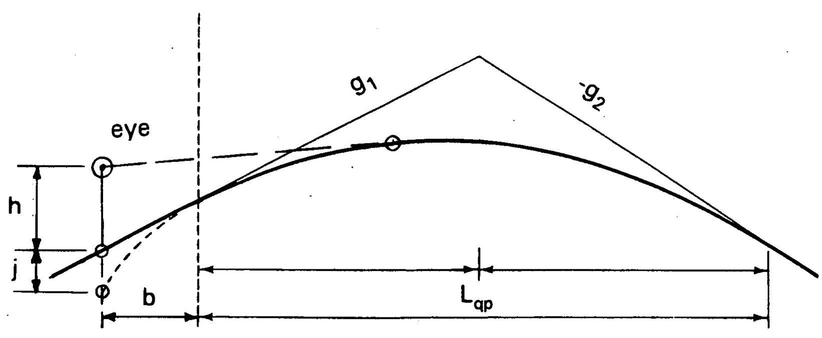

FIGURE 2 Derivation of PTSD for crest vertical curve, driver ahead of curve.

$$\text{available PVSD} = \arccos\left(1 - \frac{M}{R}\right) * \frac{R}{28.648} \quad (22)$$

where R is the radius in feet of the path traveled by the vehicle and M is the lateral offset distance from the path traveled by the vehicle to the object obstructing the driver's view. This view-restricting object may be a vehicle in the next lane or a roadside object.

The other causal situation is related to a horizontal curve being so sharp that the roadway ahead falls outside of the driver's normal high-resolution vision cone. If the conservative assumption is used, the driver must retain in his or her cone of vision the lane markings defining the driver's own lane. Continuing with the curve to the right, assume a lane width W, limits of well-defined vision on either side of a "straight ahead line of sight" defined by a cone of 2θ, and the driver's head turned ϕ degrees into the curve. The outside (i.e., to the left of the driver) lane line will fall outside the cone's right edge at a distance ahead of the driver equal to the needed PVSD for any radius R less than the R approximated in the following equations.

$$\sqrt{R^2 - [PVSD * \cos(\theta + \phi)]^2} = R - \frac{W}{2} - PVSD * \sin(\theta + \phi) \quad (23)$$

$$R = \frac{PVSD^2 + \frac{W^2}{4} + W * PVSD * \sin(\theta + \phi)}{W + 2 * PVSD * \sin(\theta + \phi)} \quad (24)$$

R is a radius of the outside (left) line of the travel lane, shown in Figure 3. For a two-lane roadway, the outside lane line is the centerline.

APPLICATION FOR A DESIGN ANALYSIS

The previously discussed "easily envisioned scenario involving inadequate PVSD" is a location where the construction plans show a +3.68 percent grade followed by a −4.64 percent grade. These grades are connected by a crest vertical curve of 73.2 m (240 ft), on which the design speed is 48 km/hr (30 mi/hr). An intersecting street forms a T intersection at the crest. The calculated stopping sight distance, according to the 1990 Green Book (*1*) is 59.6 m (195.7 ft).

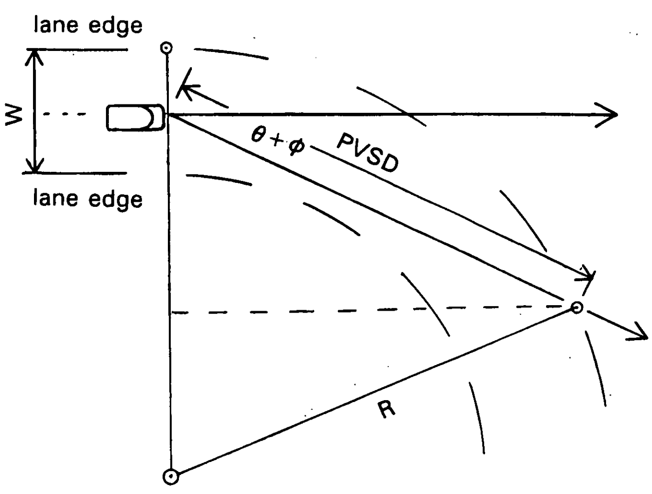

FIGURE 3 Horizontal alignment curving out of sight.

Using Equation 16, the calculated distance at which a driver loses sight of the pavement surface over the crest of the vertical curve is

$$TSD = \sqrt{\frac{2 * 73.2 * 1.067}{0.0368 + 0.0464}} = 43.3 \quad (25)$$

$$(TSD = \sqrt{\frac{2 * 240 * 3.5}{0.0368 + 0.0464}} = 142.06 \text{ ft})$$

The PVSD needed for the 85th percentile speed of 71 km/hr (44 mi/hr) and an assumed 2.5 sec to react and maneuver is 49.2 m (161.3 ft). Thus, the available PTSD is slightly less than the needed PVSD. When driving through the actual intersection, the driver momentarily experiences an absence of control and guidance cues while approaching the crest. (The road surface in the crest area lacks pavement markings.) Providing short dashed markings through the intersection would be one way of addressing this situation and helping unfamiliar drivers to negotiate the roadway.

RELATION TO CURRENT RESEARCH

The preview sight distance issue is related to the ongoing study of driver workload and design consistency. A driver who travels a roadway that has continuous geometric design inadequacies and who perceives the inadequacies may have the advantage of being more alert than a driver on a 10-km straight road who suddenly encounters the one 35-km/hr curve, but neither driver has the ability to anticipate or respond to a design inadequacy until it comes into view. It seems that on a roadway that has continuous design inadequacies, the driver would devote a greater proportion of attention to road-following, thus diminishing the attention that can be devoted to other tasks such as monitoring vehicles and pedestrians entering from the side. Indeed, a prolonged, continual state of heightened alertness may accelerate driver fatigue.

The preview sight distance concept also affects the re-evaluation of stopping sight distance criteria. Current criteria for visibility over a crest vertical curve allow a driver with a 1.06-m (3.5-ft) eye height to see a 0.15-m (0.5-ft) high object in time to stop, assuming a 2.5-sec perception-reaction time. For a tangent gradient difference of 7.0% and a 90-km/hr (56-mi/hr) design speed, a 490-m (1608-ft) vertical curve results. If the object height were revised upward to a 0.38-m (1.25-feet) taillight height, then needed vertical curve length would decrease to 365 m (1196 ft). Such a vertical curve would provide 106 m (346 ft) of PTSD, while 100 m (328 ft) would be needed to allow a 4.0-sec preview for perception-reaction and maneuver. At higher design speeds, the 0.38-m (1.25-feet) object height would permit 4.0 sec or more preview time, but crest curves designed for this object height on roadways with design speeds less than 82 km/hr (51 mi/hr) would not have an available PTSD that allows 4.0 sec of roadway surface preview.

Table 3 presents the SSD for given speeds along with the PVSD required for a 4.0-sec preview. The listed object heights (h_2) are those that, when used for vertical curve–SSD design, would also yield an adequate PTSD.

CONCLUSION

Although roadways designed to meet current stopping sight distance standards may also have more than adequate preview sight

TABLE 3 Vertical Curve Design Object Heights To Provide PVSD

	Design speed - km/hr			
	50	65	80	90
Needed SSD - m (ft)	63	97	140	169
PVSD for 4.0 sec. - m (ft)	56	72	89	100
Object height (h_2) - m (ft)	0.016	0.13	0.34	0.50

1 km/hr = 0.62 mph
1 m = 3.28 ft

distances, roadway sections on which the running speeds exceed the design speeds may have inadequate PVSD. Where inadequate PVSD exists, the flow of vehicle control and guidance cues to the driver may be deficient, causing the driver to either sacrifice vehicle control or to concentrate on control to the exclusion of other driving tasks (such as monitoring other traffic).

A summary of needed preview times measured by other researchers showed findings ranging from 2 to 9 sec, with variations in speed and experiment conditions explaining part but not all of the variations between the studies. Preview times measured by the author were slightly lower than those found in the literature. Given that the author's lower values represent only one subject, and that a "best case performance" was measured, the author's lower values are not surprising.

The equations that were presented can be used to evaluate the geometry of existing designs in suspect or problem roadway segments. When establishing design values for PVSD, the engineer must remember that the driver cannot perform all driving tasks simultaneously. Therefore a minimal PVSD, measured when the driver is only concentrating on control and guidance, may be inadequate for all but simple driving situations. Previous research and the author's experience suggest that PVSD values of from 2.5 to 4.0 sec or more sec may be needed. Additional research into human factors could better define the amount of time a driver needs to preview adequately the upcoming roadway alignment and still have time to perform other necessary driving tasks. Even though more effort is needed to define desirable PVSD for various situations, designers can still be cognizant of the concept. One application of the PVSD principle is the design of the roadway in advance of exit ramp gores located in crest vertical curves.

An analysis can identify sections of roadway that have insufficient PVSD. These sites may be candidates for upgrading traffic control devices or other remedial actions to provide the driver with an adequate flow of roadway cues for control and guidance. If inexpensive countermeasures such as upgrading traffic control devices prove to simplify the driving task or reduce accidents, then the roadway agency investment would be easily justified.

ACKNOWLEDGMENT

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