USSC **FOUNDATION**

RECOMMENDED MOUNTING HEIGHTS FOR FREESTANDING ON-PREMISE SIGNS

USSCF ON-PREMISE SIGNS / RESEARCH & STANDARDS

Recommended Mounting Heights for Freestanding On-Premise Signs

A Research Project Of The
USSC FOUNDATION

By
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Garvey & Associates
State College, Pennsylvania

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PREFACE

Virtually all sign codes in the United States have regulations establishing the height of freestanding on-premise sign structures. Sign height is an example of content-neutral time, place and manner regulation of speech (on signs) that is permitted under First Amendment case law, and that the US Supreme Court recently discussed in the 2015 *Reed v Gilbert* case.

There has been a concern for decades that some local sign height regulations do not comply with the needs of the motorist and traffic safety.

In 2003, the USSC Foundation released its first scientific study on sign height, titled *Sign Visibility, Effects of Traffic Characteristics and Mounting Height*, Pennsylvania Transportation Institute, Pennsylvania State University (2003). The 2003 sign height study examined the relationship between low-mounted freestanding signs, vehicular traffic, and sign visibility. The Penn State study found that the view of messages displayed on low-mounted freestanding signs was often blocked by other vehicular traffic, a high percentage of the time. This lack of sign visibility, caused by the blocking, directly impacted motorists and their ability to see and read signs.

A result of the findings from the 2003 USSC study was a realization that restricting sign height to a low level was not appropriate for many roadways. The uses along a particular roadway, or the zoning district where the signs were located, was not relevant to the visibility of the freestanding signs. The sign visibility had everything to do with the type of roadway involved, the number of traffic and parking lanes, the speed of traffic, and traffic density. The simple solution to the problem presented by low sign mounting was to raise the height of the signs; a reasonable approach based on common-sense.

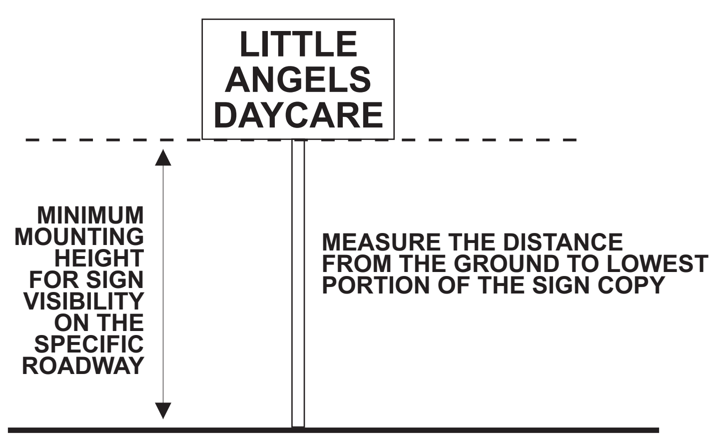
Since 2003, the USSCF sign height research has had an impact on sign design and sign regulations, in addition to being used to create national guideline standards for on-premise signs. But at the same time, many codes have stubbornly maintained restrictions on freestanding sign height that do not take into account the research. And the unfortunate trend to has been reduce freestanding sign height in some local zoning districts to levels roughly at six feet (6'-0”) to the top of the sign (the so-called “maximum sign height”).

NEW USSCF STUDY

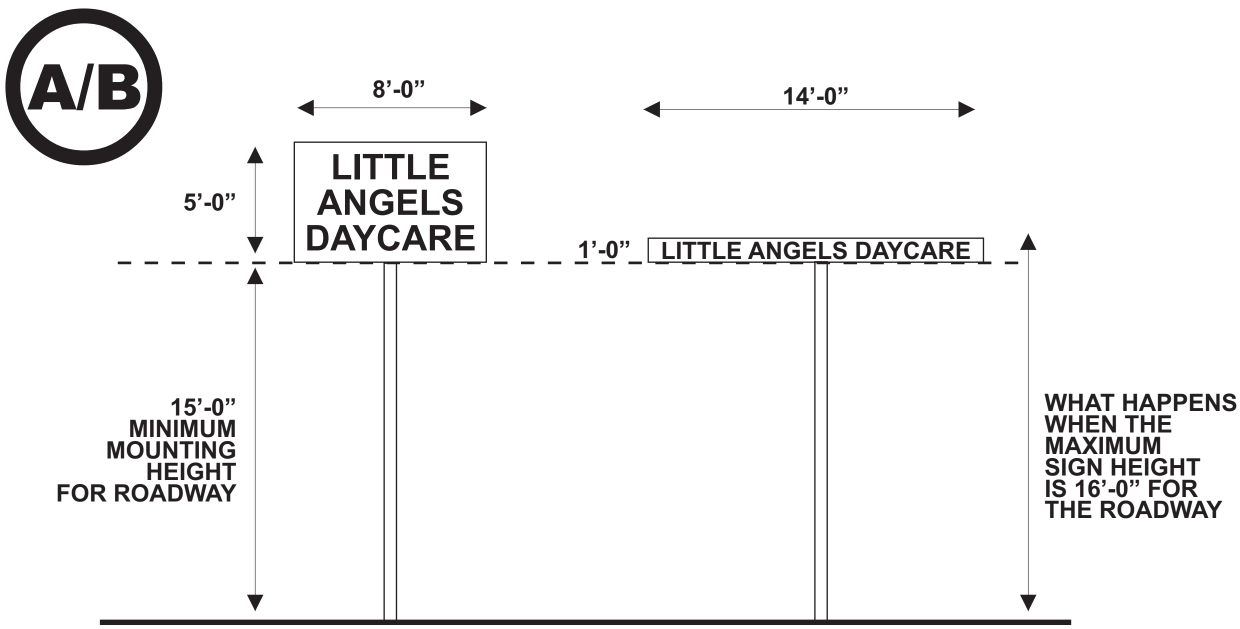
This new Garvey and Associates research suggests a change in focus when dealing with freestanding sign height. Instead of focusing on maximum sign height for any given zoning district or area, sign regulations should instead accommodate the ***minimum height necessary*** for messages on freestanding signs to be visible and legible for motorists, in any given zoning district or area. This is a paradigm shift in how regulators, municipalities, and the sign industry conceptualizes regulations pertaining to freestanding sign height.

Going forward, the focus will be: the distance from grade/ground level to the lowest portion of the sign message, i.e. the actual “sign”, or to the bottom of the sign (not including trim, masonry, structure or decorations). And the focus will not be to establish an arbitrary maximum height for a given zone, that may or may not accommodate adequate sign visibility and legibility, but to try to accommodate the appropriate minimum sign mounting height for any given roadway.

TAKEAWAY #1



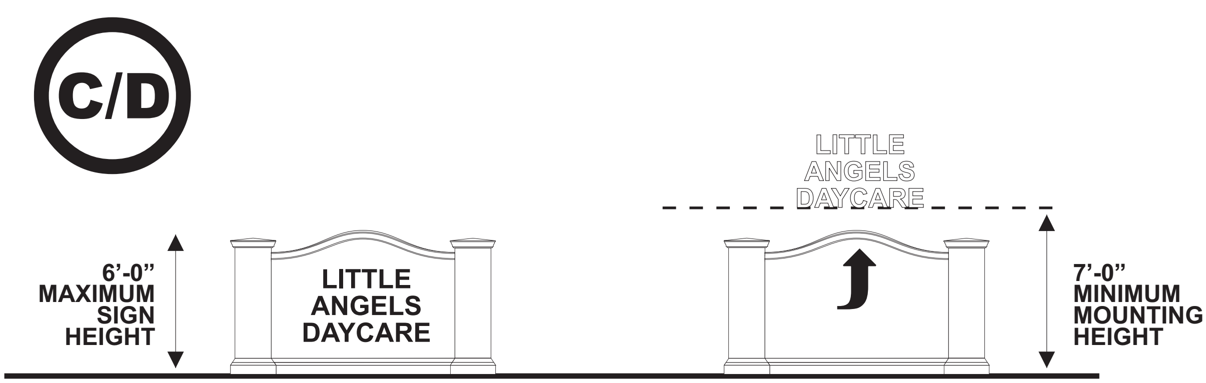
TAKEAWAY #2: EXAMPLES



A. PERMITTED SIGN AREA: 40 SF
MINIMUM MOUNTING HEIGHT: 15'-0"
PERMITTED SIGH HEIGHT:
THE MMH + SIGN ITSELF

B. PERMITTED SIGN AREA: 40 SF
MINIMUM MOUNTING HEIGHT: 15'-0"
PERMITTED SIGH HEIGHT:
16'-0" MAXIMUM HEIGHT

MAXIMUM SIGN HEIGHT
NEEDS TO BE ADJUSTED



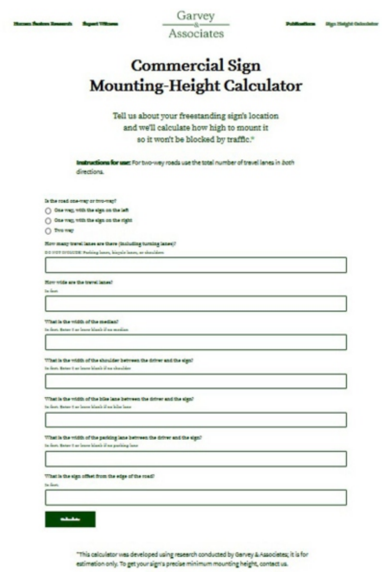
C. PERMITTED SIGN HEIGHT: 6'-0"
MONUMENT HEIGHT: 6'-0"

B. PERMITTED SIGN HEIGHT: 6'-0"
MINIMUM MOUNTING HEIGHT: 7'-0"
WHAT HAPPENS WHEN THE MAXIMUM
SIGN HEIGHT CONFLICTS WITH THE\
MINIMUM MOUNTING HEIGHT

MONUMENT NEEDS TO BE RAISED

SIGN HEIGHT CALCULATOR

VISIT www.garveyandassociates.com



ON LANDING PAGE
CLICK ON
"SIGN HEIGHT CALCULATOR"
IN THE UPPER RIGHT

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Recommended Mounting Heights for Freestanding On-Premise Signs

by Philip M. Garvey and M. Jennifer Klena, Garvey & Associates

Background and Objectives

Freestanding on-premise signs are commercial (and non-commercial) signs that are not attached to a building or other structure 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 a sign visibility and driver safety perspective, this sign characteristic is being regulated from the standpoint of aesthetics (Jourdan, et al., 2013). For example, Agoura- Hills, CA has set a maximum height of six-feet to the top of monument signs in part to "preserve and enhance the unique character and visual appearance of the city," and in 2018, Duchess County, NY recommended a maximum height of four to seven 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." There are indeed countless examples of regulatory entities enacting restrictions on sign height, typically focused on a maximum sign height of six feet. This trend runs counter to research which has long shown that low sign mounting heights restrict motorists' ability to find and read signs (e.g., MUTCD, 1935 and Peitrucha, et al., 2002) and therefore have a negative impact on traffic safety (e.g., Kuhn, et al., 1997). The consensus of regulators seems to be that lower signs are better, with a de facto standard maximum height of six feet to the top of the sign in some zones and/or for certain sign users.

The objective of this report was 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, 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 sight-lines was conducted.

Sign Mounting Height Defined

Traffic Signs (e.g., Stop Signs, Street Name Signs, Construction Signs)

The federal Manual on Uniform Traffic Control Devices (MUTCD) sets the minimum allowable sign height for traffic and regulatory signs in commercial areas at seven feet “measured vertically from the bottom of the sign to the curb” 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 five-foot minimum is required for rural signs. There are no set limits on maximum mounting height.

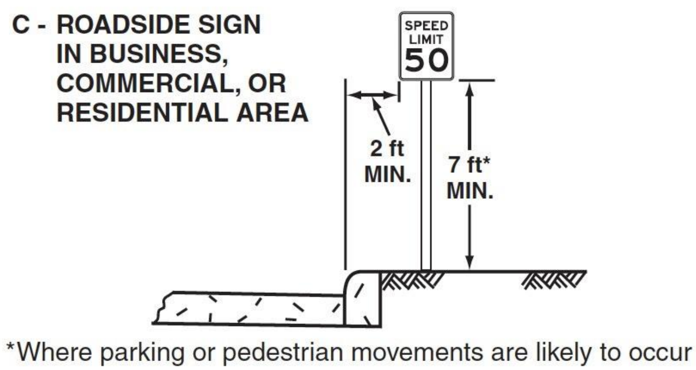

Figure 1. Traffic sign mounting height (MUTCD, 2009).

On-Premise Signs

Contrary to regulations for traffic signs, on-premise sign mounting height is controlled by local and county ordinances which 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 these sign regulations." (From Ashland NE Zoning Ordinance). It should be noted that there are no set limits on minimum mounting height for on-premise freestanding signs.

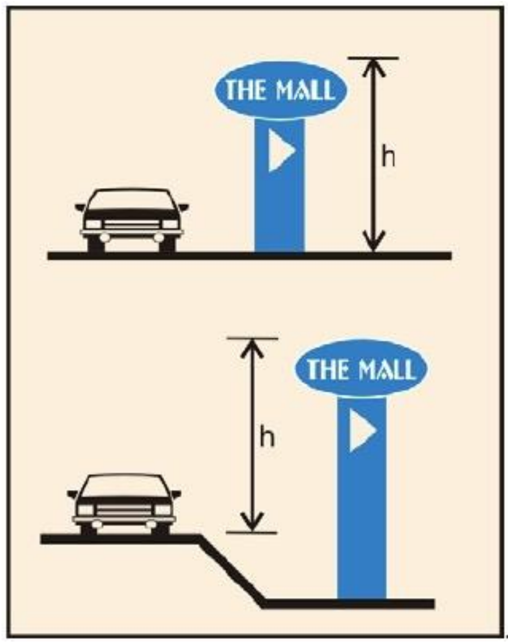

Figure 2. On-premise sign mounting height (Bertucci and Crawford, 2011).

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 five and seven feet minimum mounting heights for traffic signs discussed above, FHWA's 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 seven foot requirement is for areas where parking, other obstructions and pedestrians and bicyclist are found. Typically in urban, business, commercial, or residential areas, the seven feet height protects pedestrians and bicyclist 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 five-foot minimum is allowed. The five-foot minimum affords visibility around obstacles like 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, et al., N.D. and 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 five-inch letter heights would have a maximum mounting height of 16.5 feet (see Figure 3 for more examples).

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' line of sight and visual field as Jourdan did above, has been discussed since the 1950's (see Garvey and Kuhn, 2011 for a review). The USSC Foundation Model Sign Code (Bertucci and Crawford, 2011), also research based, 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." These authors recommended maximum free standing sign heights of eight 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 which most directly pertains to the present paper was that conducted by Pietrucha and his colleagues (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 ten foot wide signs with a maximum mounting height of five 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 and his colleagues 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."***

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 Free-standing 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 vehicles. 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” (AASHTO, 2011). 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 and Dixon, 2012). With regard to the blocking vehicle, although trucks and buses have a higher profile and are therefore more likely to block on-premise signs, because passenger vehicles make up the preponderance of vehicles on the roadway, they 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 American Association of State Highway and Transportation Officials (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 U.S. passenger vehicles and drivers. These numbers are used by engineers in roadway and intersection design and have also been adopted by the Federal Highway Administration 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 (these 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.

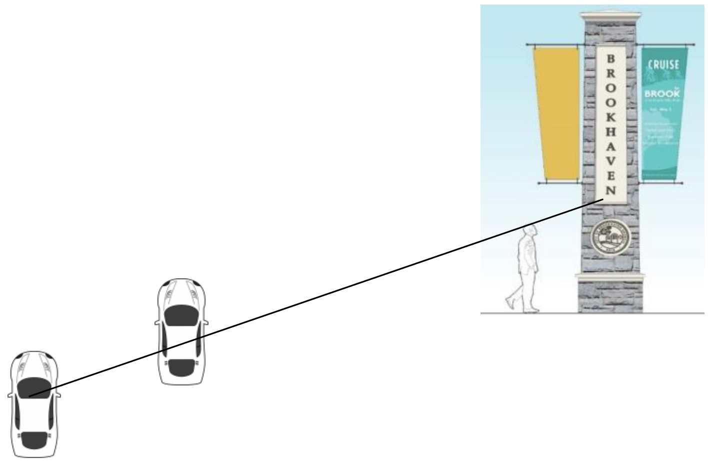

Figure 4. Line of sight from driver's eyes over blocking vehicle to the bottom of the sign copy.

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 width.

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 ten feet wide (NACTO, 2013a), the one-way roads had two eight foot wide parking lanes (NACTO, 2013a), one along each side of the roadway, the two-way roads had no parking lanes, but did have two foot wide shoulders along both sides 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 Appendix A for illustrated representations.)

Appendix B 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 the signs on both the left and right side of the roadway, at sign offsets from the roadway edge of 10 and 20 feet (the same offsets used by Peitrucha, et al., 2002). The results are shown in Appendix C.

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, 2013) published a simple procedure to "determine whether an object is a sight obstruction." 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 and his colleagues 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."

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 4).

Figure 5. 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) and 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 C. 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 a 10 ft offset was 7.48 ft (sd=1.43) and the average for the field validation was 7.52 ft (sd=1.34). Using the mathematical model, the average minimum mounting height for signs with a 20 ft offset was 8.78 ft (sd=1.64) and the average for the field validation was 8.75 ft (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 ft 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 ft and blocking vehicle height of 4.25 ft 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 can not be taken at face value for the purposes of establishing on-premise freestanding sign mounting heights. There are two reasons for this.

First, Fambro, et al., 1997 (the research used by AASHTO to get their numbers) found that more than 97 percent of passenger vehicles on U.S. roadways in 1993 had higher driver eye height than the 3.5 ft recommended by AASHTO and 90 percent of passenger vehicles were taller than AASHTO's 4.25 ft. Using these low numbers makes sense for AASHTO, as they were designing intersection sight distances and stopping sight distances and these heights enabled them to do so conservatively, 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 will 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 its data from the population of passenger vehicles that were on United States roads in 1993. This in itself would not be a problem, if vehicle type and dimensions had remained stable over the past quarter century. This, however has not been the case. There is clear evidence that personal vehicle size has been steadily rising. This is the 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.

New NCHRP research on this issue has been proposed 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 appropriate on-premise sign minimum mounting height is a critical, time-sensitive issue, waiting until the mid-2020's for a possible update of AASHTO's numbers is not an option. So in the absence of more recent research available now, the findings from Fambro and his colleagues' 1997 work were mathematically "updated" for use in this report.

This required a two-step process. First, as Fambro and his colleagues reported their 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 combined. To do this, Fambro's 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 = 1.473

<u>15th percentile driver eye height = 3.85 ft</u>

85th percentile passenger car height = 4.67 ft x 0.663 = 3.1

85th percentile multipurpose vehicle height = 6.3 ft x 0.337 = 2.123

<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 US roadways. FHWA's National Household Travel Survey revealed that in 2017, 52 percent of US registered personal vehicles were cars and 48 percent were multi-purpose 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 = 1.869

15th percentile multipurpose vehicle driver eye height = 4.37 ft x 0.4795 = 2.0954

<u>15th percentile driver eye height = 3.96 ft</u>

85th percentile passenger car height = 4.67 ft x 0.5205 = 2.43

85th percentile multipurpose vehicle height = 6.3 ft x 0.4795 = 3.021

<u>85th percentile blocking vehicle height = 5.45 ft</u>

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 found in Appendix B, replacing the 3.5 ft and 4.25 ft heights, the updated 2017 calculation is shown in Appendix D. The results are included in red at the bottom of the table in Appendix C.

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 of the key findings 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 esthetically 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 for this report yields specific sign height minimums as measured from the ground to the bottom of the sign 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 D be used to determine the *minimum mounting height* of on-premise freestanding signs. The calculator can be found at **www.garveyandassociates.com** and will provide the height when users answer the following eight questions:

1. Is the road one-way or two-way?
2. How many travel lanes are there (including turn lanes)?
3. How wide are the travel lanes?
4. What is the median width (if there is one)?
5. What is the shoulder width (if there is one)?
6. What is the bike lane width (if there is one)?
7. What is the parking lane width (if there is one)?
8. What is the sign offset from the travelled way?

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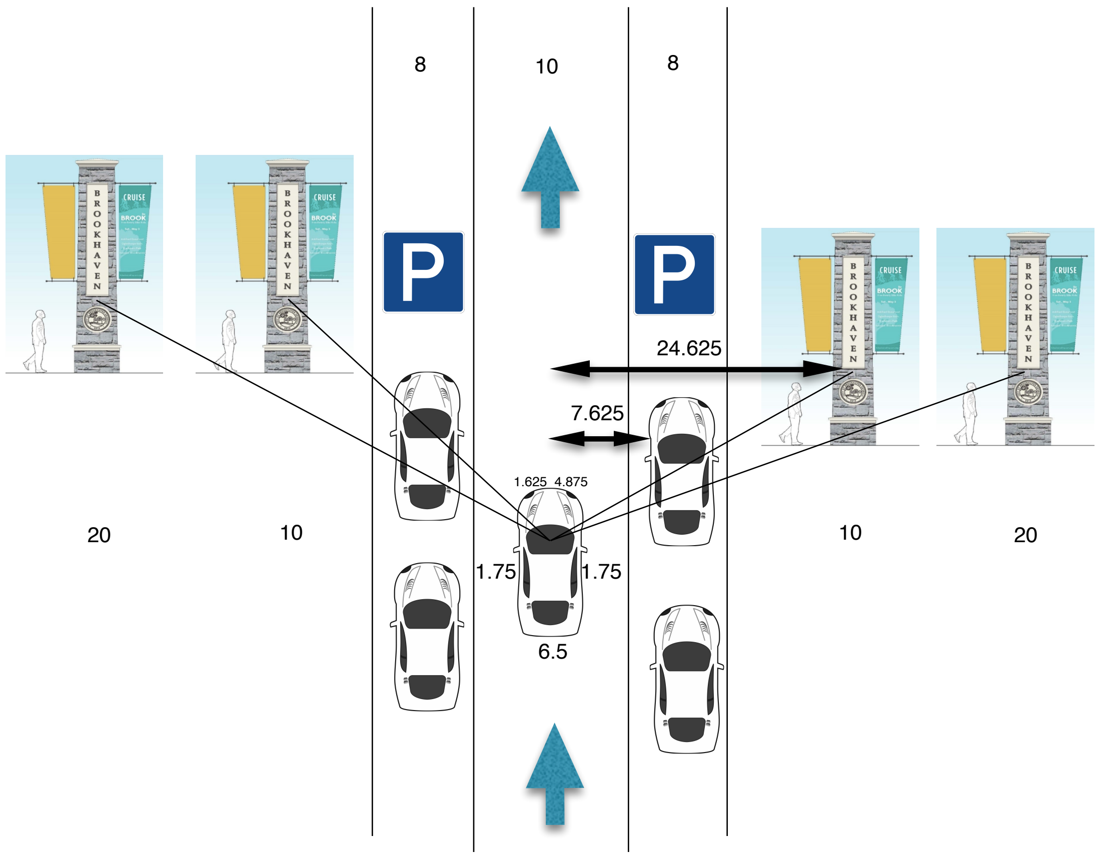
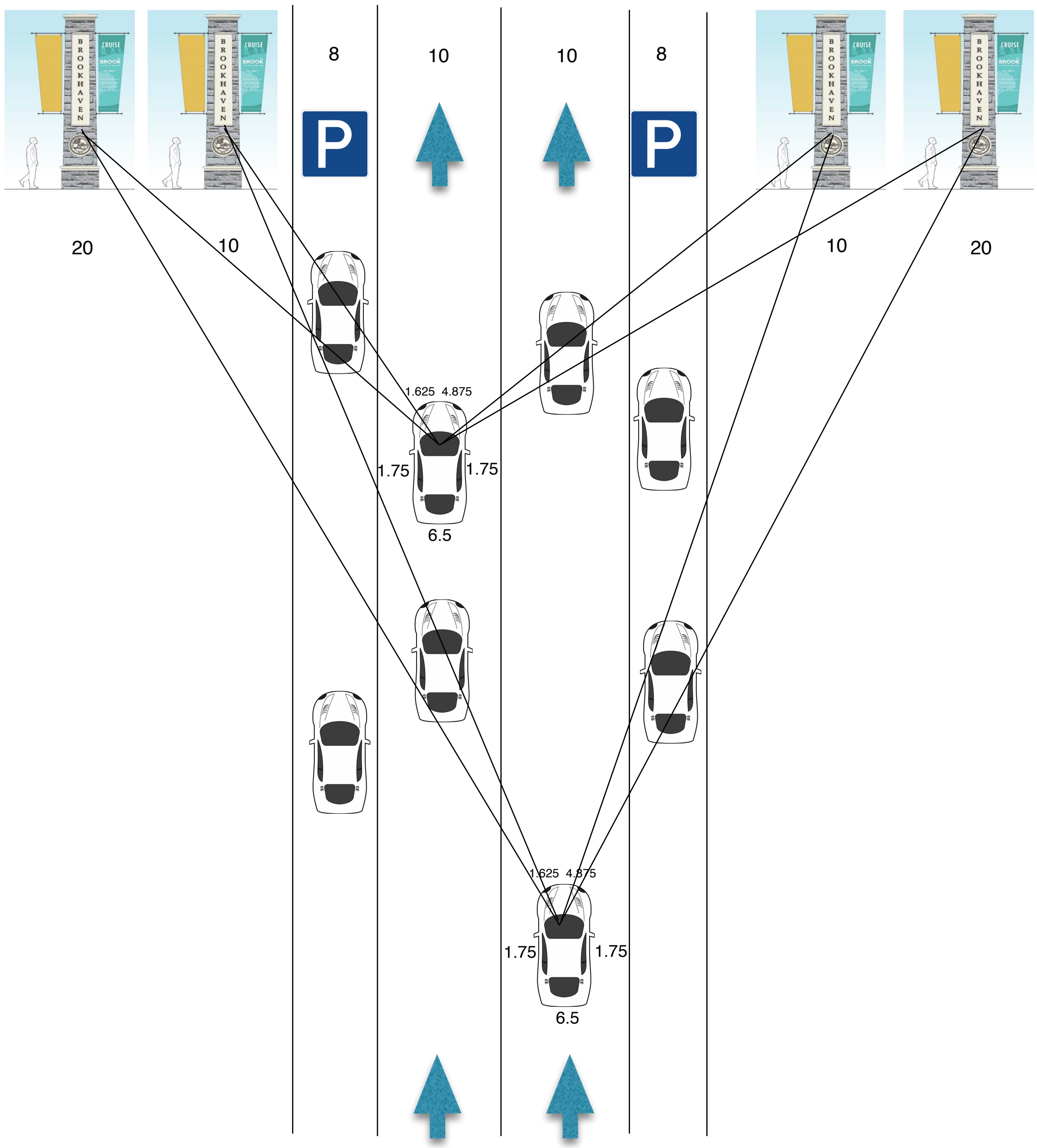
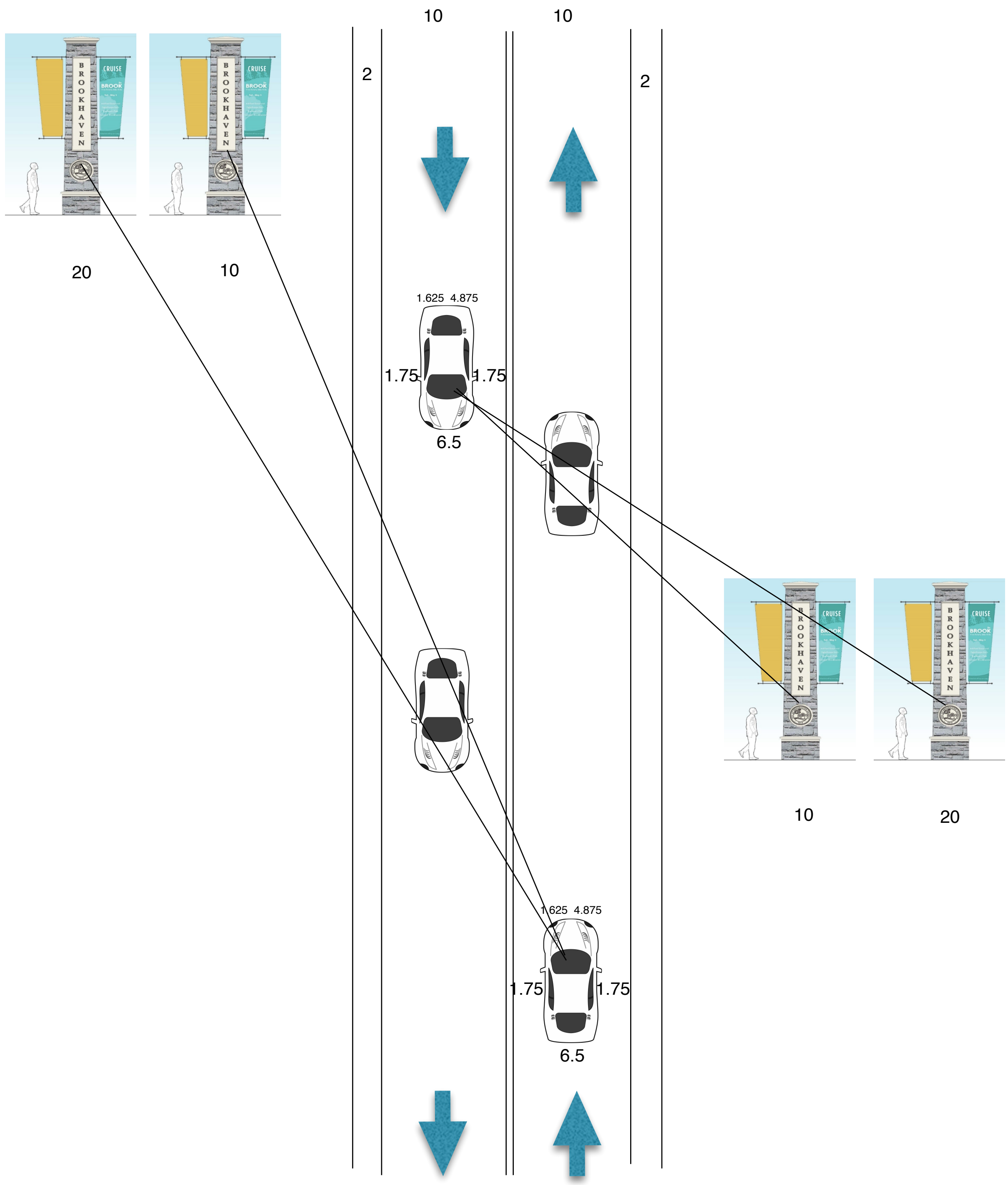
APPENDIX A - ROADWAY DIAGRAMS 1



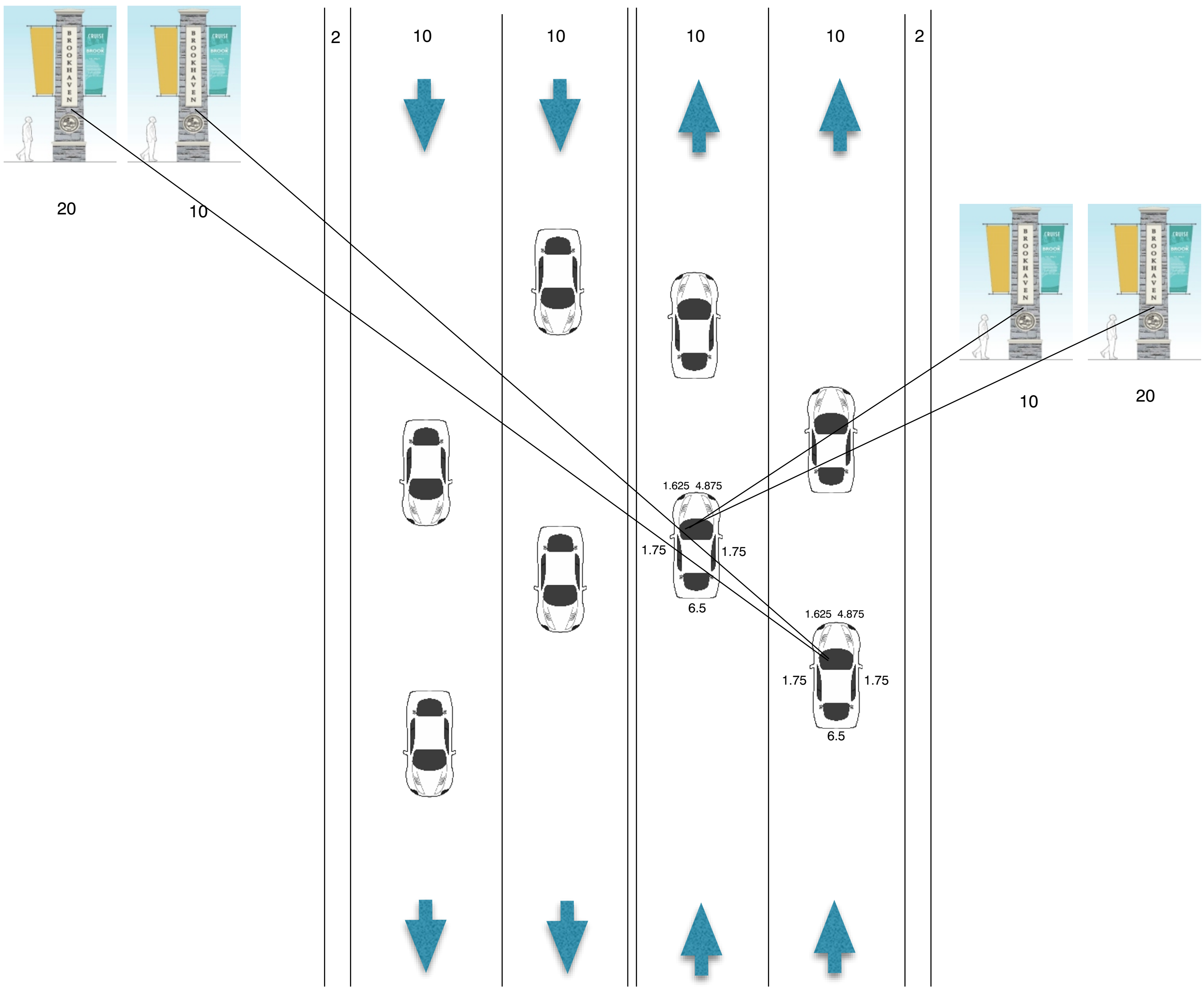
APPENDIX A - ROADWAY DIAGRAMS 1 cont'd



APPENDIX A - ROADWAY DIAGRAMS 1 cont'd



APPENDIX A - ROADWAY DIAGRAMS 2



Appendix B

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 3.5 ft driver eye height and 4.25 ft personal vehicle height were used, the travel lane was 10-feet wide, with two, 8-ft 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 vehicle, and the cars parked in the parking lanes were located one foot from the travel lane, the sign had a 10-foot offset from the traveled way and was located on the right side of the road (see Appendix A, page one 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 $y_1 = 3.5$
[x_1 is the observer location and is a constant, y_1 is the observer eye height and is a constant.]

And where: ($x_2 = d$, $y_2 = 4.25$)
[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_1 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 C - SIGN HEIGHT RESULTS

Results

Method of Determining Minimum Mounting Height		10-ft wide travel lanes																			
		Parking Lanes (8-ft wide)										No Parking Lanes (2-ft shoulder)									
		One lane, one way				Two lanes, one way						Two lanes, two way (undivided)		Four lanes, two way (undivided)							
		Sign on Right		Sign on Left		Sign on Right			Sign on Left			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			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)		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	7.625	24.625	4.375	21.375	Same as one lane	8.375	34.625	5.125	31.375	Same as one lane	5.125	25.375	8.375	28.625	5.125	45.375	5.125	35.375	
	20		34.625		31.375			44.625		41.375			35.375		38.625		55.375		45.375	
		Slope	Minimum Mounting Height	Slope	Minimum Mounting Height		Slope	Minimum Mounting Height	Slope	Minimum Mounting Height		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	0.0984	5.92	0.1714	7.16		0.0896	6.60	0.1463	8.09		0.1463	7.21	0.0896	6.06	0.1463	10.14	0.1463	8.68	7.48
	20		6.91		8.88			7.50		9.55			8.68		6.96		11.60		10.14	8.78
Field Validation	10		6.00		7.17			6.75		8.08			7.25		6.25		10.00		8.67	7.52
	20		7.00		8.75			7.58		9.42			8.67		7.17		11.42		10.00	8.75
Using Updated Fambro Data	**10**	**0.1967**	**8.84**	**0.3429**	**11.33**		**0.1791**	**10.20**	**0.2927**	**13.18**		**0.2927**	**11.43**	**0.1791**	**9.13**	**0.2927**	**17.28**	**0.2927**	**14.35**	
	20		**10.81**		**14.76**			**11.99**		**16.11**			**14.35**		**10.92**		**20.21**		**17.28**	

Appendix D

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 ft driver eye height and 5.5 ft personal vehicle height developed in this paper from Fambro, et al.'s data were used, the travel lane was 10-feet wide, with two, 8-ft 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 vehicle, and the cars parked in the parking lanes were located one foot from the travel lane, the sign had a 10-foot offset from the traveled way and was located on the right side of the road (see Appendix A, page one 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: ($x_2 = d$, $y_2 = 5.5$)
[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.

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