Estimation of Distance Headway on Two-lane Highways Using Video Recording Technique

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ABSTRACT

Distance headway is the physical separation, in meters, between any pair of successive vehicles in a traffic lane measured from same common feature of the subject vehicles; either rear-to-rear or front-to-front. It is a significant microscopic traffic flow characteristics parameter used in various traffic engineering applications such as level of service, highway capacity analysis, traffic safety and microscopic traffic simulation. Its values are also essential in evaluation of congestion level and overtaking manoeuvre related problems. Distance headway, being spatial parameter is difficult to measure directly in the field. However, it is usually estimated from other parameters; particularly, traffic density, which is also difficult to measure directly but estimated from other parameters based on spot observation. Estimates of distance headways from such approaches may not be real representation of desired values, especially for situations where the parameter is to be evaluated at intervals over a roadway segment. This paper presents a novel approach for direct field measurement of distance headway on two-lane highways using video recording instrumented vehicle. Data for the study were collected from six segments of two-lane highways from Johor, Malaysia. Findings form the study demonstrate that the approach reported herein can be used to measure distance headway directly in the field as against the existing practice of estimating it from other variables based on spot observation despite the fact that it is a spatial parameter.

Keywords: Two-lane highways, Distance headway, Measurement, Instrumented test vehicle, Video recording

1.0 Introduction

Distance headway or spacing is referred to as the separation between two consecutive vehicles in a traffic stream measured from the same reference point of the subject vehicles; such as front or rear bumper or axles. It is an important microscopic traffic flow characteristics parameter used in many traffic engineering applications such as level-of-service and highway capacity analyses, traffic safety analysis, evaluation of congestion level and problems associated with overtaking manoeuvres. Despite the significance of distance headway in traffic engineering applications, the parameter does not lend itself easy to measure directly in the field being a spatial related index. As a result of that it is usually derived from other traffic flow parameters; specifically, traffic density (a spatial variable) which is also difficult to measure directly but estimated from other variables based on specific point observation.

Estimation of distance headway from other parameters especially those measured based on specific point observation might not represent the desired estimates; particularly for situations where the index is to be evaluated at certain intervals over a road section. Since distance headway is a spatial parameter, one possible approach to measure it directly in the field could be through the use of conventional non-contact distance measurement techniques. The most common non-contact distance measurement methods are laser-based (Chavand *et al.*, 1997; Culshaw *et al.*, 2003; KlimKov, 1996; Sviridov and Sterlyagov, 1994; Tiedeke *et al.*, 1990) and ultrasonic-based (Carullo *et al.*, 1996; Parvis and Carullo, 2001; Song and Tang, 1996) as utilized for various distance related applications. A common limitation of ultrasonic and laser-based measurement approaches is that the performance of the systems and accuracy heavily rely on the reflective properties of the object's surface under measurement. For objects whose surfaces have poor reflective properties, the systems perform poorly or completely not; they also lack the capability of recording the real time events or images of objects while making the distance measurement.

To alleviate the problems associated with the conventional non-contact distance measurement techniques and improve the accuracy of measured distance, other approaches; especially, those that do not grossly depend on the reflectivity of object surface need to be examined. This could be achieved through the application of image-based distance measurement technique using CCD (digital camera) which was found to be effective for object's distance and size related measurements (Hsu *et al.*, 2009; Lu *et al.*, 2006).

This paper presents a different approach of using image-based non-contact distance measurement technique for estimation of distance headway on two-lane highways in which data for the study were collected with the aid of video recording instrumented test vehicle.

2.0 Methodology

This study was carried out to investigate the application of videography method for estimation of distance headway on two-lane rural highway segment based on a moving video recording technique through the use of test vehicle. A video recording instrumented test vehicle was utilized for the study based on the principles of moving car observer (MCO) method (Robbertson and Findley, 2010). Data for the study were collected on six different segments of two-lane highways within Johor, Malaysia.

2.1 Data Collection

As mentioned in the preceding section, a video recording instrumented test vehicle drove into the traffic stream under study was used for the data collection. A typical passenger car equipped with a Video-Velocity-Box (VBox) was used as the test vehicle. VBox is a real-time and on-board events recording system comprising of video recorder, GPS data-logger, camera, and an SD memory card. The VBox is usually connected to the test vehicle via cigar plug system and powered by the same system. On connecting the VBox to the test car, the system detects and records the vehicle's speed at any point in time as it moves along the road section. The camera attached to the system and fixed on the test car's front windscreen records the traffic events of on roadway under study. The system automatically stores the logged events onto the memory card inserted into the VBox and subsequently uploaded for further processing.

In course of the data collection, a segment length of 3.50 km was used in which the test car was drove into the traffic stream for recording the real time traffic events. Floating-car driving technique was employed, as it was demonstrated that estimates from such driving style results in an unbiased estimates of the measured parameters and represent the average behaviour of the stream under study (Roger *et al.*, 2004). The video recorded events were then uploaded and played back in a computer to extract the needed data. In the course of the playback, the speed of the test car at any point along the roadway is displayed on the computer screen. A typical video scene during the playback is shown in Figure 1.

Figure 1: Playback Video Scene

2.2 Determination of Distance Headway

To estimate the distance headway between the test car and its lead vehicle while moving, the principle of image-based non-contact distance measurement was employed. To achieve this, the camera used for the traffic events recording was standardized (calibrated) prior to the data collection. The standardization was aimed at developing a model relating the actual distance headway, H_d (between the test car and lead vehicle) and rear width of lead vehicle (X) for various positions of lead vehicle while the test car being fixed at a particular location. This approach was employed based on the fact that the rear width of the lead vehicle decreases with increase in spacing between the two vehicles.

The calibration was conducted using two vehicles with one as test car while the other as lead vehicle. Four (4) different classes of vehicles commonly found on Malaysian roads were considered as the lead vehicles based on the Malaysian Highway Capacity Manual classification system (HPU, 2011). This was done in order cover the various classes of vehicles to be met in the field. The test car equipped with VBox system for continuous events recording was stationed at one point while the lead vehicle placed ahead of it at an initial spacing of 7.5 m rear to rear; and then varied in increment of 5 m. All events were recorded into the VBox, subsequently uploaded and played back in a computer for data extraction. During the playback, the rear width of the lead vehicle (X (mm)), was measured for each position and recorded against the actual ground distance headway, (H_d (m)) between the vehicles. From pairs of measured variables, a model relating H_d and X was developed for estimating distance headway from the video display based on the rear width of lead vehicle.

3.0 Results and Discussions

3.1 Models for Estimating Distance Headway

Four (4) separate models were developed for the four (4) common classes of vehicles found on Malaysian roads. These include; passenger cars/small vans (C1), medium size trucks/lorries (C2), large trucks/lorries/trailers (C3), and buses (C4). For all the classes considered; C1 through C4, types of vehicles with relatively same rear width were categorized into a particular class. Equations 1 to 4 shows the models developed for the classes C1 to C4, respectively.

$$\text{C1:} \quad H_d = \frac{1}{237.71X^{0.920}} \quad \{R^2 = 0.9994\} \tag{1}$$

$$\text{C2:} \quad H_d = \frac{1}{326.80X^{0.923}} \quad \{R^2 = 0.9998\} \tag{2}$$

$$\text{C3:} \quad H_d = \frac{1}{365.01X^{0.920}} \quad \{R^2 = 0.9996\} \tag{3}$$

$$\text{C4:} \quad H_d = \frac{1}{358.42X^{0.919}} \quad \{R^2 = 0.9997\} \tag{4}$$

From equations 1 to 4, for any measured value of rear width of lead vehicle (*X*) for a particular category of vehicle, the corresponding value of distance headway (H_d) is estimated. Results from the models developed demonstrate that there is a strong correlation between the dependent and the independent variables used. This is clearly confirmed by the high values of the coefficient of correlation (R^2) for all the models.

An extract of representative distance headways (spacings) measured during the calibration process across the mixed classes of vehicles are as presented in Table 1. A comparison between the actual spacings and estimated ones were compared.

Table 1: Comparison of Actual and Estimated Distance Headways

Lead Vehicle Class	C1	C1	C1	C2	C2	C2	C3	C3	C4	C4
Actual Spacing (m)	7.50	10.00	25.00	30.00	35.00	40.00	50.00	60.00	70.00	75.00
Estimated Spacing (m)	7.47	10.09	25.12	29.95	35.08	39.67	49.53	59.57	69.60	75.07
Error (%)	-0.45	0.89	0.56	-0.15	0.24	-0.82	-0.94	-0.72	-0.57	0.09

Based on the results presented in Table 1, the models developed were found to produce good estimates; as estimated spacings differ from the actual values within a percentage error of about ±1.00% only.

The proposed method presented in this study was also used for measuring distance headway in the field over a 3.50 km long segment by making series of test runs using MCO method. Table 2 presents a representative measured distance headways extracted from the observed samples. By incorporating the test car speed (V); as displayed during playback, the method can be extended to estimate 'time headway, H_t' (a significant parameter in the analysis of two-lane highways) along the roadway section. This is shown in the last column of Table 2.

Table 2: Estimated Distance and Time Headways from Proposed Method

LV Class	V (km/h)	V (m/s)	X (mm)	H_d (m)	H_t (sec/veh)
C1	53	14.72	18.0	22.77	1.55
C2	51	14.17	10.5	37.38	2.64
C1	54	15.00	6.0	45.72	3.05
C2	62	17.22	8.0	48.01	2.79
C2	64	17.78	5.0	73.99	4.16
C1	66	18.33	6.5	42.47	2.32
C2	34	9.44	33.0	13.03	1.38
C4	56	15.56	14.0	31.61	2.03
C2	66	18.33	6.5	58.12	3.17
C2	41	11.39	17.0	24.00	2.11

LV = Lead vehicle, X = rear width of LV

4.0 Conclusions

This research attempted to appraise the application of image-based non-contact distance measurement technique for measuring distance headway on two-lane highways using a video recording instrumented vehicle. Based on the results obtained from this study, the following conclusions were drawn:

i. The calibration method presented in this study can be applied to other types of digital camera for various kinds of distance related measurements.

ii. The proposed approach presented in this work can be used for measurement of distance headway along highway segment.

iii. For known test vehicle speed as in the case of this research, time headway can also be estimated as the quotient of the measured spacing and test vehicle's speed.

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