Free-Gap Evaluation for Two-Lane Rural Highways

António Lobo, Maria Alice Prudêncio Jacques, Carlos Manuel Rodrigues, and António Couto

Studies related to operating speed predicting models' development require vehicles' speed under free-flow conditions to be collected at different sites. Thus, a critical issue is the definition of the gap (or headway) from which the speed of one vehicle is not affected by the speed of the vehicle ahead. In many studies, a 5-s headway was adopted as the reference headway value from which a vehicle could be assumed to travel at a free-flow speed. Justifications for this value's application are not clearly presented in the literature, and some authors suggest the use of other reference values. This paper presents a definition for platoon from observed values of vehicles' time gap. The reference gap value between two successive vehicles considered as traveling in a nonplatoon condition is defined as "free gap." A five-step methodology is described and tested for road conditions in Portugal. The application performed showed both the adequacy of the methodology proposed and the convenience of exploratory studies aimed at the identification of platoon gap (or headway) suitable for specific operating speed studies. According to the methodology proposed, a 6-s gap is a suitable reference for future data collection on operating speed on Portuguese roads. This result suggests the need to review the headway reference values found in the literature for representing free-flow general conditions.

Studies related to estimating operating speed for two-lane rural highways were performed in many places at different times. The term "operating speed" has changed in meaning over the years (*1*). A commonly adopted definition in studies of two-lane rural highways is that proposed by AASHTO (*2*), according to which the operating speed is the speed chosen by drivers during free-flow conditions. In this sense, it reflects the driver's response to road geometric and environmental characteristics because the driver is not affected by the presence of other vehicles. Operating speed is also affected by driving general practices and culture as well as by vehicle technology. For this reason, operating speed prediction models have been developed in different countries and, in many countries, have been developed in different regions and times. Knowledge of operating speed and its road-related factors is important for many traffic engineering activities, such as road safety analyses, speed limit definitions, and highway design consistency studies.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2223, Transportation Research Board of the National Academies, Washington, D.C., 2011, pp. 9–17.
DOI: 10.3141/2223-02

Operating speed is most frequently represented by the 85th percentile speed (V_{85}) of vehicles passing at a given road location, in a nonplatoon condition, and it is usually determined by spot speed measurements. The *Highway Capacity Manual* (HCM) 2000 recommends that the number of observations for V_{85} calculation be equal to or greater than 100 (*3*). Therefore, one critical issue for studies of operating speeds is to define when a platoon condition is present. Another relevant question is related to the identification of the road volume for which the number of vehicles in a nonconstrained operation is enough for V_{85} estimation.

In most studies on the development of operating speed prediction models, a nonplatoon condition is usually defined by means of minimum headway between successive vehicles in a traffic stream. However, these studies do not describe the procedure adopted to establish the reference value taken. Also, this traffic measure is affected by the type of the two successive vehicles considered. Equipment available for automatic speed data collection is, in some cases, able to collect headway and gap values simultaneously. The gap between two successive vehicles, being the interval between the rear bumper of the first vehicle and the front bumper of the second as the vehicles pass a point on the roadway, is not affected by the vehicles' type. Therefore, the definition of platoon condition based on gap values can be useful for general applications.

In this context, this paper aims to present and test a procedure to define a gap value between two successive vehicles from which the vehicles can be considered as traveling in a nonplatoon condition. This reference value is referred to as "free gap." In addition, the procedure allows for the identification of the traffic volume suitable for ensuring the sample size required for V_{85} measurements. Therefore, the procedure is proposed as the initial activity to be performed for V_{85} data collection for operating speed evaluation and modeling.

This paper is organized into five sections. After this introductory section, a brief literature review is presented on headway reference values considered for platoon definition in different operating speed studies. The third and fourth sections describe, respectively, the procedure proposed and its application to Portuguese conditions. This application is the initial step for a broad operating speed data collection activity planned to be performed at Portuguese roads for the development of a respective operating speed prediction model. The last section presents this study's main conclusions.

PLATOON DEFINITION FOR OPERATING SPEED MEASUREMENTS

Although there is not one definition for platoon, this term is commonly applied to a group of vehicles traveling together in which the vehicles behind the leading vehicle are usually not at their desired speed. That is, the following vehicles are experiencing some travel delay. Platoons are formed on two-lane, two-way rural highways because of difficulties in overtaking maneuvers caused by geometric features, opposing traffic, or both.

Operating speed measurements need to consider the speed of vehicles traveling at free-flow conditions and, therefore, during the speed data collection procedure, it is important to recognize vehicles in platoons. One fixed parameter used for this purpose is the time headway, from which it can be assumed that the following vehicle is not delayed by the leading vehicle. In the HCM 2000, this headway is established for two-lane highways as 3 s, whereas in previous versions of the manual, it was defined as 5 s (*3*). In both cases, no strong reasons are given for the value considered. Other authors, such as Guell and Virkler (*4*), have indicated different values of headways to constitute delay on two-lane highways. These authors, on the basis of theoretical considerations regarding deceleration rates and on speed of leading and following vehicles, found that headways of 3.5 s or 4.0 s might be suitable for this purpose. Gattis et al. reviewed different studies in which the headway time used to define delay at two-lane highways varies from 3.5 s to 6 s (*5*).

Studies conducted in different countries aimed at determining operating speed usually adopted the headway of 5 s as the reference headway to characterize a vehicle traveling under free-flow conditions. This is the case, for instance, in research by Fitzpatrick et al. (*6, 7*), Crisman and Perco (*8*), and Abdul-Mawjoud and Sofia (*9*). None of these studies describes the approach adopted to identify this headway value as the headway associated with free-flow vehicles on two-lane highways. One study pertaining to this question, although it applied to urban traffic, was developed by Vogel (*10*). The author proposed a methodology for identifying the headways associated with free-flow vehicles in urban areas, the application of which produced headways greater than 6 s.

The headway concept is concerned with the time interval between the passage of two successive vehicles at a point on the roadway, usually observed for the front bumper of both vehicles. Also, in considering the commonly adopted definition for gap as the time between vehicles measured from the rear of a vehicle to the front of the following vehicle, the relationship presented in Equation 1 applies. In this equation, for the sake of simplicity, it is assumed that the headway is measured by the passage of the front bumper of both vehicles.

$$h_i = g_i + \frac{l_{i-1}}{v_{i-1}} \tag{1}$$

where

h_i = headway of vehicle i (s),
g_i = gap of vehicle i (s),
l_{i-1} = length of the leading vehicle ($i-1$) (m), and
v_{i-1} = speed of the leading vehicle (m/s).

It is important to highlight that the gap parameter value is not affected by the type of the leading vehicle (expressed by its length) or by its speed. The headway parameter, on the contrary, reflects both the length and speed of the leading vehicle. Therefore, its value must be considered in a more contextualized situation.

The need for extensive operating speed data collection for developing operating speed prediction models requires a suitable definition for the free-flow headway (or free-flow gap). This definition guarantees that the speed values of only nonplatoon vehicles are taken into account and also prevents free-flow vehicles from being excluded from the sample. For this matter, it is convenient to perform a separate study in some highway sections with general features representative of the sections to be included in the final work. A methodology for doing so is presented next.

METHODOLOGY PROPOSED

The definition of a free-flow condition for the purpose of operating speed measurement can be done by means of both parameters: headway and gap. Usually the headway tends to be used, especially because of its relative simplicity for direct measurement in the field, in relation to gap observations. However, some available equipment for spot speed measurement in loco can provide both measures. The methodology was developed to deal with gap measurements. The advantage of using gap instead of headway is because the first is not affected by the leading vehicle's length and speed and, therefore, is a more representative global measure for platoon characterization.

This methodology has two main purposes: (*a*) definition of the gap value from which a vehicle may be considered as operating under free-flow conditions (referred to here as free gap); (*b*) identification of volume levels in an unconstrained traffic situation from which it is possible to obtain a sample of 100 or more vehicles for the sake of operating speed calculations (V_{85}). This is important because time and financial constraints require that data collection in each specific location should be as short as possible and still guarantee the quality of operating speed measurements. Therefore, the main idea underlying this work is to limit speed data collection over long time periods to a few representative locations. From the findings, faster and accurate extensive data collection activity can be performed, ensuring that only free-flow vehicles will be considered to provide operating speed values.

Step 1. Selection of the Sites to Be Studied

First, it could be assumed that free-gap values vary from one site to another. However, in terms of future operating speed studies, it is convenient to adopt a gap value suitable to all situations or at least to group road section types, such as tangents and curves. Subsequently, sites representing the overall sites' main traffic and road characteristics to be further analyzed must be selected.

Step 2. Operating Speed Evaluation Versus Gap Values

To make a large number of valid observations of both traffic directions on the sites selected, speed data collection should be performed over approximately 6 consecutive hours of noncongested traffic. Gap and speed values for each vehicle are recorded and treated. The gap values given by the equipment used come down to hundredths of a second. For this step, gap values less than 0.50 are rounded to zero, values from 0.50 to 1.49 are rounded to 1, and so on. With a view to estimating the gap value from which the vehicles could be unimpeded, for each rounded gap value (g_i), the V_{85} corresponding to vehicles with gaps greater or equal to g_i is calculated and plotted along a graphic form (Figure 1).

The visual analysis of the produced graphs allows for initial considerations of the effect of gap values on the operating speed for

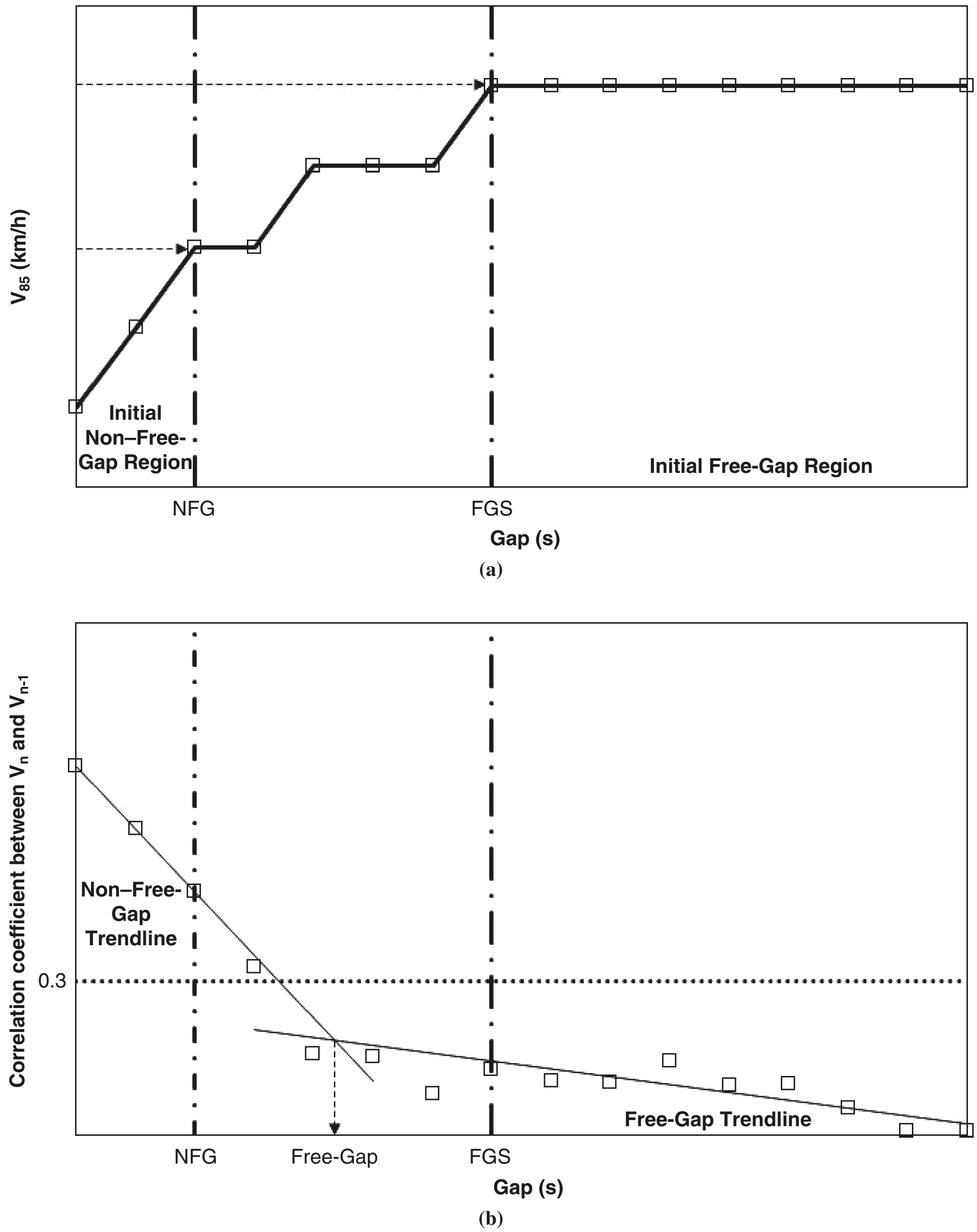

FIGURE 1 Methodology proposed: Steps 2 and 3.

each case. In uncongested traffic, gap values from which V_{85} reaches stable values indicate that the vehicle's speed is likely to not be more affected by the gap value and, as a result, by the presence of the vehicle ahead. Given the methodology proposed, it is assumed that the smallest gap value from a sequence of four or more gaps with the same V_{85} values (FGS) belongs to the set of candidate gaps from which the free gap will be selected, as well as the gaps higher than the same. This set is said to form the graph region termed as "initial free-gap region." On the contrary, the highest gap value for which the graph shows a systematic V_{85} growing (NFG) is assumed as the initial upper limit of the set of gaps not related to free-flow operations. This set, therefore, is said to form the graph region named as "initial non–free-gap region." These regions are shown in Figure 1, and were defined for the purpose of the analysis referred to in Step 3. The graph region between NFG and FGS contains the gap values that it is not possible to classify a priori into non–free-gap and free-gap regions. Naturally, only after the definition of the free-gap value is it possible to identify the actual non–free-gap and free-gap regions.

Step 3. Correlation Between the Speeds of the Leading and Following Vehicles

If a vehicle is traveling in a free-flow condition, its spot speed is not affected by the speed of the preceding vehicle. Again, in taking into account the rounded gap values defined in Step 2, the correlation between each vehicle's spot speed (V_n) and the spot speed of the respective vehicle ahead (V_{n-1}) is determined (simple linear regression analysis). Graphs showing the correlation between vehicles' speed and gap value are constructed. The analysis is then conducted in a similar way to that adopted by Vogel for free headway definition for urban roads (*10*). The major difference is that the aforementioned author arranges the regions in free and nonfree headways according to considerations regarding the correlation values themselves. For the present methodology, this is done on the basis of the results generated from Step 2. Two linear regressions for correlation values versus gap values are built (Figure 1). The first linear regression considers the correlation values for gaps less than and equal to NFG, and the second one for gaps greater than and equal to FGS. The gap value corresponding to the intersection point of the two previously mentioned linear functions represents the free gap for the situation studied. Hence, the correspondent correlation value for this gap can be calculated.

Although no specific correlation value can be established a priori, it can be assumed that correlation values under 0.30 mean weak correlations (*11*). However, the selected point could present a higher correlation value, which could be explained by the differences in approaching behavior caused by factors not related to the driver's desired speed, such as road geometry and traffic volume. Therefore, for correlation values greater than 0.30, the free gap will only be estimated at Step 4. If the gap value corresponding to the correlation equal to 0.30 is higher than the FGS defined in Step 2, the former value is assumed to be the new FGS. Thus, establishing a correlation equal to 0.30 for FGS leads to a wider range for the region between NFG and FGS.

Step 4. Gap Value and the Probability of Equal Speeds by Leading and Following Vehicles

This is the final piece of free-gap analysis. It aims to identify the probability of the following vehicle's speed not being equal to the leading vehicle's speed. As criteria, it is assumed that (*a*) following vehicles with gaps equal to or smaller than NFG are at non-free-moving conditions; (*b*) following vehicles with gaps equal to or greater than FGS are free-flow vehicles; (*c*) for the region between NFG and FGS, successive vehicles' speed is effectively different if the speeds differ from each other by more than 10% of the vehicles' average speed value (10% represents the maximum error, which is usually assumed at spot speed data collection); (*d*) for the observations mentioned at (*c*), following vehicles with speed different from the speed of leading vehicles can be taken as being at a free-flow condition and are classified as free-moving vehicles.

In this way, observations are divided into two categories: free- and non-free-moving vehicles. Non-free-moving vehicles are considered at the same speed as the vehicle ahead. On the basis of this division, a new categorical binary variable can be created. This variable (Y) will be made equal to zero for non-free-moving vehicles and one otherwise. With this variable in mind, it is possible to evaluate the association between free-moving vehicles and vehicles' gap. The dichotomous nature of the dependent variable facilitates the application of binary logistic regression, for which the probability of being in platoons against free-moving vehicles is estimated by a maximum likelihood method.

In this logistic regression model, the latent variable is formulated by Equation 2.

$$f(x) = \beta_0 + \beta_1 \cdot x \tag{2}$$

where x is ln(gap) and β_0, β_1 are regression coefficients.

The natural logarithm of the gap variable values is used for allowing normal distribution of the model's independent variable (x).

With this latent variable, the conditional probability of a positive outcome (free-moving vehicles, $Y = 1$) is determined by Equation 3:

$$\text{Prob}(Y = 1|x) = \frac{\exp(f(x))}{1 + \exp(f(x))} \tag{3}$$

The resulting model, calibrated for each site, is then used to calculate (*a*) the probability of free-moving vehicles for the free gaps selected in Step 3 (probability values above 0.50 provide a strong indication on the suitability of the previously selected gap to represent the free-flow conditions for the sites under analysis); and (*b*) the free-gap values for the situations that revealed high correlation values (>0.30) for the intersection point of the linear regressions performed in Step 3. In the latter cases, the free gaps are defined by $P(Y = 1) = 0.50$.

Step 5. Volume Level Suitable for Data Collection

As stated before, if the operating speed study includes many road locations, it is desirable to have some guidelines to define the number of hours over which speed data must be collected for the minimum of 100 speed observations to be reached. The number of different possible values of gap presented in a traffic stream depends strongly on traffic volumes.

By disaggregating the total data collected along the overall observation period in hourly volumes, it is possible to identify the number of the total hourly gaps that are equal to or greater than the free gap defined in the previous steps. That is, it is possible to identify specific volume levels per direction in an uncongested traffic condition that are enough for V_{85} determination.

APPLICATION PERFORMED

The application of the methodology was planned as the initial activity in developing an operating speed prediction model for Portuguese roads. It was performed as follows. Because the application of Step 5 has no special features, it will not be detailed here; only the final results are presented.

Site Selection

The field study was conducted on an 11-km-long section of the road N 222, located in Porto's environs. The average cross section is formed by two 3.60-m-wide lanes and two 2.30-m-wide shoulders. Data collection was performed at four sites with different geometric characteristics: two sites are located in tangents and two in horizontal curves. One of the chosen sites in tangent is 240 m long with a grade of 2.6%; the other is 513 m long with a grade of 1.9%. Regarding the chosen curves, one has a radius of 220 m, with a length of 360 m and a grade of 6.0%; the other has a radius of 545 m, with a length of 221 m and a grade of 2.6%.

The 513-m-long tangent had a posted speed limit of 70 km/h. There were no signs for the local speed limits at any of the other sites. Therefore, the Portuguese speed limit of 90 km/h for two-lane rural roads applies.

The pavement along the whole extension of the road section studied was considered to be in good condition.

Data Collection

The data were collected and recorded with traffic counting devices, consisting of a Doppler radar sensor with an integrated Flash RAM data memory and a real-time clock. Data download is performed by connecting these devices to a computer, either by means of a serial or a Bluetooth.

The traffic counters were placed approximately at the midpoint of the selected tangents and curves, with the lighting poles on the roadside to fix the equipment. The average mounting height of 2.5 m and the traffic counters' position were selected to avoid biased behavior by drivers. This precaution was taken because drivers tend to brake given when they see unfamiliar objects installed on the roadside.

Data collection was performed under clear weather conditions (dry pavement) and for a period of 12 h (between 8:00 a.m. and 8:00 p.m.) to evaluate the hourly traffic volumes between the morning and the afternoon peaks. Not even at peak hours did the traffic reach a congested level.

Data Description

A database was constructed for each site, containing each vehicle's passing time (hh:mm:ss), speed, and gap to the vehicle ahead.

Previous tests with the same traffic counters revealed that these devices detect and register the presence of pedestrians. To remove pedestrians from the collected databases, all observations with recorded speeds beneath 10 km/h were deleted. Therefore, the gaps for the following observations had to be recalculated. Pedestrian activity is usually low in rural areas, and the road section studied is not an exception. The data loss caused by pedestrian elimination was smaller than 0.1% of the total number of observations. Further, because the overtaking vehicles may have had very small gap values captured by the devices, an exploratory analysis was initially performed to verify whether for the gaps less than 0.5 s the speed differences between leading and following vehicles made sense in a platoon condition. For all studied sites, more than 35% of the following vehicles registered a greater speed than leading vehicles, sometimes with values higher than 10 km/h. For this reason, the gap value equal to zero was not included in studying the free gap.

For both directions in each site, the average and the standard deviation values of recorded hourly traffic volumes and speeds are presented in Table 1. These values reflect the database before the records of gap values less than 0.5 s were removed.

Free Gap Definition

Steps 2, 3, and 4 of the methodology were applied for each of the four studied sites. To facilitate the comparative analysis, the results of the two straight segments for Steps 2 and 3 are presented in the same figures (Figures 2 and 3). In all figures, the gap value of 16 represents all records related to gaps greater than and equal to 16 s. The same was done for the two curved segments (Figures 4 and 5). Table 2 presents the major statistics and the equations related to the four logistic regression models, and Tables 3, 4, and 5 show the overall gap analysis results for all four sites studied.

Two observations arise from Table 5. The first is that the found free gap is not significantly different for each site, with the difference between the maximum and the minimum values being smaller than 1 s. If one considers the case of cars (about 4.5 m long) at the average speed value measured at each site, the corresponding free headways would be 5.6 s for Tangent 1 and Curve 1; 5.3 s for Tangent 2; and 4.9 s for Curve 2. In rounded values, these values are the same as the rounded gaps shown.

Moreover, in the cases of Tangent 2 and Curve 1, the application of Step 3 resulted in wider ranges for the regions between NFG and

TABLE 1 General Data on the Sites Selected

Data Description	Tangent 1 Length = 240 m, Grade = 2.6%	Tangent 2 Length = 513 m, Grade = 1.9%	Curve 1 Radius = 220 m, Length = 360 m, Grade = 6.0%	Curve 2 Radius = 545 m, Length = 221 m, Grade = 2.6%
Number of vehicles	7,156	10,637	8,503	6,637
Bidirectional hourly volume (vph)				
Average	596	886	709	553
Standard deviation	132	237	186	147
Minimum	430	564	452	359
Maximum	835	1,331	1,063	790
One-way hourly volume (vph)				
Average	298	443	354	277
Standard deviation	77	152	115	78
Minimum	197	280	200	173
Maximum	499	904	718	473
Speed (km/h)				
Average	73.3	67.7	63.8	72.0
Standard deviation	15.7	14.4	14.2	15.5

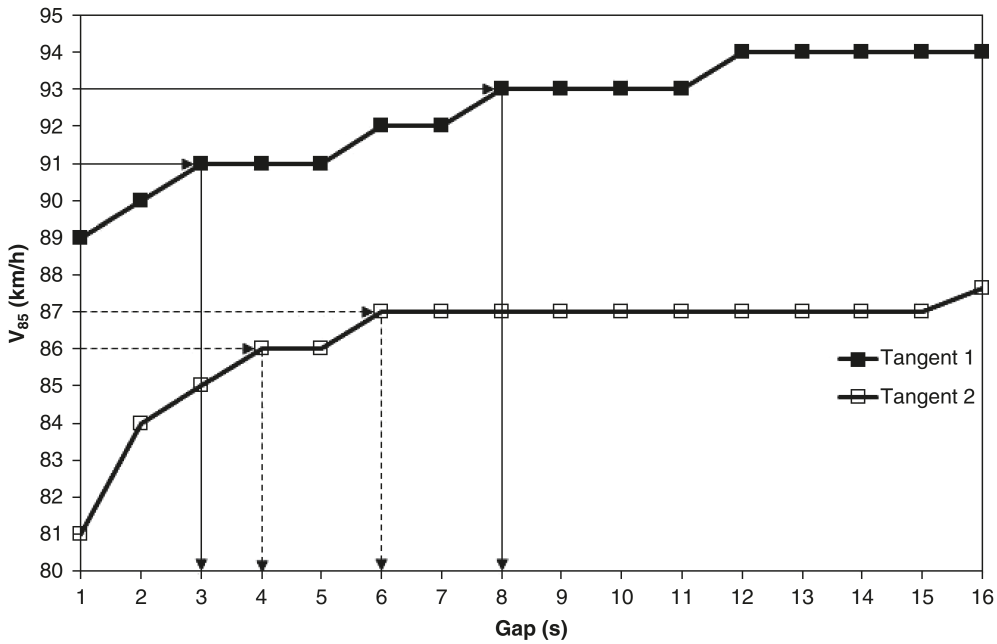

FIGURE 2 Results of Step 2 for the sites in tangent.

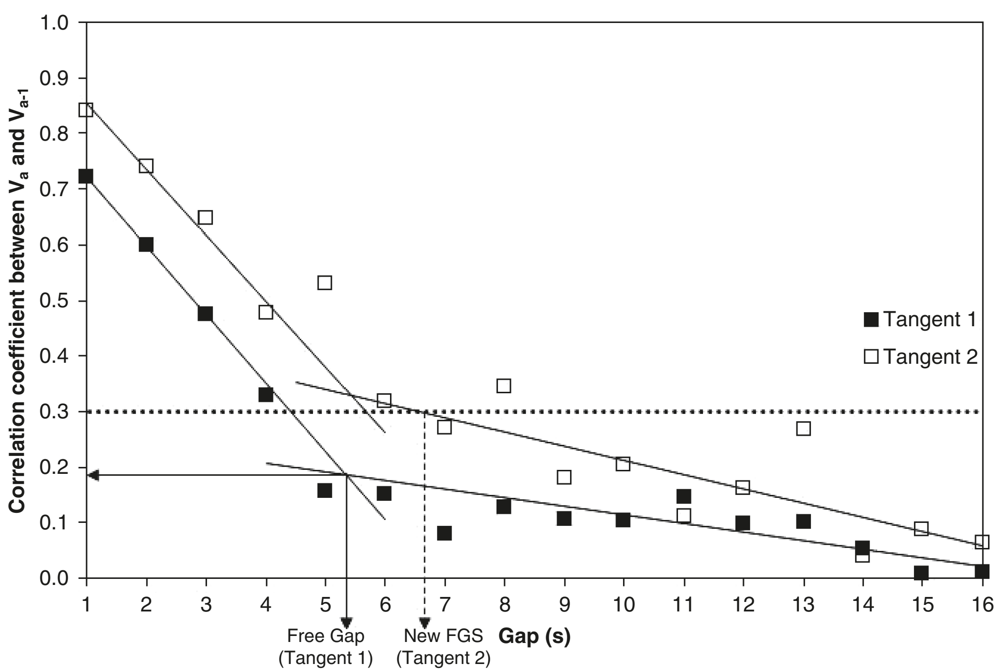

FIGURE 3 Results of Step 3 for the sites in tangent.

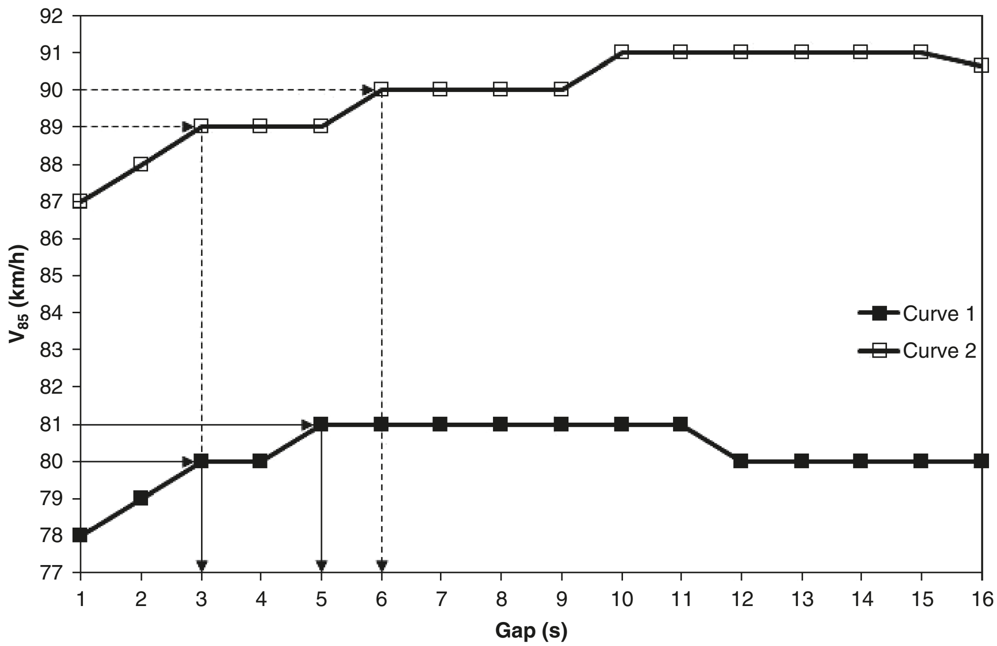

FIGURE 4 Results of Step 2 for the sites in curve.

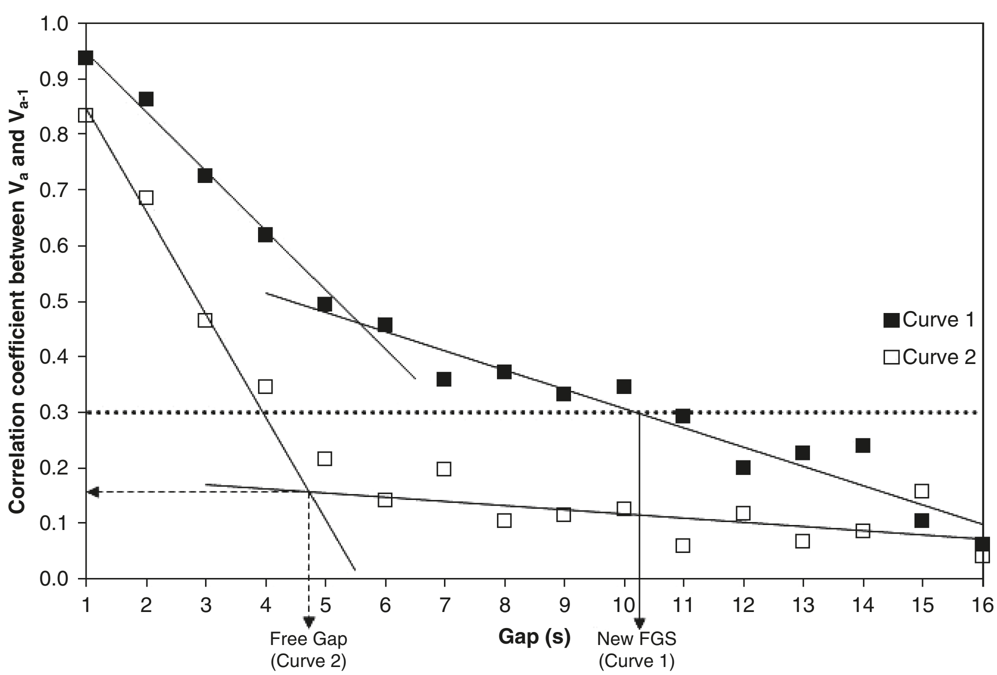

FIGURE 5 Results of Step 3 for the sites in curve.

TABLE 2 Logistic Regression Models

Site	Parameter	Estimated Value	Standard Error	$P[\|Z\|>z]$
Tangent 1	β_0	−5.986	0.183	0.000
	β_1	3.971	0.114	0.000
	Goodness of fit			
	Log likelihood	−1,299.561		
	Number of observations	6,696		
Tangent 2	β_0	−12.523	0.412	0.000
	β_1	7.735	0.251	0.000
	Goodness of fit			
	Log likelihood	−941.171		
	Number of observations	9,796		
Curve 1	β_0	−5.799	0.153	0.000
	β_1	3.426	0.086	0.000
	Goodness of fit			
	Log likelihood	−1,488.501		
	Number of observations	7,702		
Curve 2	β_0	−7.988	0.292	0.000
	β_1	5.609	0.197	0.000
	Goodness of fit			
	Log likelihood	−816.839		
	Number of observations	6,232		

TABLE 3 Summary of Results from Step 2

	Non–Free-Gap Region		Free-Gap Region	
Site	Initial Gap (s)	Final Gap (s)	Initial Gap (s)	Final Gap (s)
Tangent 1	1	3	8	16+
Tangent 2	1	4	6	16+
Curve 1	1	3	5	16+
Curve 2	1	3	6	16+

FGS, with the free gaps being obtained only at Step 4. In fact, higher speed correlations occurred for both sites, since Tangent 2 presents the higher average hourly volume of 886 vehicles per hour (vph) and Curve 1 presents the steeper grade of 6.0% (heavy vehicles may disturb traffic flow). However, the free gaps obtained at Step 4 for these two sites are similar to the values estimated for Tangent 1 and Curve 2, which may reveal that there are no relevant differences in drivers' approaching behavior.

Because the purpose of the application was to find a single rounded free-gap value covering the requirements for free-flow speed at all sites to be studied along Portuguese roads, the more conservative choice was to select the gap of 6 s as the free gap. This value was suitable for all the sites studied, and it may serve as a reference for future data collection on operating speed. This choice also does not require excessively long periods of field collection for most Portuguese rural roads. In future research on operating speed along Portuguese roads, the necessary validation of the selected value for other sites will be possible.

The free gap produced by this study, which led to a 6-s free headway, differs from the commonly used 5-s free headway. It is clearly different from the 3-s free-flow headway recommended by the HCM 2000 (*3*). This result implies that further international studies are also required.

Volume Evaluation

The application of the last step of the methodology proposed, considering the hourly volume data collected during the 12-h period studied, indicated that hourly volumes in the range from 250 to 500 vph were suitable for the data collection intended.

TABLE 4 Summary of Results from Step 3

	Non–Free-Gap Region		Free-Gap Region		Free Gap	
Site	Equation	R^2	Equation	R^2	Value	Correlation
Tangent 1	$Y = -0.1229X + 0.8448$	1.00	$Y = -0.0153X + 0.2673$	0.72	5.4	0.19
Tangent 2	$Y = -0.1179X + 0.9712$	0.98	$Y = -0.0254X + 0.4664$	0.65		>0.30
Curve 1	$Y = -0.1068X + 1.0550$	0.97	$Y = -0.0347X + 0.6542$	0.92		>0.30
Curve 2	$Y = -0.1846X + 1.0306$	0.99	$Y = -0.0075X + 0.1929$	0.30	4.7	0.16

TABLE 5 Results from Steps 3 and 4 and Complementary Analysis

	Step 3		Step 4			
Site	Free-Gap Value (s)	Free-Gap Range (s)	Free Gap (s)		$P(Y=1)$ (%)	Rounded Free Gap (s)
Tangent 1	5.4		5.4	→	67.1	6
Tangent 2		4–7[a]	5.1	←	50.0	6
Curve 1		3–11[b]	5.4	←	50.0	6
Curve 2	4.7		4.7	→	66.7	5

[a] Free-gap range does not include values 4 or 7.
[b] Free-gap range does not include values 3 or 11.

CONCLUSIONS

As for any type of highway, the definition of gap values, as well as headway values, associated with vehicles operating in free-flow conditions is an important issue for data collection planning focusing on operating speed measurements along two-lane, two-way highways. There is no consensus in the literature regarding the gap or headway value from which the free-flow conditions generally hold, given noncongested traffic flow situations. However, in many studies, 5-s headways have been used as a reference value for data collection on free-flow vehicles' speed, and it seems to be an underestimated value when compared with the 6-s free gap found in this paper. Most studies do not question the possible differences that may occur from site to site as a reflection of road geometry and from area to area (city, state, or country) as a function of general driver behavior.

Nonetheless, one cannot simply adopt a very high reference value that will cover the conditions of all possible sites and places. Because field data collection usually requires important technical and financial resources, it is essential to generate good quality data in the least amount of time possible. The assumption of very high gaps (or headways) for representing free-flow vehicles will imply longer data collection periods or will limit the collection period to hours of very low traffic flow. In both cases, the optimal use of available resources, especially automatic data collection equipment, cannot be achieved. The methodology presented in this paper seeks to cope with this situation by defining the gap value representing the free-flow speed situation (free gap) for a particular planned operating speed study.

The proposed five-step methodology was applied to estimate the free-gap values in four selected sites that present diverse geometric features (tangents with different extensions; curves with different radii and grades). The results indicate cohesiveness among the four sites, with free-gap values varying from 5 s to 6 s. Because the purpose of this study was to obtain a single rounded free-gap value as a reference for Portuguese two-lane rural roads, the selected free gap is 6 s. The results also show that the commonly used free-flow headway of 5 s effectively applies to some sites. However, the use of 5 s as a general reference must be reviewed, as well as the HCM recommended value, which was lowered from 5 s to 3 s after the review conducted in 2000 (*3*).

Further validation of the selected free-gap values calculated for Portuguese conditions is planned to be performed in the near future as part of the ongoing research on an operating speed prediction model for the country's two-way, two-lane rural highways.

ACKNOWLEDGMENT

This study was conducted through the SAFESPEED project, financed by the Portuguese Science and Technology Foundation.

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The Operational Effects of Geometrics Committee peer-reviewed this paper.