Comparative Assessment of Macroscopic Traffic Flow Properties Estimation Methods: A Case for Moving Car Observer Method

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Abstract: *Different methods of estimating macroscopic traffic properties is expected to have varying results even when they are carried out on the same road and during the same time interval. A comparative assessment was carried out between traffic data collected at a point and that collected over a short section; Moving car observer method(MCO). Student's t-test was used to evaluate both data and it was observed that there was no significant difference between them. The MCO method correlates well with conventional data collection method and it can be used as a substitute for it, assuming conventional data collection method is true*

Keywords: *Macroscopic traffic flow properties, Speed, Flow, MCO method, Student's t-test*

I. Introduction

It is very important for planning and designing and redesigning a new or existing road and its infrastructure to carryout traffic studies in the form of traffic flow properties measurement. Traffic flow characteristics most commonly estimated in the field are speed, travel time, flow and density which basically give an idea of the whole picture i.e. macroscopic level. In some cases, spacing and headway can also be measured from macroscopic data and these are termed as microscopic flow properties that are, observing traffic flow on an individual vehicle level [10]. There are various ways of measuring traffic flow rates, example of a conventional method is the stationary count. However, stationary counts have some disadvantages, for example; vehicular speeds are measured at a point, also in the case of pneumatic tubes, which are relatively efficient but more expensive, and often stationary counts requires a large manpower.

An alternative method is to use moving observers i.e. measuring traffic flow within the traffic mix over a section of the road. Thus estimating speed and flow within the traffic stream itself and requiring lesser man power. In carrying out the MCO method, there are driving styles which are used. The driver of the test vehicle can use his sense of judgment to travel at average speed within the traffic stream or tries to safely overtake as many cars as does overtake him which is known as MCO, or tries to drive at legal speed limit unless constrained by prevailing traffic conditions

The MCO method is mostly used for estimating traffic flow properties and in order to improve its accuracy in the estimation of traffic flow properties, the procedure can be repeated a number of times on the same section of road [9], [5].

This method is said to give an un biased estimate even though errors may occur due to observer's fault [2]. MCO measures these properties over a section especially speed; space mean speed, whereas spot measurement gives the time mean speed. However, some authors raise concerns for low traffic flows; that an impractical repetition may be required to achieve reasonable accuracy [1] .In modern times, difficulty might be encountered especially in taking account of the vehicles overtaken and those that overtook the test vehicle in high traffic volume conditions. This can be a source of error, however, it is possible to combine the floating car and average car to counter the aforementioned problem [3].

In general, the main advantages of MCO are its perceived comparatively low cost when compared with the conventional data collection and its compatibility with more advanced data collection techniques which can cover more study area. While on the other hand, it has the disadvantages of: possible human error especially collecting data while the vehicle is in motion, modern techniques which uses Global Positioning System (GPS) facilities can collect complex and second by second data which can create difficulty in storage, also big data mining problem can ensue where modern computing tools are lacking, etc. Statistical comparison between the point measurement and short section measurement are believed to be more of same [1]. Numerical comparisons between moving observer flow estimates and counts made by a stationary observer during the same period is basically premised on the point that, fixed-point counts are assumed as true estimate of flow or at least a representative of the flow even though discrepancies might exist which can be termed as errors. Although it is more reasonable and appropriate to use MCO figures especially if one were interested in the road as a section not a point [4].Thus this study uses statistical tool to compare the moving with the

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stream data collection method and point data collection method of macroscopic traffic flow properties assuming the point measurement is a true representation of existing flow condition.

2. Methodology

This study area has a mild traffic condition; thus, traffic flow properties were estimated using moving car observer (MCO) method in accordance with the Manual of Transportation Engineering Studies [8]. In this driving style, the test vehicle is driven within the traffic stream under study and overtakes as many vehicles as overtaking it; through this, the test car estimates the behavior of an average vehicle in the traffic stream [6]. Also, a point measurement of the traffic flow properties was estimated concurrently.Figure 1 and 2 shows Google earth image of the study route as well at a stationary point.

Figure 1: Google map of Skudai Highway 5Km for MCO data collection

Figure 2: Google Map for Stationary Point data collection

2.1 Theory

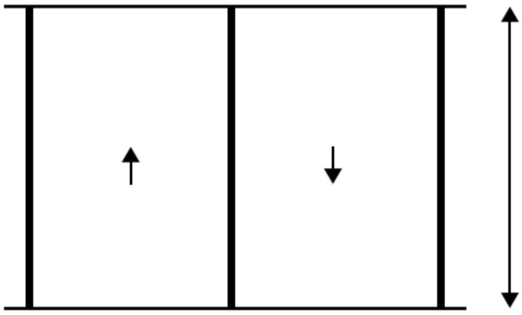

Figure 3: Illustration of Moving Car Observer Method Section

$$q = U \times k(1)$$

Where q = traffic flow in Vehicle/Hour, u= speed in Km/Hour and k = density in Vehicle/Km.

Let's take M_o, M_p and M be number of vehicles which overtake the test vehicle and the number of vehicles the test car over takes, and the difference between them respectively.

$$Mo = q \times T$$

where T = period.

Similarly, when the stream is seemingly stationary and test car overtakes with speed 'U' over a length L;

$$Mp = k \times L \qquad \text{but } L = U \times \mathrm{T}$$

Therefore, $Mp = k \times U \times T$

The difference between M_o and $M_{p\ is}$ given by

$M=M_o - M_p$ which can be re- written as

$$M = (q \times T) - (k \times u \times T) \qquad (2)$$

This is the basic equation that relates q, k to the counts M, T, u which can be obtained from the data.

If the car is run twice, from section X-X to Y-Y and Y-Y to X-X. Let M_a and M_w denote the number of cars counted on the opposite side when the test car is moving from section X-X to Y-Y and Y-Y to X-X respectively. Here subscript 'a' and 'w' denotes 'against' and 'with' respectively.

Thus, $$Mw = (q \times Tw) + (k \times Uw \times Tw) \qquad (3a)$$

$$Ma = (q \times Ta) - (k \times Ua \times Ta) \qquad (3b)$$

The opposite sign denotes opposite direction which car moves and these set of equation can be re written as

$$(q \times Ta) - (k \times L) \qquad (4a)$$

$$(q \times Tw) - (k \times L) \qquad (4b)$$

Add equation 4a and 4b, $k \times L$ is eliminated and making q the subject formula

$$q = \frac{\mathrm{Mw} - Ma}{\mathrm{Ta} + \mathrm{Tw}} \qquad (15)$$

Equation (5) gives the first parameter, flow of the stream.

Calculating the space mean speed from equation (4b)

$$Ma = (q \times Ta) - (k \times Ua \times Ta)$$

$$\frac{Ma}{Ta} = q - \frac{q}{u} \times Ua \text{ but } k = \frac{q}{u} \text{and}$$

$$Ua = \frac{L}{Tw}$$

$$\frac{Ma}{Ta} = q - \frac{q}{u} \times (\frac{L}{Tw})$$

Similarly, if the mean speed U is Us, therefore average travel time $Tav = \frac{L}{Us}$

$$\frac{Ma}{Ta} = q(1 - \left(\frac{Tav}{Tw}\right)$$

$$Tav = Tw - \frac{Mw}{q}$$

But, $Tav = \frac{L}{Us}$

$$\frac{L}{Us} = Tw - \left(\frac{Mw}{q}\right)$$

Making (U_s) the subject formula

$$U_s = \frac{L}{Tw - (\frac{Mw}{q})} \quad (6)$$

This is the mean speed of the test car over the section, thus giving the second fundamental quantity of flow theory, U_s

Therefore, from equation (1)

$$\text{The density,} k = \frac{q}{u} \quad (7)$$

$$U_s = n \div \sum_{i=1}^{n} (\frac{1}{Ui})$$

3. Results and Discussion

3.1 Results

The results of the surveys are presented in Tables 1 to 4. Tables 1, 2,3 and 4 are the results of volume studies on both opposing roads for both stationary count and moving observer count.

Table. 1. Summary of MCO Results for section XX to YY

S/No	Flow in vehicle/hour	U_s in Km/hour	K in vehicle/Km
1	1397	80	17
2	1860	75	25
3	1592	74	22
4	2069	81	26
5	1389	68	20
6	1351	64	21
Average	1578	73	21

Table. 2. Summary of MCO Result for section YY to XX

S/No	Flow in vehicle/hour	U_s in Km/hour	K in vehicle/Km
1	1474	71	29
2	1385	76	22
3	1354	74	18
4	1708	88	19
5	1402	83	17
6	1153	64	18
average	1394	75	20

Table 3: Volume studies on section XX

Volume	Time					
	Time	3.00 - 3.15 Pm	3.15 - 3.30 Pm	3.30 - 3.45 Pm	3.45 - 4.00 Pm	Total
Car	Veh/hr	238	212	210	245	905
	Pcu/hr	238	212	210	245	905
Motor Cycle	Veh/hr	83	61	71	68	283
	Pcu/hr	62	46	53	51	212
Van	Veh/hr	34	32	36	27	129
	Pcu/hr	51	48	54	41	194
Lorry	Veh/hr	19	25	22	30	96
	Pcu/hr	38	50	44	60	192
Total	Veh/hr	374	330	339	370	
	Pcu/hr	389	356	361	397	1503

Table. 4. Volume studies on section YY

Volume	Time					
		3.00 - 3.15	3.15 - 3.30	3.30-3.45	3.45 - 4.00	Total
Car	Veh/hr	185	179	182	145	691
	Pcu/hr	185	179	182	145	691
Motor Cycle	Veh/hr	33	65	51	59	208
	Pcu/hr	25	49	38	44	156
Van	Veh/hr	33	21	25	34	113
	Pcu/hr	50	32	38	51	170
Lorry	Veh/hr	36	21	29	25	111
	Pcu/hr	72	42	58	50	222
Total	Veh/hr	287	286	287	263	
	Pcu/hr	331	301	316	290	1239

Histogram of the speed studies is presented for both section XX and section YY. The mean speed for section

XX to YY is approximately 74km/Hr while going reverse direction was slightly higher at 77 Km/hr which closely compares to the speed estimated from MCO method of about 73Km/hr for section XX to YY and 75Km/hr for the reverse. This results agrees with [5] which proposes a typical linear relationship between them and showing a marginal difference between space mean speed as obtained by MCO and time mean speed as obtained from stationary count.

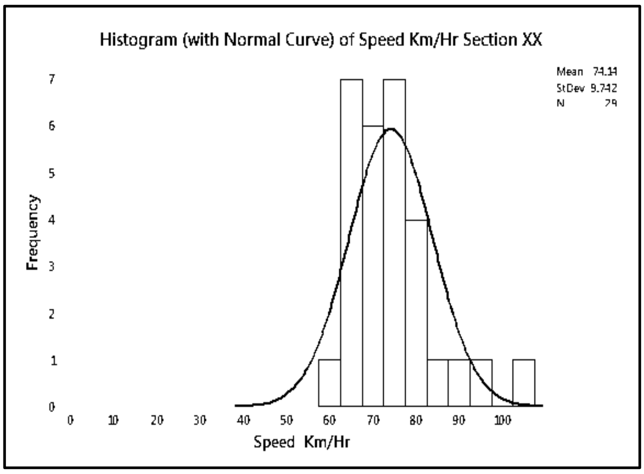

Plate 1: Histogram with Normal Curve for Speed(section XX) in Km/Hr

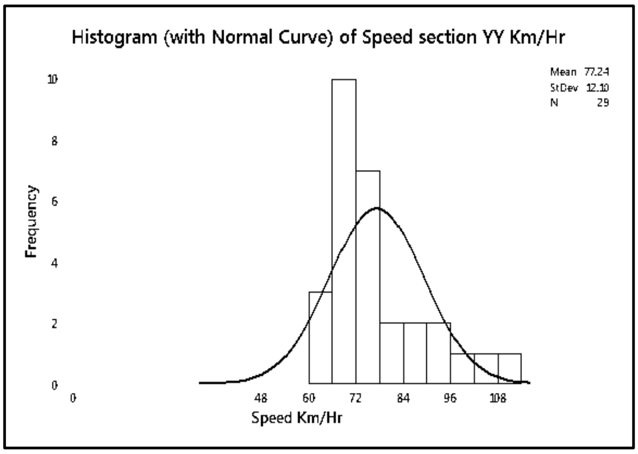

Plate 2: Histogram with Normal Curve for Speed (section YY) in Km/Hr.

3.2 Discussion

The statistical analysis confirms the accuracy of the moving observer method estimates by comparing to the results for the stationary observer method assuming the latter is true. Using student *t*-statistics; a two tailed test assuming unequal variance, it is expected that traffic flow and speed using the moving observer method is suspected to be equal to the flow and speed using the stationary observer method.

Hypothesis Test:

- H_0 null hypothesis: q (moving observer) = q (stationary observer).
- H_A: q (moving observer) ≠ q (stationary observer).
- Rejection: we reject H_0; null hypothesis if $t_{calculated}$ is greater $t_{critical}$ else we accept the null hypothesis
- Also we can use p-value to reject the null hypothesis or otherwise. Should the p-value be less than alpha we reject the null hypothesis else we accept the null hypothesis.

From Table. 7, it can be seen that the t statistics is much lower than T critical therefore we accept the null hypothesis. Also, the P-value is greater than alpha value chosen. This implies that there is no significant difference between speed estimated from MCO method and speed estimated at a stationary position.

From Table. 8 it can be seen that the t statistics is much lower than T critical therefore we accept the null hypothesis. Also, the P-value is greater than alpha value chosen. This implies that there is no significant difference between rates of flow estimated from MCO method and rate of flow from stationary position.

Table. 7: T-Test for Speed Studies

	Manual	***MCO***
Mean	74.63636	73.75
Variance	25.05455	37.84091
Observations	11	12
Hypothesized Mean Difference	0	
df	21	
t Stat	0.380337	
P(T<=t) one-tail	0.353758	
t Critical one-tail	1.720743	
P(T<=t) two-tail	0.707515	
t Critical two-tail	2.079614	

Table 8: t-test for Volume studies

	Volume(Manual	***Volume(MCO)***
Mean	1370.625	1511.166667
Variance	24919.41071	64904.87879
Observations	8	12
Hypothesized Mean Difference	0	
df	18	
t Stat	-1.522270676	
P(T<=t) one-tail	0.072657808	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.145315615	
t Critical two-tail	2.10092204	

4. Conclusion

In conclusion, comparison between estimates of macroscopic traffic properties over a section against a fixed spot measurement was carried out. These properties have no significant difference when the values of the estimates were compared. It is safe to use MCO method for collecting traffic data assuming that the fixed point estimates represent accurate measurements. It can be recommended that; to obtain a higher level of accuracy, the following can be considered:

- A methodology for enlarging the sample size or increasing the number of runs reasonably should be developed.
- Classifying the measurements by the type of vehicle, conducting the same study for different road classes since traffic flow and speed could have different values for different vehicle types, road classes.
- Also studying at peak, mid-peak, off-peak hours could be important.

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