Recommended Mounting Heights for Freestanding On-Premise Signs

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BACKGROUND AND OBJECTIVES

Freestanding on-premise signs are commercial signs that are not attached to buildings or other structures and include ground-mounted, monument, pylon, and pole signs. This report focuses on issues related to the appropriate mounting height of freestanding signs.

On-premise sign mounting height is generally controlled by local governments using content-neutral time, place, and manner regulations. In the absence of solid data on appropriate mounting height from the perspectives of sign visibility and driver safety, this sign characteristic is being regulated from the standpoint of aesthetics (Jourdan, Hurd, Hawkins, & Winson-Geideman, 2013). For example, Agoura Hills, CA (n.d.) has set a maximum height of 6 feet to the top of monument signs in part to "preserve and enhance the unique character and visual appearance of the city" (p. 2), and in 2018, Dutchess County, NY recommended a maximum height of 4 to 7 feet to the top of some freestanding signs, stating that the signs could then be "better integrated with landscaping" and "less likely to obstruct views of neighboring properties or the sky" (p. 2). There are indeed countless examples of regulatory entities enacting restrictions on sign height, typically focused on a maximum sign height of 6 feet. This trend runs counter to research that has long shown that low sign mounting heights restrict motorists' ability to find and read signs [Manual on Uniform Traffic Control Devices (MUTCD), 1935; Pietrucha, Donnell, Lertworawanich, & Elefteriadou, 2002] and therefore have a negative impact on traffic safety (Kuhn, Garvey, & Pietrucha, 1997). The consensus of regulators seems to be that lower signs are better, with a *de facto* standard maximum height of 6 feet to the top of the sign in some zones and/or for certain sign users.

The objective of this report is to develop best practices for optimal freestanding on-premise sign mounting height based on roadway factors, sign visibility, and traffic safety, relying on existing research and practice and basic geometry, and describing variations for different road types and sign lateral offsets.

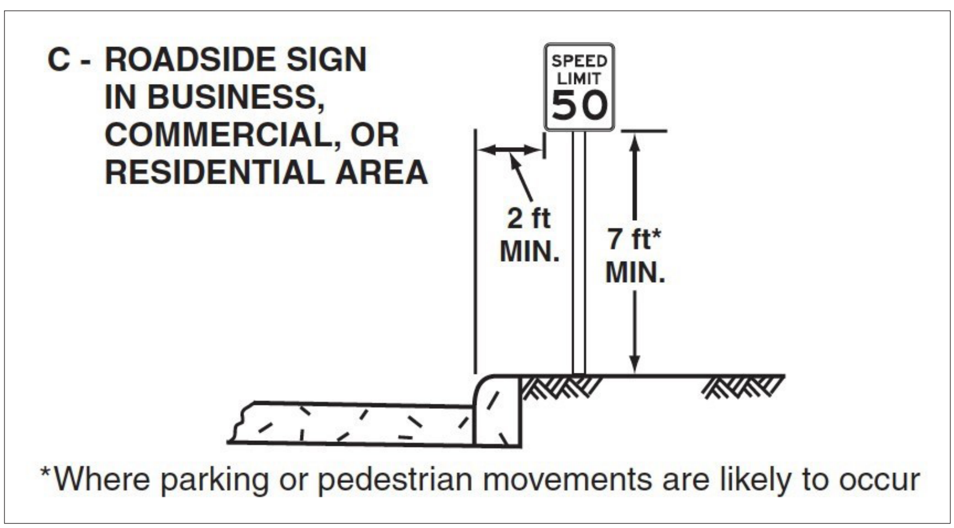
To achieve this, the existing on-premise and traffic sign mounting height research was reviewed, and the current state-of-the-practice was summarized. In addition, a technical analysis of on-premise sign height and sign visibility based on roadway cross-section and driver-to-sign sightlines was conducted.

SIGN MOUNTING HEIGHT DEFINED

Traffic Signs (e.g., Stop Signs, Street Name Signs, Construction Signs)
The federal MUTCD (2009) sets the minimum allowable sign height for traffic and regulatory signs in commercial areas at 7 feet "measured vertically from the bottom of the sign to the top of the curb" (p. 42), or if there is no curb, to the edge of the road (Figure 1). The purpose of this minimum height is to keep pedestrians from hitting their heads on the signs and to reduce the likelihood that views of the signs will be blocked by parked or moving traffic. A minimum height of 5 feet is required for rural signs. There are no set limits on maximum mounting height.

On-Premise Signs
Contrary to regulations for traffic signs, on-premise sign mounting height is controlled by local and county ordinances that limit the maximum height from the road surface to the top of the sign (Figure 2). The purpose of these restrictions is typically stated as follows: "to encourage the effective use of signs as a means of communication in the City; to maintain and enhance the aesthetic environment and the City's ability to attract sources of economic development and growth; to improve pedestrian and traffic safety; to minimize the possible adverse effect of signs on nearby public and private property; and to enable the fair and consistent enforcement of

Figure 1 / Traffic sign mounting height (MUTCD, 2009).



these sign regulations" (Ashland, NE, 2006, p. 7-1). It should be noted that there no city or county set limits on minimum mounting height for on-premise freestanding signs.

RESEARCH LITERATURE

Traffic Signs

There has been very little research on appropriate mounting heights for either on-premise or traffic signs. When asked if there was any research basis for the requirement of 5- and 7-feet minimum mounting heights for traffic signs discussed above, the Federal Highway Administration's (FHWA) MUTCD Team stated that their minimum mounting heights date back to the earliest edition of the MUTCD (1935), and have been in every subsequent edition. The 7-feet requirement is for areas where parking, other obstructions, and pedestrians and bicyclists are found. Typically in urban, business, commercial, or residential areas, the 7-feet height protects pedestrians and bicyclists from head injuries and provides adequate sign visibility given the higher presence of vehicles and equipment that can obstruct views of the signs. In rural areas, where these types of obstructions and concerns are less common, a shorter 5-feet minimum is allowed. The 5-feet minimum affords visibility around obstacles such as snow banks, snow drifts, and vegetation commonly found along rural roads. In summary, the FHWA stated that it is unaware of any specific research that supports the sign height requirements. However, they did say that these minimums have generally proven to be adequate and are readily accepted by the engineering community (FHWA, personal communication, September 4, 2018).

On-Premise Signs

A model sign code was developed by Urban Design Associates under contract to the International Sign Association (ISA) in an attempt to provide sign regulation based on research, rather than by committee (Jourdan, Hawkins, Abrams, & Winson-Geideman, n.d.; Jourdan et al., 2013). These authors developed a formula for maximum sign height that would allow the entire sign to be in the driver's useful visual field. A key element in their calculations was sign letter height. For example, signs with 5-inch letter heights would have a maximum mounting height of 16.6 feet (see Figure 3 for more examples).

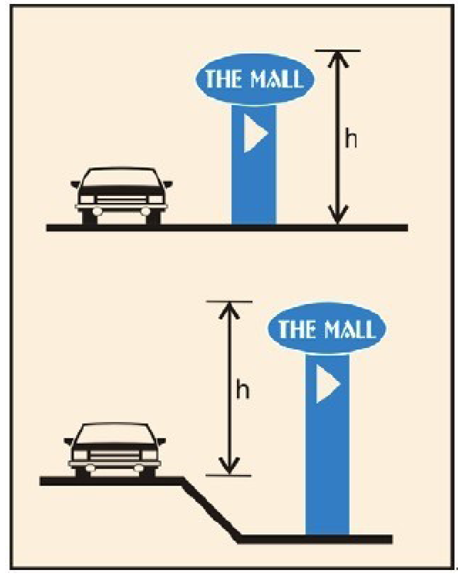


Figure 2 / On-premise sign mounting height (Bertucci & Crawford, 2011).

Letter Height, inches	5	10	15	20	25	30
Maximum Sign Height, ft	16.6	29.7	42.9	56.0	69.1	82.2

Figure 3 / Maximum sign height to top of sign (Jourdan et al., n.d.).

Specifying appropriate sign height as a function of drivers' lines of sight and visual fields, as Jourdan et al. (n.d.) did in Figure 3, has been discussed since the 1950s (see Garvey & Kuhn, 2011, for a review). The research-based United States Sign Council Foundation Model Sign Code took a different approach; the primary goal of these standards was to "insure that all on-premise signs have sufficient area and mounting height to provide a motorist with adequate time and travel distance to detect a sign, read and understand its contents, and then execute an appropriate driving maneuver" (Bertucci & Crawford, 2011, p. 39) These authors recommended maximum free standing sign heights of 8 feet in residential zones, 12 feet in office and professional zones, and anywhere from 14 to 86 feet (depending on zoning district and speed limit) in commercial and industrial areas.

Finally, the research that most directly pertains to the present paper was conducted by Pietrucha et al. (2002). These researchers determined the probability of another vehicle blocking the line of sight between a driver and a low-mounted on-premise freestanding sign. They looked at 10-feet wide signs with maximum mounting heights of 5 feet measured from the grade level to the top of the sign. Consistent with commercial areas where many on-premise signs are found, the researchers analyzed four-lane undivided roadways with 35- and 45-mile-per-hour speed limits. These researchers found that depending on the rate of traffic, the signs were blocked anywhere from 11 to 90 percent of the time. While they did not provide a recommendation for a minimum sign mounting height that would alleviate this problem, Pietrucha et al. (2002) concluded, "the most direct solution [to reduce sign blockage] is to elevate the sign to the point where copy presentation is above the blocking aspect caused by other vehicles on the road" (p. 26). The remainder of this report details an effort on the part of the present authors to do this.

TECHNICAL ANALYSIS: CALCULATING THE MINIMUM ON-PREMISE FREESTANDING SIGN MOUNTING HEIGHT NECESSARY TO AFFORD DRIVERS A CLEAR LINE OF SIGHT OVER OBSTRUCTING VEHICLES

Overview

To design any roadway feature, it is necessary to make assumptions and compromises. This is true for complex intersection design, roadway alignment, railroad crossings, and bridges; to design a minimum mounting height for freestanding on-premise signs that will ensure they are not blocked by other vehicles is no exception. As with the development of any roadway design, the goal here is not to accommodate every possible scenario, as that would be impossible, or at a minimum impractical, but rather to establish a mounting height at which most drivers will have an unobstructed view of most signs, most of the time.

Design Vehicles

To accomplish this, one must first decide what to use as the design vehicle. That is, what kind of vehicle is the driver who is looking for the sign driving (the observation vehicle) and what kind of vehicle is potentially blocking the sign (the blocking vehicle). The conservative (with regard to sign visibility) choice for the observation vehicle is a "passenger vehicle," which would include "passenger cars of all sizes, sport/utility vehicles, minivans, vans, and pick-up trucks" [American Association of State Highway and Transportation Officials (AASHTO), 2011, p. 2-1]. This is conservative because the eyes of a passenger vehicle driver are low to the ground compared to those of a heavy truck or bus driver—two other possible design observation vehicles. To design a minimum sign mounting height that would accommodate truck or bus drivers would result in signs that are too low for drivers of passenger vehicles to see (Layton & Dixon, 2012). With regard to the blocking vehicle, while trucks and buses have a higher profile and are therefore more likely to block on-premise signs, passenger vehicles make up the preponderance of vehicles on the roadway and have the greatest probability of coming between an observer and an on-premise sign.

Driver Eye Height and Blocking Vehicle Height

The next thing to do is determine what height to use for the driver of the observation vehicle's eyes and what height to use for the blocking vehicle. To that end, the AASHTO (2011) established a standard of 3.5 feet for driver eye height in passenger vehicles and 4.25 feet as the height of a standard passenger vehicle. While it is obvious that driver eye height and vehicle height can vary greatly across the driver and vehicle population (as there are tall and short drivers, drivers with good or slouchy posture, and larger and smaller vehicles), these heights were selected through research to accommodate the majority of U.S. passenger vehicles and drivers. These numbers are used by engineers in roadway and intersection design and have also been adopted by the FHWA for the size and placement of traffic signs for no-passing zones (MUTCD, 2009). However, due to trends in U.S. vehicle design and consumer preferences, it is possible that these numbers are outdated; this will be discussed further below.

Method

Mathematical. To determine whether an observer has a clear line of sight from their vehicle to an on-premise sign, it is necessary to know the height of the observers' eyes and the height of the blocking vehicle (these will be constants in our equation), the distance between the observer and the blocking vehicle (this will be a variable), and the distance between the observer and the target sign (this will also be a variable). These four data points allow one to calculate the slope of a line with the origin at the observer's eye, passing over the top of a blocking vehicle, and ending on the bottom of the sign copy (Figure 4). A clear line of sight to the bottom of the sign copy will allow the observer to read the entire sign.
The distance between the observers' eyes and the blocking vehicle and the distance between the observers' eyes and the sign are a function of the roadway cross section, the side of the road the sign is on, and the lateral offset of the sign from the roadway. Roadway cross section is the number of lanes, the lane width, and the presence or absence of parking lanes and their widths.

While the possible configurations are virtually limitless, for the purposes of explication in this report, the line of sight and the resulting minimum on-premise sign mounting heights from the road surface to the bottom of the sign was calculated for four common roadway configurations:

1. one-way, one lane;
2. one-way, two lane;
3. two-way, two lane; and
4. two-way, four lane.

For this exercise, all travel lanes were assumed to be 10-feet wide (NACTO, 2013a). The one-way roads had two 8-feet wide parking lanes (NACTO, 2013a), one along each side of the roadway; the two-way roads had no parking lanes, but they did have 2-feet wide shoulders along both sides

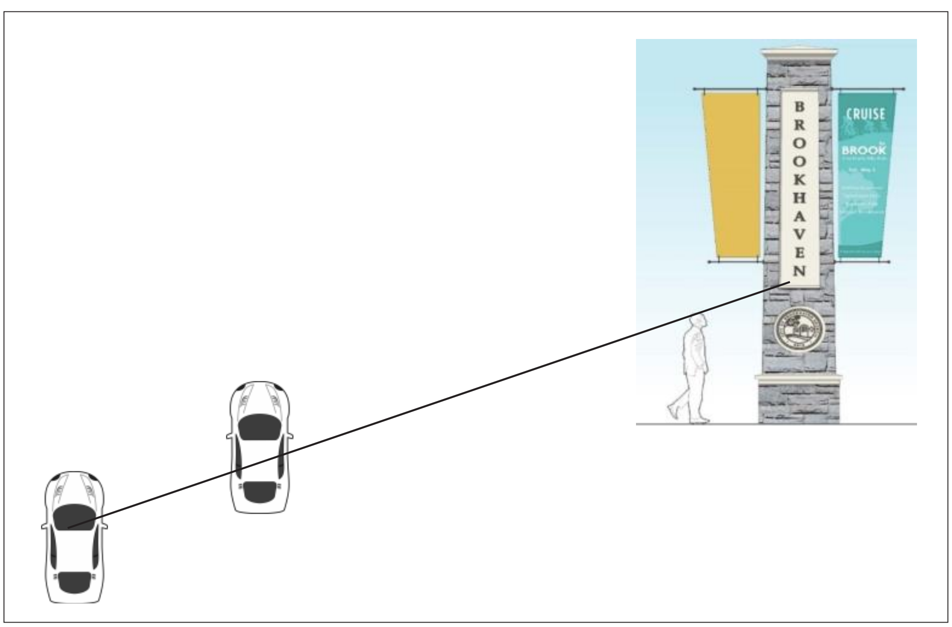


Figure 4 / Line of sight from observer driver's eyes over blocking vehicle to the bottom of the sign copy.

of the roadways. The passenger vehicles were set at a width of 6.5 feet (NACTO, 2013b). They were assumed to be driven in the center of the travel lanes, the drivers' eyes were assumed to be in the middle of the left half of the vehicle, and the cars parked in the parking lane were assumed to be located one foot from the travel lane. See Figure 5 for illustrated representations.

Appendix A contains a detailed explanation of a geometric equation that can be used to determine the minimum recommended sign mounting height for any on-premise freestanding sign. The example employs AASHTO's recommendations for design driver eye height and vehicle height. The math uses the slope of the line of sight from an observer's eyes just over the top of a blocking vehicle.

With this technique, minimum sign mounting heights were established for each of the four scenarios listed above, for all travel lanes, with signs on both the left and right sides of the roadway, at sign offsets from the

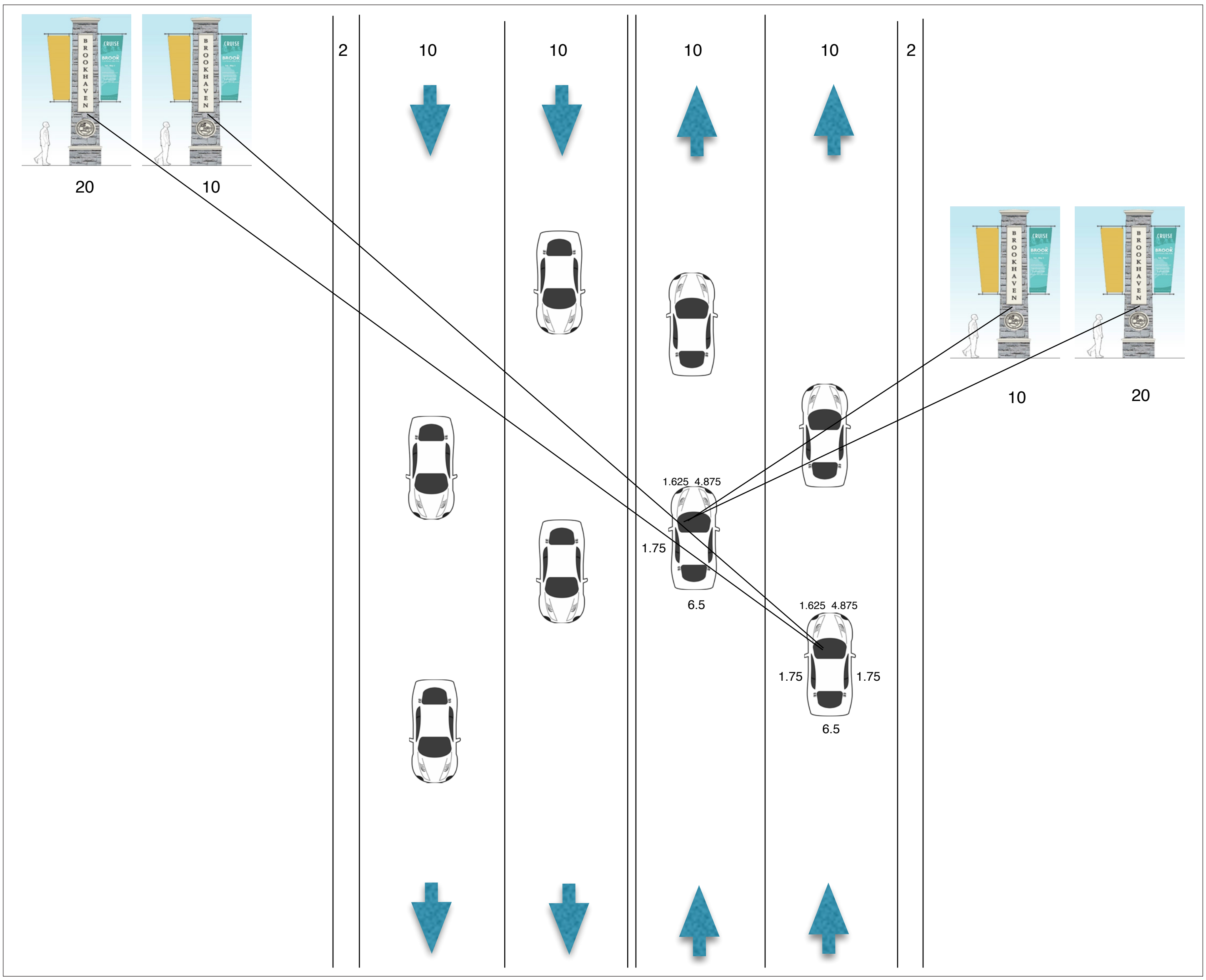


Figure 5 / Illustrated example of roadway conditions.

roadway edge of 10 and 20 feet, the same offsets used by Pietrucha et al., 2002. The results are shown in Appendix B.

Field Validation. While mathematical calculations are extremely useful in establishing minimum sign mounting height, and can be applied to any roadway cross section and sign lateral offset, it is important to field-validate the results to ensure their accuracy. Using AASHTO's vehicle and driver eye heights, the National Association of City Transportation Officials (NACTO, 2013c) published a simple procedure to "determine whether an object is a sight obstruction" (p. 4.3. While NACTO was interested in evaluating intersection sight distance, with slight modifications their methods were used here to field-validate the mounting heights established mathematically for on-premise signs. This would, as Pietrucha et al. (2002) said, ensure that the signs are elevated "to the point where copy presentation is above the blocking aspect caused by other vehicles on the road" (p. 26)

NACTO's procedure involved constructing a black sighting device (3.5-feet high) to mimic the point of view of a driver and an orange sighting device (4.25-feet high) to mimic a blocking vehicle (Figure 6).

Figure 6 / Data collection apparatus and setup.

When placed in alignment with a proposed on-premise sign at the desired distance, the experimenter can determine at what height the sign needs to be for the entire message to "clear" the obstructing vehicle. This is done by visually lining up the horizontal black bar (driver eye height) with the horizontal orange bar (blocking vehicle), having another experimenter standing on a ladder at the distance of the proposed sign, and extending a measuring tape up into the air until it just clears the lined-up horizontal bars.

The results are displayed in blue highlight at the bottom of the table in Appendix B. The findings show equivalence between the mathematical model and the field measurements. Most of the field measurements were within one inch of the mathematical model, with the smallest difference being 0.01 feet and the largest being 0.21 feet. Using the mathematical model, the average minimum mounting height for signs with an offset of 10 feet was 7.48 feet (sd = 1.43), and the average for the field validation was 7.52 feet (sd = 1.34). Using the mathematical model, the average minimum mounting height for signs with an offset of 20 feet was 8.78 feet (sd = 1.64), and the average for the field validation was 8.75 feet (*sd* = 1.52). Independent samples t-tests were conducted to compare the results of the mathematical model and the field measurements. These analyses revealed no statistically significant differences between the computed and the measured data ($t = -0.06$, $p = 0.48$ and $t = 0.03$, $p = 0.49$, respectively for the 10- and 20-feet offsets), thus field-validating the results of the geometric calculations.

Driver Eye Height and Blocking Vehicle Height Revisited

AASHTO's driver eye height of 3.5 feet and blocking vehicle height of 4.25 feet discussed above and used in the calculations for the current research are well established, accepted, and respected in the transportation field. Upon close inspection, however, it becomes clear that these numbers cannot be taken at face value for the purposes of establishing on-premise freestanding sign mounting heights. There are two reasons for this.

First, Fambro, Fitzpatrick, & Koppa, 1997 (the research used by AASHTO to determine design height) found that more than 97 percent of passenger vehicles on U.S. roadways in 1993 had higher driver eye height than the 3.5 feet recommended by AASHTO, and 90 percent of passenger vehicles were taller than AASHTO's design height of 4.25 feet. Using these low numbers makes sense for AASHTO, as it enabled the organization to conservatively design intersection sight distances and stopping sight distances, but to achieve the objective of the present study (i.e., to establish a minimum mounting height at which most drivers will have an unobstructed view of most signs, most of the time), it makes more sense to use a driver eye height and passenger vehicle height that is more representative of actual driving conditions. To do this, the 15th percentile driver eye height and 85th percentile vehicle height were chosen. This accounts for driver eye height in smaller cars and smaller multipurpose vehicles when they encounter the blocking height of larger cars and larger multipurpose vehicles. These percentiles accommodate 70 percent of driving scenarios, with only the smallest observation vehicles and largest blocking vehicles not being accounted for.

Second, the research AASHTO used to derive their numbers drew data from the population of passenger vehicles that were on United States roads in 1993. This would not be a problem if vehicle type and dimensions had remained stable over the past quarter century. However, this has not been the case. There is clear evidence that personal vehicle size has been steadily rising, a result of the well-documented increase in popularity of SUVs and pickup-trucks, and systemic changes to both car and SUV dimensions. Unfortunately, there is no report like Fambro's that has established current dimensions for personal vehicle height or measurements of driver eye height.

The National Cooperative Highway Research Program has proposed new research on this issue for 2020, and that proposal is under review. If changes are recommended from that research, AASHTO would "most likely" include them in a future edition of the Green Book (AASHTO, personal communication, November 5 and 7, 2018). However, as establishing an appropriate on-premise sign minimum mounting height is a critical, time-sensitive issue, waiting until the mid-2020s for a possible update of AASHTO's numbers is unfavorable. In the absence of more current research , the findings from Fambro et al. (1997) were mathematically "updated" for use in this report, via a two-step process.

First, as Fambro et al. (1997) reported data separately for cars and multipurpose vehicles, it was necessary to combine those numbers into a single eye height and vehicle height for all 1993 passenger vehicles. To do this, the data were weighted by vehicle type. In 1993, cars accounted for 66.3 percent of personal vehicles, and the combination of SUVs, vans, and pick-up trucks (aka, multipurpose vehicles) only accounted for 33.7 percent (Fambro et al., 1997). The 15th percentile car and multipurpose vehicle eye heights and the 85th percentile car and multipurpose vehicle heights were combined as shown below:

U.S. PASSENGER VEHICLE DISTRIBUTION: 1993

Passenger Cars = 66.3 percent
Multipurpose Vehicles = 33.7 percent

15th percentile passenger car driver eye height = 3.59 ft x 0.663 = 2.38
15th percentile multipurpose vehicle driver eye height = 4.37 ft x 0.337 = 1.47
<u>15th percentile driver eye height = 3.85 ft</u>

85th percentile passenger car height = 4.67 ft x 0.663 = 3.10
85th percentile multipurpose vehicle height = 6.3 ft x 0.337 = 2.12
<u>85th percentile blocking vehicle height = 5.22 ft</u>

The second step was to take those 1993 numbers and update them using the current distribution of vehicle types on the U.S. roadways. FHWA's National Household Travel Survey revealed that in 2017, 52.05 percent of U.S.-registered personal vehicles were cars, and 47.95 percent were multipurpose vehicles. The above 1993 numbers were weighted by vehicle type to establish a single 15th and 85th percentile for all 2017 passenger vehicles combined using the following calculations, with the following results:

U.S. PASSENGER VEHICLE DISTRIBUTION: 2017

Passenger Cars = 52.05 percent
Multipurpose Vehicles = 47.95 percent

15th percentile passenger car driver eye height = 3.59 ft x 0.5205 = 1.87
15th percentile multipurpose vehicle driver eye height = 4.37 ft x 0.4795 = 2.09
15th percentile driver eye height = 3.96 ft

85th percentile passenger car height = 4.67 ft x 0.5205 = 2.43
85th percentile multipurpose vehicle height = 6.3 ft x 0.4795 = 3.02
85th percentile blocking vehicle height = 5.45 ft

These results were then rounded to the following estimate of the 2017 U.S. vehicle population to be used in establishing minimum on-premise freestanding sign mounting heights:

Driver Eye Height = 4.0 ft
Blocking Vehicle Height = 5.5 ft

These numbers were inserted into the formula discussed earlier and listed in Appendix A, replacing the 3.5 feet and 4.25 feet heights. The updated 2017 calculation is shown in Appendix C. The results are included in red at the bottom of the table in Appendix B.

RESULTS AND CONCLUSIONS

The ultimate objective of this research project was to establish evidence-based optimal freestanding on-premise sign mounting heights from a sign visibility and traffic safety perspective. The evidence used was a review of the literature and current practices and new design research conducted specifically for this report.

When past research on traffic and on-premise sign mounting heights was evaluated, one key finding was that there was a philosophical difference in the very definition of sign mounting height. Traffic signs have a mandatory *minimum mounting height* from the road to the *bottom* of the sign, while on-premise signs typically have a mandatory *maximum mounting height* from the road to the *top* of the sign. Traffic sign mounting height definition is based on sign readability and safety, while on-premise sign mounting height is defined in such a way as to make the signs more aesthetically pleasing (i.e., to be less "obtrusive"). While no one would try to argue for less attractive on-premise signs, their primary purpose is to be seen and read in a timely fashion by the motoring public. For this to occur, the signs must be mounted high enough to avoid being blocked by other vehicles on the roadway.

The design research conducted especially for this report yields specific sign height minimums as a function of roadway cross section, the side of the road on which the sign is mounted, and the sign's lateral offset. It is recommended that the sign height calculator (developed using the results of this research and the calculations detailed in Appendix C) be used to determine the *minimum mounting height* of on-premise freestanding signs. The calculator (available online at https://www.garveyandassociates.com/calculator) will provide the user with the minimum sign mounting height when they answer the following nine questions:

1. What side of the road is the sign is on?
2. Is the road one-way or two-way?
3. How many lanes of traffic are there?
4. How wide are the lanes?
5. What is the width of the median or turning lane? (Enter "0" if there is no median or turning lane.)
6. What is the width of the shoulder? (Enter "0" if there is no shoulder.)
7. What is the width of the bike lane? (Enter "0" if there is no bike lane.)
8. What is the width of the parking lane? (Enter "0" if there is no parking lane.)
9. What is the sign offset from the traveled way?

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APPENDIX A

This Appendix provides a detailed example of the mathematical procedure used to determine the minimum freestanding on-premise sign mounting height necessary to avoid blockage by other vehicles.

For this exercise, AASHTO's (2011) 3.5-feet driver eye height and 4.25-feet personal vehicle height were used, and the travel lane was 10-feet wide, with two 8-feet wide parking lanes, one along each side of the roadway. All vehicles were set at a width of 6.5 feet. They were driven in the center of the travel lanes, the drivers' eyes were in the middle of the left half of the vehicles, and the cars parked in the parking lanes were located one foot from the travel lane. The sign had a 10-feet offset from the traveled way and was located on the right side of the road (see Figure 1, page 4, for an illustration).

STEP ONE

Solve for m, where m is the slope of a line from the driver's eye to just over a blocking vehicle.

$m = y_2 - y_1/x_22 - x_1$

And where: $x_1 = 0$ and $y_1 = 3.5$
[x_1 is the observer location and is a constant, y_1 is the observer eye height and is a constant.]

And where: $x_2 = d$ and $y_2 = 4.25$
[x_2 is the lateral distance between the driver of the observation vehicle and the nearest blocking vehicle and is a variable; y_2 is the height of the blocking vehicle and is a constant.]

Plug in a value for x_2 and solve for m (in this example, $x_2 = 7.625$):

$m = 4.25 - 3.5/7.625 - 0$

$m = 0.75/7.625$

$m = 0.09836$

STEP TWO

Solve the line equation for a missing coordinate (i.e., y_2, which is the minimum sign mounting height) again using the equation:

$m = y_2 - y_1/x_2 - x_1$

To do this, first insert the numbers for m, y_1, and x_{1x} from above:
$0.09836 = (y_2 - 3.5)/(x_2 - 0)$

x_2 is the lateral distance between the driver of the observation vehicle and the proposed sign location. In this example $x_2 = 24.625$.

Insert the value for x_2 into the equation and solve for y_2:

$0.09836 = (y_2 - 3.5)/(24.625 - 0)$

$0.09836 = (y_2 - 3.5)/24.625$

$2.422115 = y_2 - 3.5$

$y_2 = 5.922$ — This is the minimum required mounting height for this example.

APPENDIX B

Method of Determining Minimum Mounting Height		10-ft wide travel lanes									
		Parking Lanes (8-ft wide)									
		One lane, one way				Two lanes, one way					
		Sign on Right		Sign on Left		Sign on Right			Sign on Left		
						Driver in Right Lane	Driver in Left Lane		Driver in Right Lane		Driver in Left Lane
	Sign Lateral Offset (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Same as one lane	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Same as one lane
	10	7.625	24.625	4.375	21.375		8.375	34.625	5.125	31.375	
	20		34.625		31.375			44.625		41.375	
		Slope	Minimum Mounting Height	Slope	Minimum Mounting Height		Slope	Minimum Mounting Height	Slope	Minimum Mounting Height	
Using AASHTO's Numbers	10	0.0984	5.92	0.1714	7.16		0.0896	6.60	0.1463	8.09	
	20		6.91		8.88			7.50		9.55	
Field Validation	10		6.00		7.17			6.75		8.08	
	20		7.00		8.75			7.58		9.42	
Using Updated Fambro Data	**10**	**0.1967**	**8.84**	**0.3429**	**11.33**		**0.1791**	**10.20**	**0.2927**	**13.18**	
	20		**10.81**		**14.76**			**11.99**		**16.11**	

Method of Determining Minimum Mounting Height		10-ft wide travel lanes								
		No Parking Lanes (2-ft shoulder)								
		Two lanes, two way (undivided)		Four lanes, two way (undivided)						
		Sign on Left		Sign on Right		Sign on Left				
				Driver in Left Lane		Driver in Right Lane		Driver in Left Lane		
	Sign Lateral Offset (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	Distance from driver eye to blocking car (ft)	Distance from driver eye to sign (ft)	
	10	5.125	25.375	8.375	28.625	5.125	45.375	5.125	35.375	
	20		35.375		38.625		55.375		45.375	
		Slope	Minimum Mounting Height	Slope	Minimum Mounting Height	Slope	Minimum Mounting Height	Slope	Minimum Mounting Height	Mean Minimum Mounting Height
Using AASHTO's Numbers	10	0.1463	7.21	0.0896	6.06	0.1463	10.14	0.1463	8.68	7.48
	20		8.68		6.96		11.60		10.14	8.78
Field Validation	10		7.25		6.25		10.00		8.67	7.52
	20		8.67		7.17		11.42		10.00	8.75
Using Updated Fambro Data	**10**	**0.2927**	**11.43**	**0.1791**	**9.13**	**0.2927**	**17.28**	**0.2927**	**14.35**	
	20		**14.35**		**10.92**		**20.21**		**17.28**	

This Appendix provides a detailed example of the mathematical procedure used to determine the minimum freestanding on-premise sign mounting height necessary to avoid blockage by other vehicles.

For this exercise, the 4.0-feet driver eye height and 5.5-feet personal vehicle height developed in this paper from Fambro, et al.'s (1997) data were used, the travel lane was 10-feet wide, with two 8-feet wide parking lanes, one along each side of the roadway. All vehicles were set at a width of 6.5 feet, they were driven in the center of the travel lanes, the drivers' eyes were in the middle of the left half of the vehicles, and the cars parked in the parking lanes were located one foot from the travel lane. The sign had a 10-feet offset from the traveled way and was located on the right side of the road (see Figure 5, page 8, for an illustration).

STEP ONE

Solve for m, where m is the slope of a line from the driver's eye to just over a blocking vehicle.

$m = y_2 - y_1/x_2 - x_1$

And where: $x_1 = 0$ and $y_1 = 4.0$
[x_1 is the observer location and is a constant, y_1 is the observer eye height and is a constant.]

And where: $x_2 = d$ and $y_2 = 5.5$
[x_2 is the lateral distance between the driver of the observation vehicle and the nearest blocking vehicle and is a variable; y_2 is the height of the blocking vehicle and is a constant.]

Plug in a value for x_2 and solve for m (in this example, $x_2 = 7.625$):

$m = 5.5 - 4.0/7.625 - 0$

$m = 1.5/7.625$

$m = 0.1967$

STEP TWO

Solve the line equation for a missing coordinate (i.e., y_2, which is the minimum sign mounting height) again using the equation:

$m = y_2 - y_1/x_2 - x_1$

To do this, first insert the numbers for m, y_1, and x_1 from above:
$0.1967 = (y_2 - 4.0)/(x_2 - 0)$

x_2 is the lateral distance between the driver of the observation vehicle and the proposed sign location. In this example $x_2 = 24.625$.

Insert the value for x_2 into the equation and solve for y_2:

$0.1967 = (y_2 - 4.0)/(24.625 - 0)$

$0.1967 = (y_2 - 4.0)/24.625$

$4.844 = y_2 - 4.0$

y_2 = 8.844 ft — This is the minimum required mounting height for this example.