CRITERIA FOR UNIFORM DESIGNING AND SIGNING OF NO-PASSING ZONES IN PORTUGAL

Paper Submitted to the 4th International Symposium on Highway Geometric Design

29 March 2009

Paper has 5894 words (2394 words, 3 tables and 11 figures)

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ABSTRACT

In Portugal there are two criteria for the definition of passing sight distance (PSD): the one from the Portuguese Design Standard (PDS), which follows the AASTHO model for defining the minimum PSD for a two-way two-lane highway, and the one from the Portuguese Standard for Road Marking (PSRM), which follows the Vienna Convention and the CEMT guidelines to define the no-passing zone marking.

The definition of a uniform PSD for road design and road signing in Portugal is fundamental, and was included in the *Plano Nacional de Prevenção Rodoviária* (National Road Safety Plan), issued in 2003.

This paper describes the method which allows the PSD to be compatible both with road design and no-passing zone marking. The method was achieved drawing comparisons between the two models used in Portugal (above mentioned) and considering the Glennon model. The method takes into account that the second phase of the AASHTO passing model corresponds to the relevant manoeuvre considered in the Glennon model and that the basic assumptions concerning passing and opposing vehicle drivers' behaviour during the passing manoeuvre are similar in both models.

The no-passing marking distances proposed, using the Glennon's Criteria applied to the PDS's PSD, were found to be consistent with the range of CEMT values, for the length of continuous no-passing lines, and with the length of warning markings, defined in the PSRM and in use in Portugal.

1. INTRODUCTION

Consistency is one of the basic principles or intrinsic qualities of signing. Consistency states that, under identical infrastructure conditions, the driver should see signs with the same value and size, located in accordance with the same rules [1]. This principle should prevail in the definition of no-passing zones and of zones where the passing manoeuvre is allowed, on two-way two-lane highways, being used a single criterion.

The definition of zones where overtaking is a dangerous manoeuvre and as such should be forbidden, involves the statistical study of running speeds and the definition of the minimum sight distance for overtaking, based on those speeds and on their distribution.

This distance depends on the speeds of both fast and slow vehicles. The sight distance that allows overtaking also depends on the speed of the opposing vehicles. The opportunities to accomplish the passing manoeuvre depend on the proportion of slow vehicles in the traffic flow and on the intensity and composition of vehicles travelling in the opposite direction.

Due to the multiple variables to be considered, these considerations illustrate the complexity of the statistic study of the passing manoeuvre. The range of vision that permits the passing manoeuvre in a given section can vary greatly depending on the values assigned to these variables and their combination. The minimum passing sight distance to adopt in sections where continuous no-passing lines are to be located thus represents a compromise.

If one takes the longest distance, i. e. corresponding to the most adverse conditions to complete a passing manoeuvre, the lines that are determined ensure safety but severely restrict the traffic flow, while these very adverse conditions occur only rarely.

When there is a significant percentage of slow vehicles, drivers often disrespect the continuous no-passing lines, if the range of vision is sufficient to pass the lead vehicle.

The sight distance to consider in the marking and signing process must be such that the frequency of passing manoeuvres achievable without danger is low when signs forbid it. Otherwise the traffic flow is limited and safety illusory, because offenses would not fail to be committed (text adapted from [2]).

This is particularly important for lower design speeds where no-passing zones prevail, usually associated with the geometric characteristics of roads designed for those speeds.

On the other hand, in the absence of opposing traffic, the option to overtake is based on information transmitted to the driver by signs and on its *ad hoc* expectation. So it should be ensured that the no-passing marking distance is appropriate for the operating speed and that remains the same along the route (consistency of marking and signing).

It is important to highlight that it is necessary but not sufficient condition to achieve a passing manoeuvre even though signs allow for it. In some stretches of road where overtaking is allowed, there are occasions when, due to traffic or weather conditions, the manoeuvre becomes dangerous or even impossible.

2. SIGHT DISTANCE TO CONSIDER ON NO-PASSING ZONE MARKING

In Portugal there are two criteria for the definition of passing sight distance (PSD): the one from the Portuguese Design Standard (PDS) [4], which follows the AASTHO model for defining the minimum PSD for a two-way two-lane highway, and the one from the Portuguese Standard for Road Marking (PSRM), which follows the Vienna Convention [7] and the CEMT guidelines [8] to define the no-passing zone marking.

These two criteria lead to different results in their application, with either too many or only a few no-passing zones determined for an actual two-way two-lane highway. The definition of a uniform PSD for road design and road signing in Portugal is fundamental, and was included in the *Plano Nacional de Prevenção Rodoviária 2003/2005* (National Road Safety Plan), issued in 2003.

AASHTO [3] defines the minimum Passing Sight Distance (PSD) for a two-way two-lane highway as the sum of four distances, corresponding to two different phases in the manoeuvre, as represented in Figure 1:

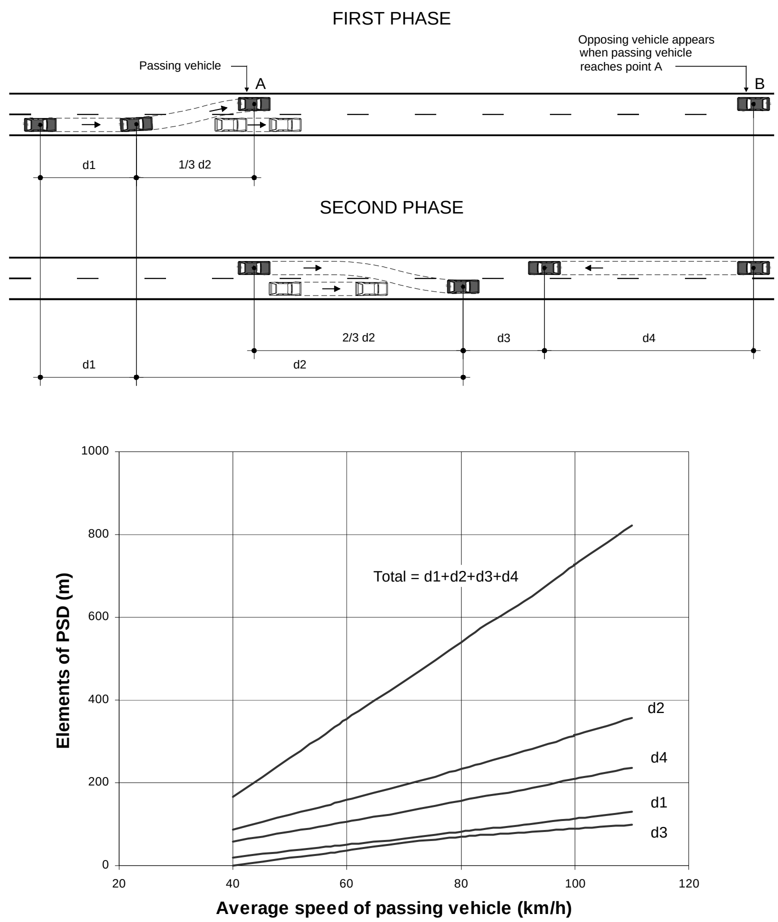

FIGURE 1 Elements of PSD [3]

d1 - Distance travelled during perception and reaction time and during the initial acceleration to the point of encroachment on the left lane.

d2 - Distance travelled while the passing vehicle occupies the left lane.
d3 - Distance between the passing vehicle at the end of its manoeuvre and the opposing vehicle.
d4 - Distance travelled by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane, or 2/3 of d2 above.

The speed considered is the design speed.

According to this approach, the driver can go back to its lane during the first phase, without overtaking, whenever the opposing vehicle is too close.

The PDS [4] follows this model and defines passing sight distance (*DVU*) as *DVU* (m) = 7 x V_{85} (km/h), where V_{85} stands for the operating speed, obtained from Table 1.

TABLE 1 Operating speed function of design speed [4]

Design speed (km/h)	Operating speed V_{85} (km/h)
60	80
80	100
100	120
120	130
140	140

Recent studies support the use of operating speed in this calculation. According to these studies speeds of passing vehicles are between 1.02 and 1.15 of V_{85} and speeds of lead vehicles are between 0.79 and 0.85 of V_{85} [5].

Glennon [6] considered not only the distance to complete the manoeuvre but also evaluated the possibility of aborting it at any time. During the passing manoeuvre the distances necessary to abort it and to complete it vary in reciprocal proportions, becoming equal at a point considered critical, that may be used to define the passing sight distance to retain (PSDG) – Figure 2.

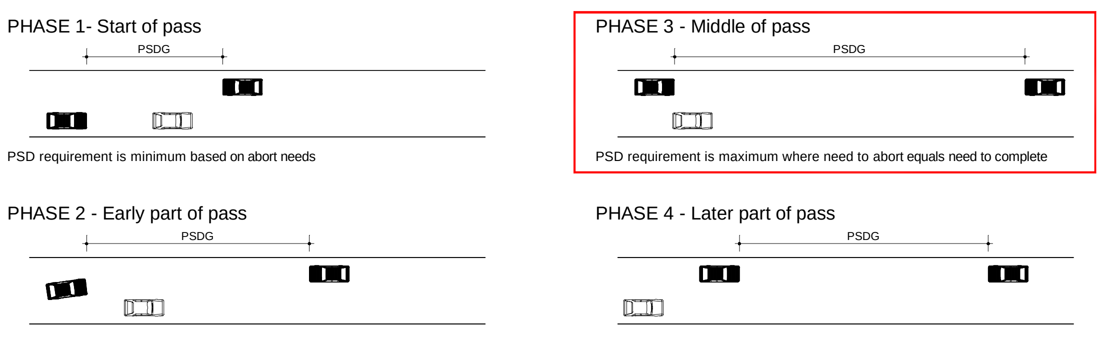

FIGURE 2 Phases of PSDG [6]

The basic assumptions concerning passing and opposing vehicle drivers' behaviour during the passing manoeuvre are similar in both models. Furthermore, the second phase of the AASHTO model corresponds to the relevant manoeuvre considered in the Glennon model – Figure 3.

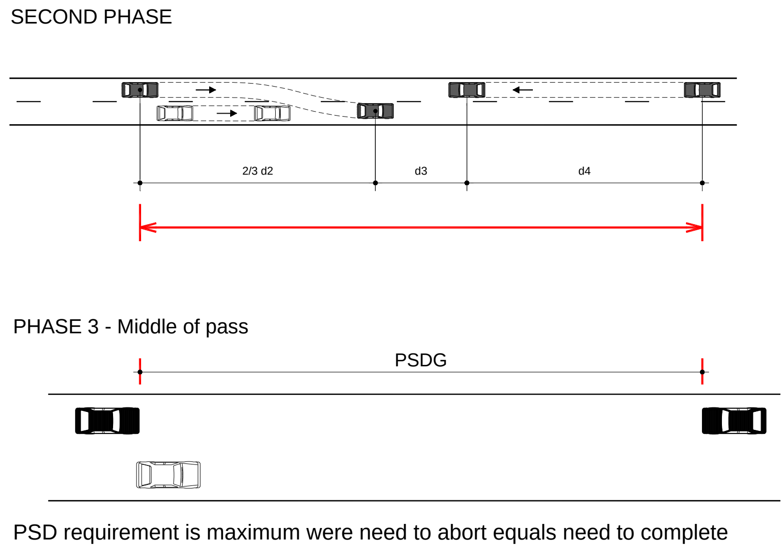

FIGURE 3 Comparison between the AASHTO and the Glennon models

On the other hand, the following relations may be assumed from Figure 1: 2/3 d2+d3+d4 ≈ 0.7 PSD and d3+d4 ≈ 0.4 PSD.

These relations permit to establish a correspondence between the passing sight distance as defined by Glennon's Criteria and no-passing zone marking and signing, as shown in Figure 4. In this figure the red sign represents "prohibition of overtaking" and the gray sign represents "end of prohibition of overtaking" [7].

The value 0.4 PSD corresponds to the start of the no-passing zone marking; the value 0.7 PSD corresponds to the section where warning markings (of the approach to a continuous line and the prohibition that line conveys [7]) should be located. In Portugal, in a two-way two-lane highway, these warning markings consist of an approach broken line supplemented by arrows showing drivers which lane they should take (see figures 10 and 11).

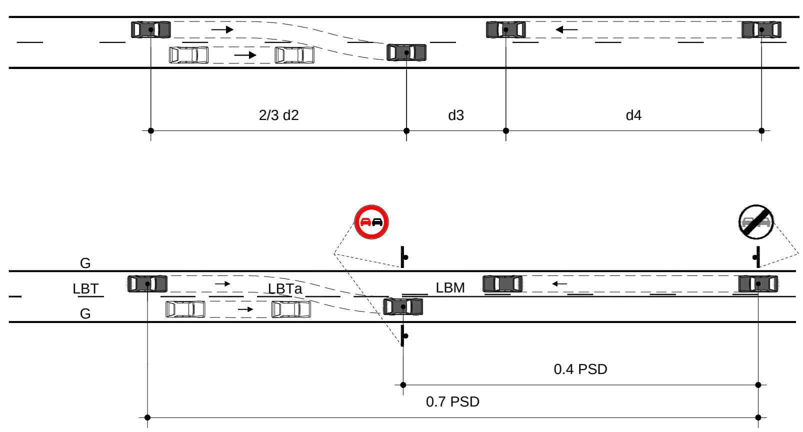

FIGURE 4 Proposed passing sight and marking distances

The Portuguese Standard for Road Marking follows the Vienna Convention [7] very closely and the CEMT guidelines [8], which consider that overtaking is forbidden where the sight distance is less than a certain minimum distance M, which is also a no-passing marking distance, as shown in Figure 5. Reports on the technical basis for the proposed range of values of M for each speed could not be found. In this figure the length of the warning line (approach broken line) is denoted as L.

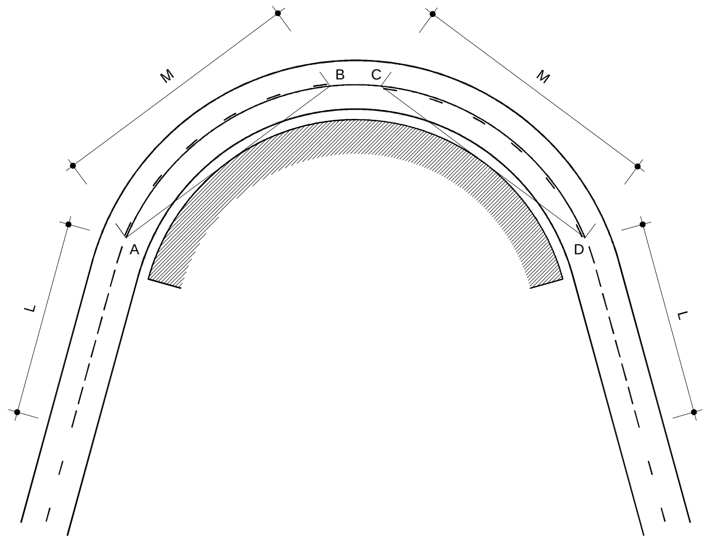

FIGURE 5 CEMT marking technique based on M value [8]

In Table 2 a comparison is made of the values for passing sight distances and for no-passing marking distances, as proposed by several sources.

TABLE 2 Passing Sight Distances and No-passing Marking Distances

	Passing Sight Distances						No-passing Marking Distances		
	AASHTO PSD		Glennon PSDG		PDS DVU	Glennon's Criteria 0.7 DVU	MUTCD [9] MPSD (*)	CEMT M (*)	Glennon's Criteria 0.4 DVU
Speed (km/h)	Design Speed	Operating Speed	Design Speed	Operating Speed	Operating Speed	Operating Speed	Operating Speed	Operating Speed	Operating Speed
40	270	-	-	-	280	195	140	35-75	110
50	345	297	-	-	350	245	160	60-120	140
60	410	346	180	-	420	295	180	85-170	170
70	485	375	225	-	490	340	210	105-215	195
80	540	407	255	180	560	390	245	130-260	225
90	615	482	280	225	630	440	280	145-290	250
100	670	541	310	255	700	490	320	160-320	280
110	730	605	345	280	770	540	355	175-350	310
120	775	670	-	-	840	590	395	190-380	335

(*) also a passing sight distance

Notice that both the AASHTO and the PDS give higher distances than 600 m, for which drivers have difficulties in interpreting the images, according to Crisman, B. *et al* [5].

Current and proposed values for passing sight distances and for no-passing marking distances are shown in a graphic form, in figures 6 and 7, respectively. In these figures "CEMT m" stands for the lower limit and "CEMT M" for the higher limit of M values.

In Table 2 "Speed" refers to design speed and to operating speed, depending on the criteria. In figures 6 and 7, only operating speed values are used (see Table 1).

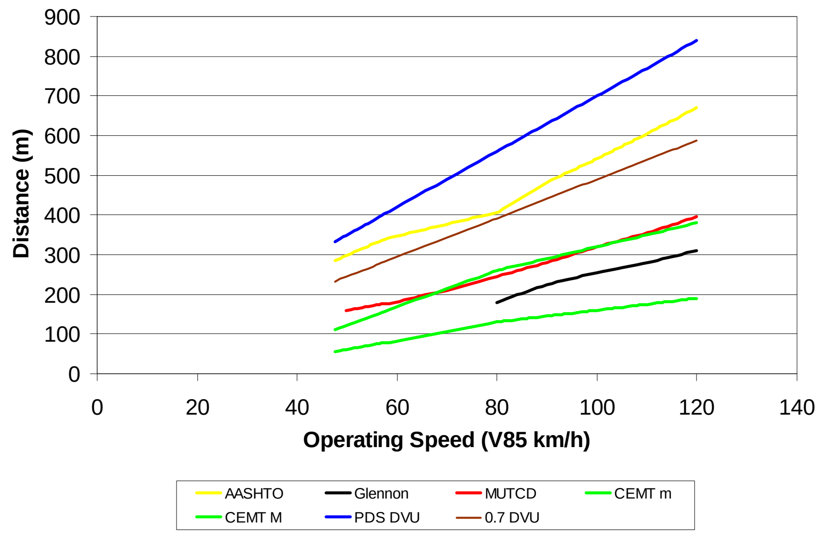

FIGURE 6 Passing sight distances

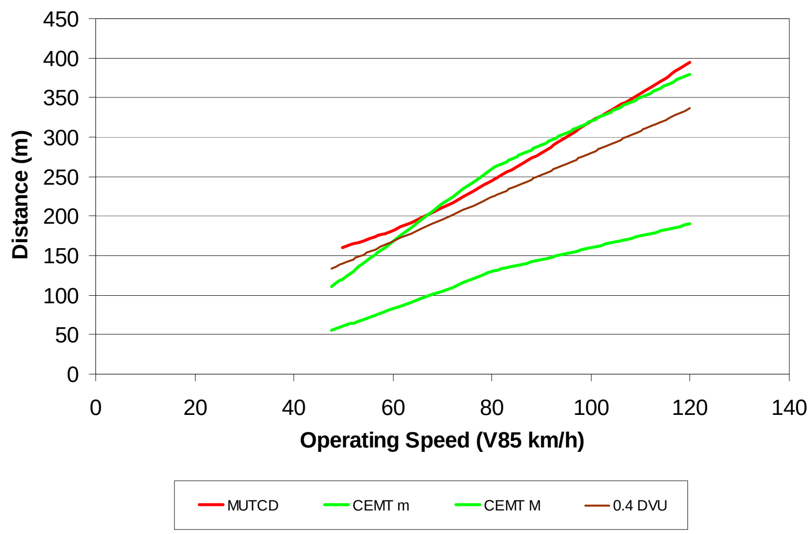

FIGURE 7 No-passing marking distances

The no-passing marking distances proposed, using the Glennon's Criteria applied to the PDS's DVU, are coherent with the MUTCD values and with the range of CEMT values, for the length of continuous no-passing lines, and with the length of warning markings, defined in the PSRM and in use in Portugal, but taking into consideration a larger range of vision for marking and signing purposes than the values stated in CEMT and PSRM, as shown in figure 8, below (the MUTCD approach is similar).

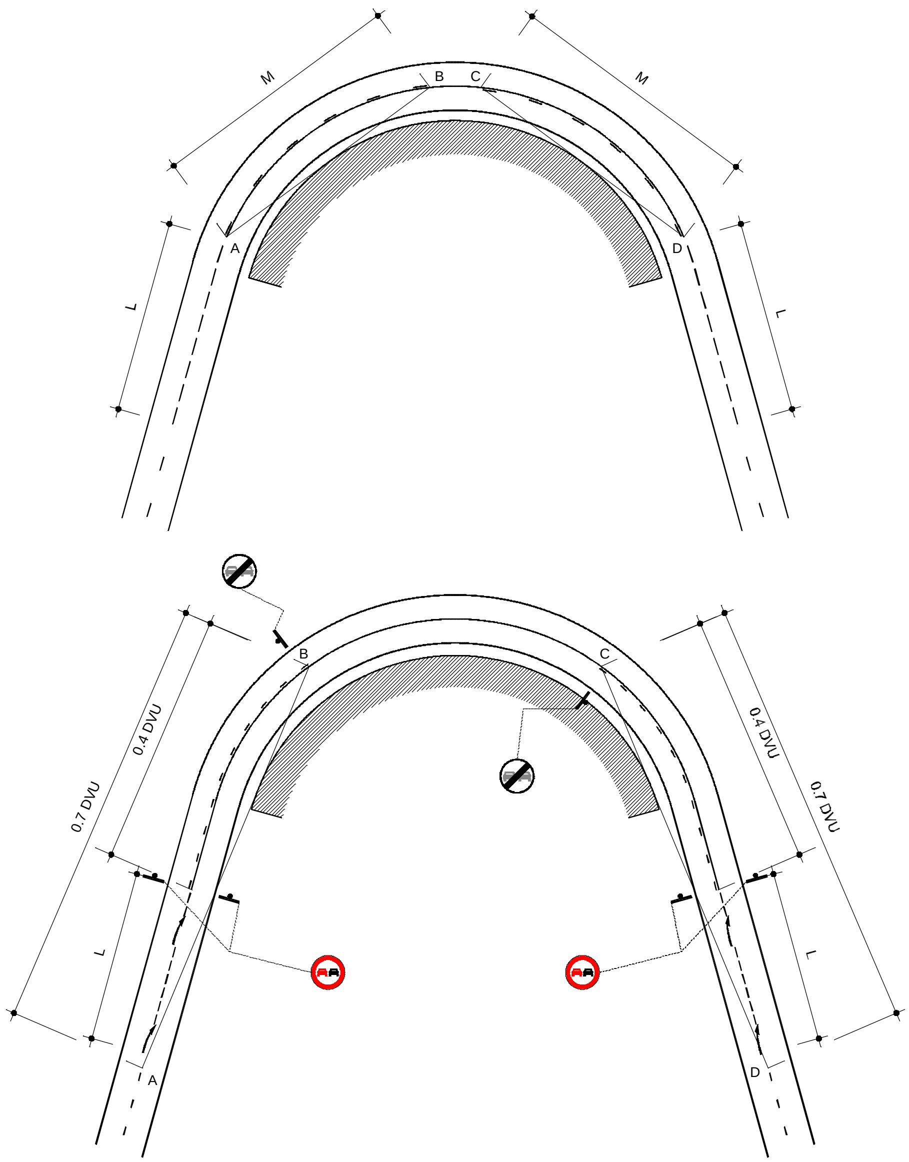

FIGURE 8 CEMT and Glennon's Criteria applied to horizontal curve

Table 3 and the histogram in Figure 9, compares the lengths of longitudinal lines used with recommended values of 0.7 DVU for various operating speeds, noting that the marking distance is very close to the range of vision considered. As the length of warning markings (for approaching a no-passing zone) given in the Portuguese guidelines, is almost the same as the length of the warning distance, therefore the warning markings and distance are consistent with each other.

TABLE 3 Sight and marking distances (m)

Operating speed V_{85} (km/h)	PSRM	Glennon Criteria		Marking distance (columns 2 + 3) L + 0.4 DVU	Marking distance÷ ÷ (0.7 DVU) (%)
	Length of approach broken line (warning marking) L	Length of continuous line (no-passing marking) 0.4 DVU	Sight distance 0.7 DVU		
40	42	110	195	152	78
50	42	140	245	182	74
60	84	170	295	254	86
70	84	195	340	279	82
80	126	225	390	351	90
90	126	250	440	376	85
100	168	280	490	448	91
110	210	310	540	520	96
120	252	335	590	587	99

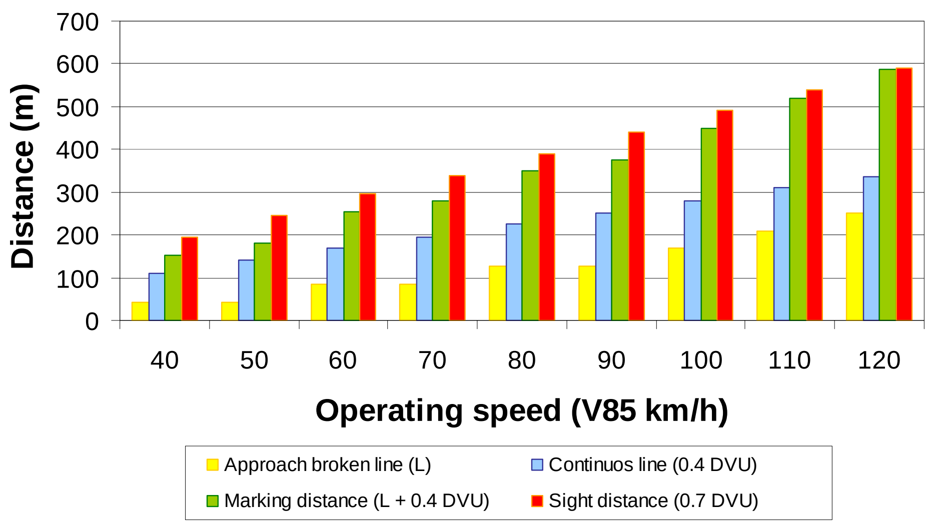

FIGURE 9 Sight and marking distances

Notice that the length of the approach broken line depends on the modulation used in longitudinal lines that are defined by PRMS for different speed intervals (e.g. 42 m for 40 km/h to 50 km/h, 84 m for 60 km/h to 70 km/h – see Table 3, column 2). That modulation causes a slighter adjustment in the upper part of those intervals, particularly for speeds of 50 km/h, 70 km/h and 90 km/h.

3. CRITERIA FOR MARKING AND SIGNING HORIZONTAL CURVES

Figure 10 shows the criteria for marking and signing horizontal curves, point A (or D) being the point where the sight distance begins to be lower than 0.7 DVU and point C (or B) being the point where that distance becomes higher than 0.7 DVU.

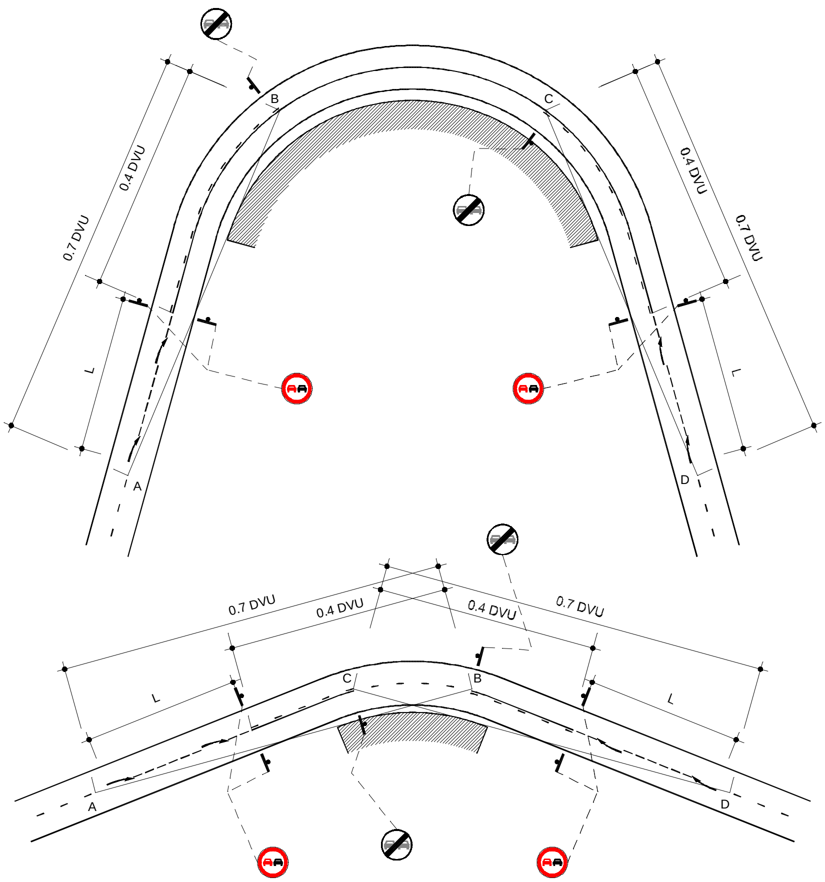

FIGURE 10 Marking and signing of horizontal curves for passing sight distance DVU

4. CRITERIA FOR MARKING AND SIGNING VERTICAL CURVES

According to the Vienna Convention [7] "range of vision" is the distance at which an object 1.0 m above the surface of the carriageway can be seen by an observer on the road whose eye is also 1.0 m above the carriageway. This definition was taken because it corresponds to the revision of the Vienna Convention, more recent than the definition of the CEMT [8].

Figure 11 shows the criteria for marking and signing vertical curves, point A (or D) being the point where the sight distance begins to be lower than 0.7 DVU and point C (or B) being the point where that distance becomes higher than 0.7 DVU.

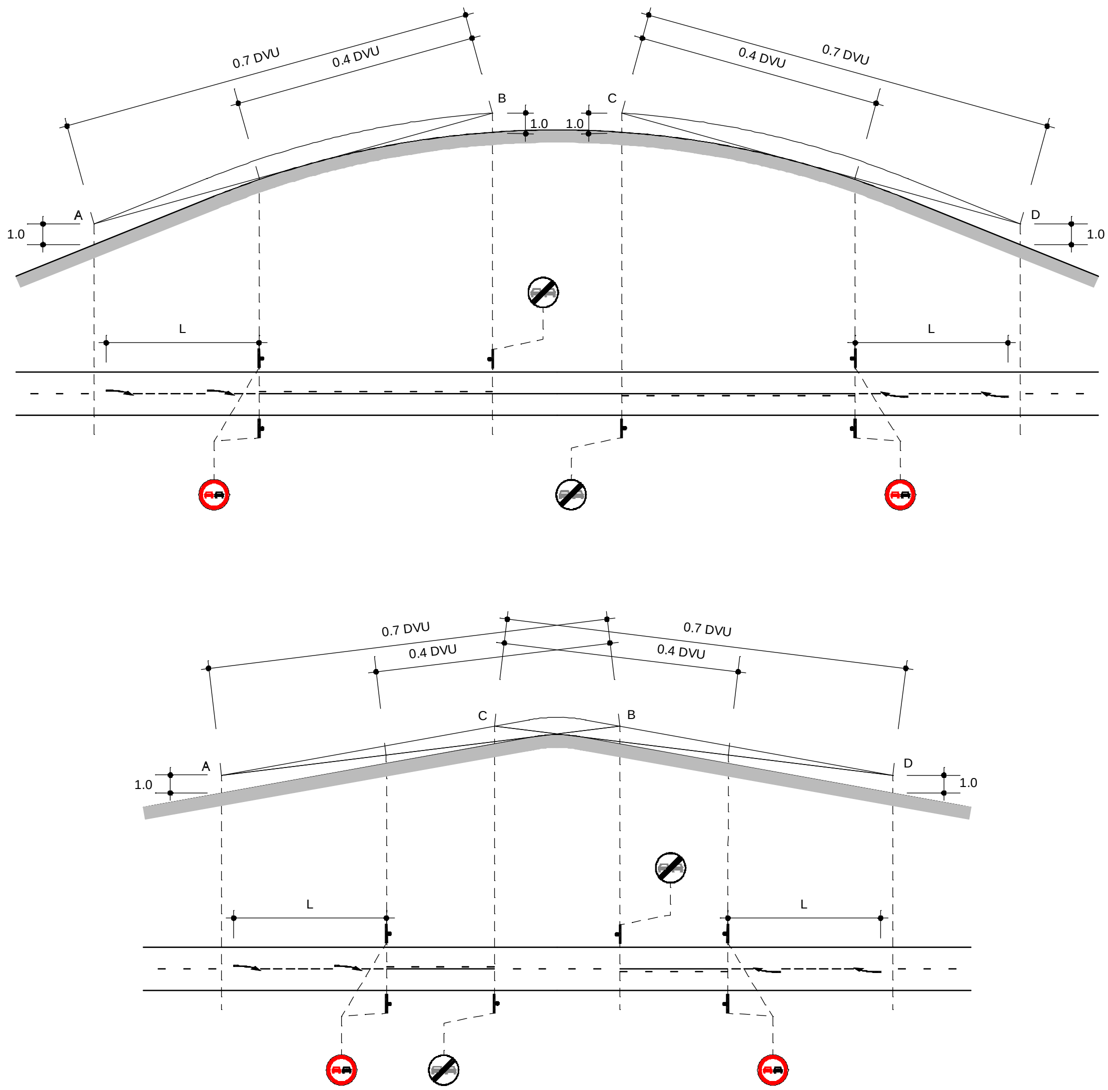

FIGURE 11 Marking and signing of vertical curves for passing sight distance DVU

The **combination of horizontal and vertical alignment** is a specific matter of each road design. Those alignments should be coordinated according to existing orientation from design standards and guidelines, including the recent Human Factors Guideline from the World Road Association (AIPCR/PIARC).

The combination of horizontal and vertical alignment might be solved by the designer, using the horizontal and the vertical alignments separately and superimposing the solutions to define the final marking and signing of no-passing zones. This separate approach might be done manually, as traditionally, or using software that combines the two solutions and approaches the tridimensional problem.

Software that provides the visualization of the road and its environment and allows the calculation of the 3D sight distance is more accurate.

This may be used in the PSD approach presented in this paper.

5. CONCLUSIONS

The definition of a uniform PSD for road design and road marking and signing in Portugal is fundamental, and was included in the *Plano Nacional de Prevenção Rodoviária 2003/2005* (National Road Safety Plan), issued in 2003.

This method which allows PSDs to be compatible both with road design and no-passing zone marking and signing was proposed at the III Portuguese Road Congress (2004) and is now a Technical Document issued by the *Instituto de Infra-Estruturas Rodoviárias, IP* (Portuguese Road Authority).

This method is a compromise between the two criteria used in Portugal, using the same values for road design and for road marking, and will promote consistency in marking and signing of no-passing zones in two-way two-lane highways in our country.

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