

headway require more frequent attention than has been given to this matter.

From the discussion just presented it is recommended that a systematic framework of research needs on entering headways be drawn that specifies frequency, location, and factors to be studied in a coordinated and comprehensive manner. This framework would then be made known to universities and other research institutions so that research efforts to advance the state of the art on entering headways could be guided in an organized and useful manner.

REFERENCES

1. B. D. Greenshields, D. Schapiro, and E. L. Ericksen. *Traffic Performance at Urban Street Intersections*. Eno Foundation for Highway Traffic Control, 1947.
2. R. M. Bartle, V. Skoro, and D. L. Gerlough. Starting Delay and Time Spacing of Vehicles Entering Signalized Intersection. *Bulletin 112*, HRB, National Research Council, Washington, D.C., 1956, pp. 33-41.
3. D. L. Gerlough and F. A. Wanger. *NCHRP Report 32: Improved Criteria for Traffic Signals at Individual Intersections*. HRB, National Research Council, Washington, D.C., 1967, 34 pp.
4. R. L. Carstens. Some Traffic Parameters at Signalized Intersections. *Traffic Engineering*, Vol. 41, No. 11, Aug. 1971.
5. G. F. King and M. Wilkinson. Relationship of Signal Design to Discharge Headway, Approach Capacity, and Delay. In *Transportation Research Record 615*, TRB, National Research Council, Washington, D.C., 1976, pp. 37-44.
6. Y.-J. Lu. A Study of Left-Turn Maneuver Time for Signalized Intersections. *ITE Journal*, Vol. 54, No. 10, Oct. 1984.
7. *Special Report 209: Highway Capacity Manual*. TRB, National Research Council, Washington, D.C., 1985.

Publication of this paper sponsored by Committee on Highway Capacity and Quality of Service.

Traffic Operation on Busy Two-Lane Rural Roads in The Netherlands

HEIN BOTMA

In the framework of updating standards for describing the quality of traffic flow on two-lane rural roads, research into the behavior of the traffic flow on relatively high-volume roads was carried out. Presented in this paper are findings about the relation between the volume and traffic composition as explanatory factors for speeds, headways, and platooning. It was found that mean speed was only marginally influenced by volume and truck percentage, whereas the standard deviation of speeds decreased substantially with increasing volume. An exponential tail model for headways, large enough to be relevant for passing opportunities, was used and its parameters were successfully related to volume. This model fits reality much better than the assumption that headways have a negative exponential distribution, which leads to severe underestimation of passing opportunities. Simple models were developed that relate the proportion of vehicles following in a platoon and the maximum platoon length in 5 min to volume and truck percentage. A comparison is made with results in the proposed Chapter 8 on Two-Lane Highways of the 1985 *Highway Capacity Manual*.

In The Netherlands, as in many other countries, traffic engineers have used information from the 1965 *Highway Capacity Manual* (HCM) to a considerable extent. However, it was increasingly believed that the procedures and data in the HCM were not always applicable. Some factors were clearly different in the United States and The Netherlands, for example, capabilities of automobiles and trucks. Moreover, some data in the HCM appeared to be outdated, as was probably realized first in the United States.

As part of determining and updating standards for design of all types of rural roads, the Transportation and Traffic Engineering Division of the Dutch Ministry of Transport and Public Works has given attention to two-lane rural roads for motor vehicles, that is, roads without bicycles or low-speed motorbikes (mopeds) on the carriageway. Given in this paper are some results of research into the behavior of the traffic flow at relatively high volumes. This behavior is relevant for determining the service volumes that define the levels of service.

As is generally accepted, speed is no longer the only most suitable criterion on which to base level of service because speeds do not depend on volume that much any more. Speed was replaced by a general criterion that can best be described as

Transportation Research Laboratory, Department of Civil Engineering, Delft University of Technology, P.O. Box 5048, 2600 GA Delft, The Netherlands.

freedom to maneuver, a concept that was translated into operational quantities such as passing possibilities, waiting time before a passing can be carried out, proportion of vehicles in a platoon, and platoon length. Based on partly known and partly estimated relations of several quantities with volume, preliminary service volumes were chosen that should be applicable for road sections with ideal geometrics and with 100-percent person cars.

To provide a stronger base for the procedure, answers were needed to questions about assumptions, relations, and values of parameters used. Goals of the study were formulated by a committee in which several Dutch road administrators participated; this study was carried out under contract by a Dutch consultant, Bureau Goudappel Coffeng B.V. at Deventer, and the Transportation Research Laboratory of the Delft University of Technology. This paper is restricted to a part of the research carried out by the Transportation Research Laboratory and does not address any consequences of the procedure used to determine the service volumes.

RESEARCH GOALS AND METHODS

Briefly, the goals of the research are to determine the relation between volume and vehicle composition and the following: speeds, headways, and platoons. This should be done on two-lane rural roads with ideal geometrics, that is,

- Level and straight sections with sufficient sight distance over at least 0.6 mi (1 km).
- Lane width between the lines of 10.2 to 10.7 ft (3.1 to 3.25 m) and clear shoulders; [the total pavement width is 23 to 25 ft (7 to 7.5 m); hence, no paved shoulders that make easy passing maneuvers possible are present].
- No intersections or other disturbances over at least 1.2 mi (2 km).

The roads should be busy, that is, with annual average daily traffic (AADT) greater than 10,000 vehicles, and weather conditions should be good.

Consequently, the explanatory factors are volume and traffic composition. Because there are two flows on a two-lane road, it was decided to define four factors in relation to volume and traffic composition in each direction. Only two types of vehicles were considered: person cars and trucks. Although it was recognized that there is a wide range of types of trucks that differ in size and power, because road authorities have data mostly on one general truck percentage, it was not considered relevant to differentiate further.

In U.S. literature, much attention is paid to the presence of recreational vehicles. Although there are roads in The Netherlands that have a high percentage of automobiles towing caravans in certain seasons, this problem did not have sufficient importance to be addressed in this rather general research.

The four factors defined in relation to volume and traffic composition in each direction were speeds, headways, platoons, and homogeneousness. Each of these factors will be discussed further.

Speeds

It was decided to represent speeds by their mean and standard deviation. Although it was known in advance that mean speed is not influenced much by volume, it was considered worthwhile to check this point again. The standard deviation of speeds was considered to be relevant for passing demand and as a measure of homogeneousness of the speeds. It was expected that it would decrease with volume, but the size of the decrease was unknown.

Headways

Passing opportunities on a two-lane road, given the sight distance is sufficient, are determined by the distribution of headways of the opposing flow. A well-known and much-used assumption is that headways have a negative exponential distribution (NED). It is then simple to calculate the proportion of headways greater than, for example, 20 sec, that can be considered to represent passing opportunities. It is also known that the NED assumption is valid only for low volumes; however, up to which volume is it applicable and what is the error for higher volumes? The goal of the research, therefore, was to determine if the NED assumption is a useful approximation, and, if not, to indicate its error when calculating the frequency of large headways.

Platoons

When passing demand exceeds passing opportunities, vehicles will have to be driven in platoons. Consequently, the level of platooning can be considered to represent an aspect of the quality of the traffic flow as experienced by the drivers. The problems are as follows:

- Determining when a vehicle belongs to a platoon, and
- Defining simple parameters that represent the level of platooning.

Concerning the first problem, to keep things simple, it was decided to define a platoon leader as a vehicle with a headway greater than h_0 sec; hence, followers in a platoon have a headway smaller than h_0 . In a preliminary analysis of the data, h_0 was given the values of 4, 5, and 6 sec. It was found that results with these three values were congruent and no preference could be deduced. Nor did speed differences between a follower in a platoon and his predecessor make it possible to discriminate among the three values. Finally, a value of 5 sec was chosen, in accordance with a proposal of the Organisation for Economic Cooperation and Development (2) and based on a detailed research of following behavior on a two-lane road by Botma et al. (3). The same value was later chosen for the proposed 1985 HCM (4).

Concerning the second problem, the level of platooning—as experienced by the drivers—can be well represented by the proportion of drivers that are following in a platoon. Given the platoon definition used, this proportion of hindered drivers

equals the proportion of headways less than 5 sec. To gain insight into the size of large platoons, the maximum platoon length that passed in 5 min was also analyzed.

Homogeneous

In most research of traffic flow on homogeneous two-lane roads, it is tacitly assumed that the properties of the flow are also homogeneous. However, when passing demand exceeds passing possibilities it can be expected that, moving in the direction of the traffic stream on a lane, the speeds will decrease and the platooning will increase.

In preliminary research, this expectation was confirmed with respect to platooning; however, with respect to speed, results were inconclusive. To obtain more knowledge of this phenomenon, it was decided to collect data simultaneously at three cross sections of homogeneous road sections at distances of 0.3 mi (0.5 km).

DATA COLLECTION

Data were collected in 1984 at five road sections throughout the country, and with AADT ranging from 10,000 to 25,500 vehicles (see Table 1). Measurements were carried out simultaneously at both lanes and three cross sections 0.3 mi (0.5 km) apart. From each passing vehicle, the moments that the axles passed a cross section were registered on magnetic tape. Using these moments, the following items per vehicle can be calculated: passing moment, headway, speed, wheelbases, and vehicle type. The vehicle type is deduced from the number of axles and the distances between them. Data were collected on two days and during three periods per day, morning rush hours (7 to 9 a.m.), nonrush hours (2 to 4 p.m.), and evening rush hours (4 to 6:30 p.m.)

TABLE 1 STUDY SITE DATA

Site No.	Site Name	AADT (no. of veh/24 hr)	Average Truck Percent	Speed Limit	
				mph	km/h
1	Vinkeveen	16,400	15	50	80
2	Hellegat	13,900	14	62	100
3	Grouw	10,100	12	62	100
4	Maarn	25,500	24	50	80
5	Doenkade	17,900	13	50	80

The passing of vehicle axles is detected with fairly unobtrusive, thin rubber tubes of 0.2 in. (5 mm) diameter at a distance of 3 ft (1 m) on the road. In preliminary research, it was found that only during the first 24 hr after installation did there appear to be a small decrease in speeds. Consequently, the tubes were installed at least 1 day before the measurements were carried out, giving the regular passing driver the opportunity to become accustomed to them. Most drivers probably did not notice the tubes because all other cables and the van with equipment were perfectly hidden.

ANALYSES AND RESULTS

Time Interval

To analyze the relations described in the Section Research Goals and Methods, it was necessary to divide the measurement periods of at least 2 hr into smaller time intervals. A 5-min interval was chosen as a compromise between having a rate of flow that is fairly constant and having a sufficient number of vehicles in an interval. This interval also proved to be satisfactory in a recent Canadian research on two-lane roads (5). Care was taken that no platoons were cut into pieces and distributed over two neighboring intervals by shifting the boundary between two intervals slightly.

Procedure

It was found that results of the two days were not considerably different and consequently could be combined into one data set, which meant that there were 30 data sets left, from 5 locations, 3 periods, and 2 directions. Because the 5-min interval was used, at least 48 data points were available per data set. Relations were obtained separately for each data set, and combinations were made dependent on the results. This was done by using statistical testing and deciding if significant differences were relevant from a practical engineering point of view.

Technique

Linear regression was used to investigate the relations that were assumed to be mostly linear. Nonlinear relations were hypothesized only when they could be theoretically based or when the data gave firm evidence of nonlinearities.

Mean Lane Speed

The mean lane speed was related to the volume and the truck percentage in both directions. It was found that only volume and truck percentage of the same direction had a linear influence on the mean lane speed. Relations were weak, and the explained variance varied from 4 to 55 percent. Over the lane-volume range of 300 to 1,100 vehicles per hour (vph), mean speed decreased on the average 6 mph (10 km/h). This confirms the expectations that the speed-volume curve is rather flat. The range of truck percentage was 5 to 30 percent; leading to a decrease in mean speed of 3 mph (5 km/h) on the average, which is rather small.

Mean lane speed was rather inhomogeneous; changes over 0.6 mi (1 km) were significant in two-thirds of all data sets. In most cases, the mean lane speed decreased in the direction of the stream, as was expected; however, in two cases it increased. This phenomenon is not yet understood, and it can only be concluded that road sections longer than 0.6 mi (1 km) are needed to provide additional understanding. Consequently, the absolute level of mean speed is somewhat unknown, its range being 50 to 62 mph (80 to 100 km/h).

Mean Two-Way Speed

Mean two-way speed was related to the two-way volume, the two-way truck percentage, and the imbalance between the lane volumes. This imbalance was defined as (maximum lane volume/minimum lane volume) minus 1 [see, for example, Steierwald and Schmidt (6)].

It was found that only volume and truck percentage had a significant and linear effect on mean speed. Relations were somewhat stronger than for mean lane speed, but still rather weak: 11 to 63 percent explained variance. Over the two-way volume range of 600 to 2,000 vph, mean speed decreased on the average 7½ mph (12 km/h); over the truck percentage range of 5 to 30 percent, an average decrease of 3 mph (5 km/h) was found.

Results of mean lane speed and mean two-way speed are fairly consistent; in both cases, volume and vehicle composition have a rather small influence.

Standard Deviation of Lane Speeds (SIGMA)

It was found that the data sets had a consistent behavior and that the inhomogeneities found did not prevent the combination of all data. The total result was (in mph):

$$\text{SIGMA} = 8.5 - 2.3 \cdot 10^{-3} \cdot Q_1 - 1.2 \cdot 10^{-3} \cdot Q_2 \quad (1)$$

(3.4%) (21%) (41%)
R² = 66% N = 30

where Q₁ is lane volume in direction of SIGMA, and Q₂ is the opposing volume. The standard errors of the coefficients are placed underneath in parentheses.

Hence, in this case, lane volumes in both directions have a significant influence on the standard deviation. However, the influence of the opposing volume is relatively small and its standard error rather high. It may be more practicable to use a model with only Q₁ as a factor, that is,

$$\text{SIGMA} = 8.3 - 2.9 \cdot 10^{-3} \cdot Q_1 \quad R^2 = 60\% \quad N = 30 \quad (2)$$

(3.4%) (15.5%)

The latter equation means that over the range of lane volumes of 300 to 1,100 vph, the standard deviation decreases from approximately 7.5 to 5 mph (12 to 8 km/h), a substantial change. Moving in the direction of the flow, SIGMA decreases on the average by 7 percent over 0.6 mi (1 km), an inhomogeneous that cannot be overlooked and can be interpreted as more platooning.

Headways

In a preliminary analysis, it was found that the NED did underestimate the frequency of large headways. As an alternative to the NED, an exponential tail (ET) model was used, taken from the family of semi-Poisson headway models [see, for example, Branston (7)]. In this model, it is assumed that for headways greater than a certain value T, vehicles do not interact and the distribution is exponential. The form of the distribu-

tion for shorter headways is not relevant for the frequencies of large headways. A value of 10 sec was chosen for T to ensure that the condition of no interaction was fulfilled. The probability that a headway h is greater than a fixed value h_i is as follows:

$$P_i = \text{Pr} (h > h_i) = P_o \cdot \exp[-\lambda \cdot (h_i - T)] \quad (3)$$

Parameter P_o is the probability that headways are greater than T seconds and parameter λ determines the steepness of the tail.

P_o and λ can be estimated for each time interval and related to the explanation factors. It was found that only the lane volume of the direction considered had a significant effect and that 11 data sets could be combined. The final models were as follows:

$$\ln (P_o) = -0.286 - 2.29 \cdot 10^{-3} \cdot Q_1 \quad R^2 = 86\% \quad N = 1,582 \quad (4)$$

(5.1%) (1.0%)

$$\lambda = 0.0314 + 0.132 \cdot 10^{-3} \cdot Q_1 \quad R^2 = 27\% \quad N = 1,582 \quad (5)$$

(11.0%) (4.1%)

Substituting these relations into the ET model (Equation 3) leads to

$$\ln (P_i) = 0.028 - 0.97 \cdot 10^{-3} \cdot Q_1 - 31.4 \cdot 10^{-3} \cdot h_i - 0.132 \cdot 10^{-3} \cdot Q_1 \cdot h_i \quad (6)$$

The latter formula is used to determine the proportion of headways greater than 14, 17, 21, and 23 sec for each 5-min interval and to do the same using the NED. The chosen values of the headways stem from a part of the study on passing behavior that is not described in this paper.

It can be observed from the data in Table 2 that the mean difference between calculated and measured proportion is small for the ET model, and large and always negative for the NED. The standard deviation of the differences is rather high; however, it should be realized that the number of large headways in 5 min is a highly fluctuating quantity.

It is remarkable that although the relation of λ with Q₁ (Equation 5) is rather weak, the end results are satisfying. It

TABLE 2 MEAN AND STANDARD DEVIATION OF PROPORTIONAL DIFFERENCES BETWEEN CALCULATED AND MEASURED PROPORTION OF HEADWAYS GREATER THAN 14, 17, 21, AND 23 SEC ACCORDING TO EXPONENTIAL TAIL (ET) MODEL AND NEGATIVE EXPONENTIAL DISTRIBUTED (NED) HEADWAYS

Headway (sec)	Mean Differences (%)		Standard Deviation Differences (%)	
	ET	NED	ET	NED
14	1.4	-15.9	34	31
17	0.4	-26.0	42	36
21	0.0	-39.4	51	41
23	-1.2	-39.0	53	41

should be added that the ET model should not be used for lane volumes less than 300 to 400 vph, in which case preference should be given to the NED. This point is shown in Figure 1, in which the number of headways greater than 21 sec is given as a function of the lane volume according to the ET model and the NED.

To investigate the homogeneity of the headways, the standard deviation was analyzed. It was found that it increased moving with the flow, corresponding to more large headways and larger platoons.

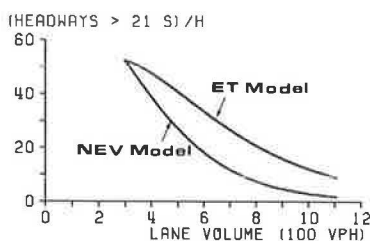


FIGURE 1 Relationship between number of headways greater than 21 sec and lane flow according to exponential tail model and negative exponential distributed headways.

Platooning

The proportion of hindered vehicles in platoons (PRHIN) and the maximum platoon length in 5 min (expressed in number of vehicles and denoted by MAXLEN) were related to the explanatory factors. It was found that the lane volume (Q_1) and the truck percentage (TP_1) of the flow considered gave the most satisfying models.

All data sets could be combined, leading to the following:

$$\text{PRHIN} = 1 - \exp[-1.70 \cdot 10^{-3} * Q_1 - 6.69 \cdot 10^{-3} * TP_1] \quad (7)$$

(1.3%) (8.5%)
 $R^2 = 77\% \quad N = 1,582$

$$\text{MAXLEN} = 2.90 * \exp[1.84 \cdot 10^{-3} * Q_1 + 4.02 \cdot 10^{-3} * TP_1] \quad (8)$$

(2.6%) (1.9%) (25.4%)
 $R^2 = 64\% \quad N = 1,582$

It can easily be derived that according to an NED and a platoon criterion of 5 sec, Equation 7 would have been

$$\text{PRHIN} = 1 - \exp[-5 * Q_1/3,600] \quad (9)$$

This can be compared with Equation 7 with TP_1 set at 0, leading to

$$\text{PRHIN} = 1 - \exp[-6.12 * Q_1/3,600] \quad (10)$$

Consequently, one needs to replace 5 sec with 6.12 to compensate for the facts that the NED is not valid and that the real level of platooning is higher. The inhomogeneity of PRHIN and MAXLEN was consistent with that of the standard deviations of the speeds and headways. Moving in the direction

of the flow, on the average PRHIN increased by 2.6 percent and MAXLEN by 0.7 vehicle over 0.6 mi (1 km). The extra representation of the platooning by MAXLEN does not lead to much independent information because PRHIN and MAXLEN have a correlation coefficient of 0.76, and the logarithms of both variables correlate even with 0.88.

COMPARISON WITH PROPOSED 1985 HCM

At the end of this project, the proposed Chapter 8 on Two-Lane Highways of the 1985 HCM became available (4). In this proposal, two relations are given that can be compared with results of this research, that is, mean two-way speed and the percent time delay as a function of two-way volume.

In Figure 2, the relationship between average speed and volume is given according to the proposed 1985 HCM and the corresponding data found in this research, corrected to a truck percentage of zero by means of the regression equations found. It can be concluded that mean speeds on two-lane roads with ideal geometrics found in this research are 3 to 6 mph (5 to 10 km/h) higher than the average result obtained in the United States.

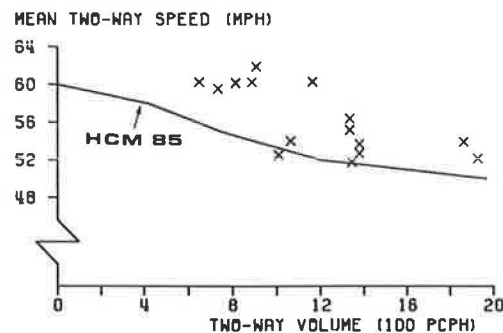


FIGURE 2 Relationship between average two-way speed and two-way volume according to the proposed 1985 HCM and the values found in this research.

The percentage time delay in the 1985 HCM is considered to be the most relevant criterion for level of service. It is operationally defined as the proportion of vehicles with headways less than 5 sec, so it is equal to the proportion of hindered vehicles (PRHIN) in this paper. Its dependence on volume is given for a two-way volume and ideal conditions, which includes a 50/50 directional split. Consequently, it can be assumed that the relation is the same for both lane flows.

Table 3 gives a comparison for volumes equal to the service volumes of the HCM. It can be concluded that the differences between both results are surprisingly small. It should be added that the model presented in this paper is not valid for volumes much greater than 1,200 vehicles per lane and hour, and that its exponential form makes it impossible to reach 100 percent hindered vehicles at capacity.

In interpreting the conclusions reached, the general conditions of this study should be kept in mind. Data were collected on two-lane rural roads with ideal geometrics and under good weather conditions; lane volumes had a range of 300 to 1,100

TABLE 3 COMPARISON OF PERCENT TIME DELAY OF PROPOSED 1985 HCM AND RESULTS OF THE MODEL IN THIS PAPER

Level of Service	Percent Time Delay (United States ^a)	Volume-to-Capacity Ratio	Service Volume	Percent Time Delay (The Netherlands ^b)
A	<30	0.15	420	30.0
B	<45	0.27	750	47.1
C	<60	0.43	1200	63.9
D	<75	0.64	1800	78.3
E	>75	1.00	2800	—

^aUsing the proposed 1985 *Highway Capacity Manual* (HCM).

^bUsing the results of the model in this paper.

vph and two-way volumes of 600 to 2,000 vph, and the truck percentage varied from 5 to 30 percent.

Theoretical analysis of the traffic flow process on a two-lane rural road leads to expectations that the flows in both directions are interacting and have dependent properties. However, in this rather practical research it was seldom found that opposing volume and truck percentage substantially influenced the properties of the flow considered. Part of this lack of influence may be due to dependencies between explanatory factors; lane volumes had a correlation of 0.37 with each other and lane truck percentages had a correlation of 0.36. Correlations between lane volumes and truck percentages were not greater than 0.1.

Mean lane speed decreases with lane volume and lane truck percentage; the decrease is relatively small. Mean two-way speed decreases with increasing two-way volume and two-way truck percentage. In accordance with mean lane speed, the decrease is minor. No influence of the directional split could be detected. Values found in this study are somewhat higher [3 to 6 mph (5 to 10 km/h)] than mean speeds presented in the proposed 1985 HCM, referring to both roads and traffic with practically the same ideal conditions.

Standard deviation of lane speeds decreases with lane volumes in both directions but is not dependent on truck percentage. Over a lane volume range of 300 to 1,100 vph, the standard deviation decreases from approximately 7½ to 5 mph (12 to 8 km/h).

The frequencies of large headways that are relevant for passing opportunities can be predicted by a model that needs only lane volume as an input. The model is valid for lane volumes greater than 300 to 400 vph and shows that the assumption of negative exponential distributed headways leads to a severe underestimation of the frequency of large headways.

The level of platooning can be well represented by the proportion of vehicles that have to follow in a platoon. This proportion depends on the lane volume and truck percentage. There is a good similarity between this model and the relation presented in the proposed 1985 HCM.

Traffic flow on homogeneous sections of two-lane rural roads can still be inhomogeneous, that is, properties of the flow change with the position along the road. Moving with the flow

on a lane, the standard deviation of speeds decreases and that of headways increases. These two changes are consistent with larger platoons and more frequent large headways that were found. However, the phenomenon is only partly understood and requires more research over sections of roads that are substantially longer than 0.6 mi (1 km), which were used in this study.

ACKNOWLEDGMENT

The research described in this paper was sponsored by the Dutch Ministry of Transport and Public Works, more specifically, the Transportation and Traffic Engineering Division of Rijkswaterstaat. We wish to thank the sponsor for his permission to publish these results.

REFERENCES

1. *HRB Special Report 87: Highway Capacity Manual*. HRB, National Research Council, Washington, D.C., 1965, 411 pp.
2. *Speed Limits Outside Built-Up Areas*. Organisation for Economic Cooperation and Development, Paris, France, 1972.
3. H. Botma, J. H. Papendrecht, and D. Westland. *Validation of Capacity Estimators Based on the Decomposition of the Distribution of Headways*. Transportation Research Laboratory, Delft University of Technology, Delft, The Netherlands, 1980.
4. *Transportation Research Circular 284: Proposed Chapters for the 1985 Highway Capacity Manual*. TRB, National Research Council, Washington, D.C., Oct. 1984.
5. M. van Aerde and S. Yagar. Volume Effects on Speed on Two-Lane Highways in Ontario. *Transportation Research*, Vol. 17A, No. 4, 1983, pp. 301-313.
6. G. Steierwald and G. Schmidt. Zur Problematik des Erhebungszeitraums bei Stromzählungen des individuellen Strassenverkehrs. *Strassenverkehrstechnik*, Vol. 13, No. 2, 1969, pp. 46-55.
7. D. Branston. *Model of Single Lane Traffic Flow*. Ph.D. dissertation. University College, London, England, 1974.

Publication of this paper sponsored by Committee on Highway Capacity and Quality of Service.