Statistical Evaluation of Moving Observer Method Accuracy for Measuring Traffic Flow Variables on Urban Roads

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***Abstract*— The accuracy of traffic data collected from the field is an essential requirement for effective and reliable outcomes for planning, design, operation and assessment of transportation facilities. Moving Observer Method (MOM) is one of the well-known techniques that is widely used for generation of traffic data on urban roads due to its cheapness and ease of field application. However, the accuracy of the data collected using MOM is sensitive to the fluctuation of traffic flow demand, especially, on urban road. This study aims to statistically evaluate the traffic flow collected using MOM on urban road. A representative urban road segment in Johor Bahru was chosen for this study. The chosen road section has five (5) major access points of driveways and intersections. Traffic flow was concurrently measured on the selected urban road segment using both manual (with the aid of field observers) and MOM approaches over a duration of 90 minutes. Traffic flow estimates from the two approaches were compared statistically. A null hypothesis put forth is that there is no significant difference between the traffic estimates from the techniques. A statistical analysis using Z-standard normal distribution at 90% confidence level affirmed the postulated hypothesis, which implies that there exists no statistically significant difference between the traffic flow estimates derived from the two methods. This finding suggests that MOM can reliably be applied to estimate traffic flow on urban roads with reasonable accuracy.**

Keywords—Moving Observer Method, Normal Distribution Test, Urban Roads.

I. INTRODUCTION

Regardless of the objectives associated with design, analysis and assessment of transportation facilities, a reliability of the outcomes is a fundamental requirement of the processes [1]–[4]. Hence, the rising need by the traffic engineers to ensure the validity and reliability of the traffic data generated using various approaches [5]. Moving Observer Method (MOM) is one of the well-known techniques that has been widely used to collect traffic data on urban roads due to its ease of field application [5]–[8]. Wardrop and Charlesworth [9] were the first authors who developed and presented the use of MOM for collection of traffic data in the field. Basically, the method involves the use of test vehicle within a traffic stream to observe traffic flow variables. The allows for the estimation of traffic flow, travel time, and space-mean speed for both directions over the segment under evaluation.

The accuracy of data collected based on MOM is well sensitive to fluctuation of stream traffic flow demand, especially on urban roads facilities [10], [11]. This is because urban roads facilities are more associated with substantial fluctuation in traffic level due to high intensities of driveways and intersections. Originally, Wardrop and Charlesworth [9] as the developer of the technique, evaluated the accuracy of data collected using the MOM by comparing its results with those obtained through manually traffic data collected by a team of field observers over the same segment of a road and period of time. By comparing the results, it was discovered that the difference of the two results varied according to the classification of vehicles; however, the difference was around 10% and lower different trials [9]. In terms of reliability, some studies reported that a disparity of the 10% between two sets of estimates can be considered as an acceptable error for traffic studies involving empirical data [11], [12]. It was however, demonstrated that MOM could give unbiased results if the trips number performed during test runs by the vehicle is between twelve to sixteen [9]. In other words, there is no need for further evaluation on the probability of obtaining similar results between the MOM and the manual approach made by the team of field observers for a long time period regardless of the trips number that could be performed by test vehicle.

Another study claimed that the probability obtaining a real and accurate data from MOM is statistically accepted [6]. These authors evaluated the accuracy of MOM result using t-test analysis between MOM and manual count results over a long time period for a study conducted on a freeway facility, where driveways and intersections are complete absent. Accordingly, their study outcome did not report the accuracy of MOM application on urban roads condition, where the effects of driveways and intersections induce substantial fluctuations in traffic volume. Hence, the aim of this current study is attempts to statistically evaluate the accuracy of the MOM application for collection of traffic data on urban roads.

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II. METHODOLOGY

This section describes the procedure employed in conducting the current study. Particularly, the processes involved in selecting the appropriate urban road segment for the data collection, application of the MOM, and the description of the manual traffic count through the use of field observers' team.

A. Selection of Urban Road

In order to select a suitable urban road for the purpose of this study, a preliminary survey was conducted over available urban roads in Johor Bahru Roads Network. This was done in order to assess the conditions to ensure that they satisfy the selection criteria. These criteria are; firstly, the segment should contain a reasonable number of driveways and intersections to cause fluctuation in the traffic flow stream over the period time during the test. Secondly, for an urban road segment to be selected, it must be of two-way directional flow. In other words, a one-way road segment is not suited for the study. This would allow for ease of turn around the two directions of the road during the test runs. Finally, the selected road segment should have a satisfactory pavement's surface condition and free from work-zone. Figure 1 shows the selected urban road segment used for this study. The chosen road segment is situated along Jalan Pendidikan (the road's name) located around Universiti Teknologi Malaysia (UTM), Taman Universiti of Johor Bahru network roads. It is a 4-lanes two-way segment (2 lanes in each direction). The segment has three signalized intersections and two driveways access points.

Fig. 1. Selected urban road for the study (Jalan Pendidikan)

B. Measurement of traffic flow using MOM

As stated earlier, the MOM involves the use of test vehicle within a traffic stream to estimate some traffic flow variables. Figure 2 depicts the concept of the MOM observation of traffic volume and travel time as the test vehicle travels with and against the direction of the traffic stream over the study segment. As shown in Figure 2, the test vehicle travels with and against a predefined directional segment of the road segment (to and fro movements) around the road segment, which makes one trip of the test vehicle.

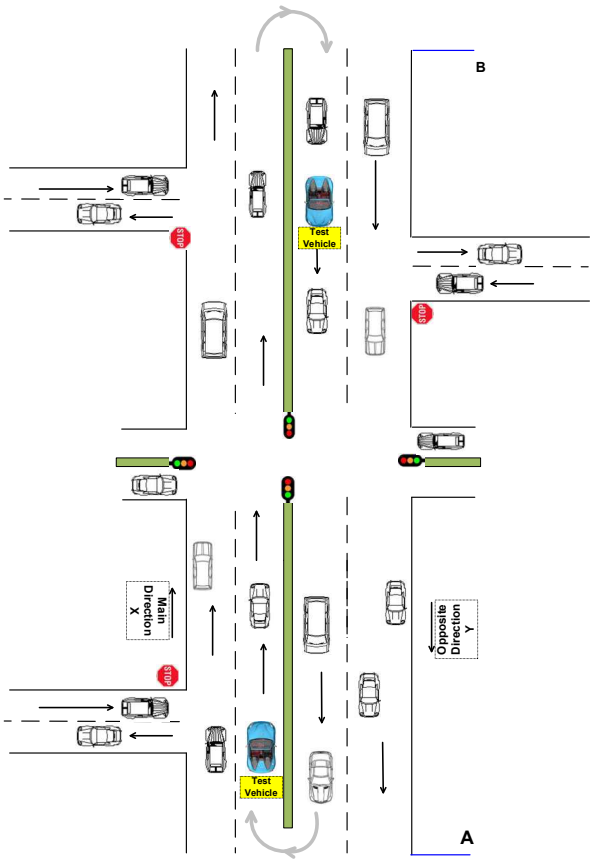

Fig. 2. Test Vehicle (MOM) Trip on Urban Road Segment for measuring Traffic Flow

The MOM results in estimates of traffic flow (q), travel time (t) and space-mean speed (SMS) of the traffic stream. In the method, the test vehicle travels over a known segment length (D) of highway with and against the traffic stream. The travel times to traverse the highway with and against the traffic stream are noted as 'tw' and 'ta', respectively. The number of vehicles overtaking the test vehicle and the number overtaken by the test vehicle are also noted while travelling with the traffic stream. The difference between these is noted as 'y'. The number of vehicles met in opposite direction while travelling with the traffic stream is noted as 'x'. Equations 1, 2 and 3 are determine the streams mean traffic flow, travel time and space-mean speed, respectively.

$$q = \frac{(x+y)}{(t_w + t_a)} \tag{1}$$

$$t = t_w - \left(\frac{y}{q}\right) \tag{2}$$

$$SMS = \frac{D}{\bar{t}} \tag{3}$$

where, q is the estimated traffic flow, x is the total number of vehicles met in opposing traffic direction while travelling with the stream, y is the total number of vehicles overtaken the observer minus the number of vehicles overtaken by the test

vehicle when traveling with the stream, tw is the travel time taken for the trip with the traffic stream of the main direction, ta is the travel time for the trip against the stream, $\bar{t}$ is the mean travel time of all vehicles in the stream, D is the segment length, and SMS is the space mean speed of the evaluated traffic stream.

It is worthy to note that among the three parameters; traffic flow, travel time and space-mean speed, this study focuses only on the measurement of traffic flow using MOM (though the other two can easily be determined from the field observed data). Hence, Equation 1 is the relevant expression for this study. As stated earlier, the terms involved in Equation 1 (x, y, tw, ta) are measurable directly through the test vehicle series of trips along the studied urban road segment.

According to Schroeder, et al. [13], three different driving techniques could be used to test vehicle runs using MOM over a road segment. These are maximum car technique, floating car technique, and average car technique. In this study, the average car technique was applied to run the test vehicle on the urban road segment. Six number of test runs were demonstrated as adequate for consistent and unbiased estimates of travel times and other traffic flow variables [14]. Likewise, some studies conducted in Malaysia using MOM demonstrated the adequacy of six numbers of test trips for reliable estimate of traffic flow over a road segment[5], [10], [15]–[17], whose bases were from the study of [13]. Hence, the current study was conducted based on six test vehicle runs, which has been deemed adequate for this kind of investigation. The actual time used for the test run was randomly selected within off-peak period during daylight between 2:00 pm and 3:30 pm.

C. Measurement of traffic flow using Manual Count

The second type of traffic flow volume measurement was counted manually with the aid of field observers' team, whom were distributed and stationed at the five locations of the driveways and intersections (Figure 1). Each person was stationed at certain location of a driveway point or intersection. As previously stated, the Moving Observer Method and a manual count were used to collect data in the field at the same duration time. Thus, each of the persons making the manual count commences the count at the same moment with commencement of the MOM observation. Likewise, they end their counting as soon the MOM process ended. The interval between the commencement and the ending moment was estimated at about three minutes. This was established based on the segment's average posted speed of 60 km/h and the segment length of 1.80 km. subsequent to the data collection and analysis, the results from the MOM and manual count were compared.

III. RESULTS

This study measure traffic flow on urban road segment using two approaches; the MOM using a test vehicle and manual count via a team of field observers. The two measurements were conducted independently but concurrently over a total duration of 90 minutes. The results of the traffic flow measurements from the MOM and manual count approach are shown in Tables 1 and 2, respectively. Table 1 presents the field recorded for each of the variables involved in Equation 1 and computed values of the traffic for each test run. the last column of Table 1 shows the computed value of the traffic flow (q). As mentioned earlier, the adopted value of q is the average of the flow derived from six test runs. The rate of change of the average traffic flow estimate is simply a reflection traffic flow fluctuation of the study period. Hence, the number of rows of this average value of traffic flow (last column) is lesser by five rows (42-5 = 37 rows) relative to the all other columns.

TABLE I. RESULTS OF TRAFFIC FLOW USING MOM.

Trip No.	x	y	t_a (sec)	t_w (sec)	q (veh/sec)	q (veh/h)	q (Avg. Six Trips) (veh/h)
1	49	1	135	129	0.19	682	**685**
2	55	1	132	131	0.21	767	**660**
3	55	3	133	135	0.22	779	**553**
4	41	4	132	133	0.17	611	**538**
5	51	7	130	132	0.22	797	**537**
6	34	1	133	133	0.13	474	**517**
7	38	2	134	136	0.15	533	**551**
8	5	4	129	132	0.03	124	**542**
9	49	2	137	130	0.19	688	**595**
10	42	4	139	134	0.17	607	**547**
11	49	3	137	139	0.19	678	**504**
12	45	6	137	135	0.19	675	**429**
13	35	1	133	137	0.13	480	**498**
14	32	1	134	136	0.12	440	**534**
15	29	1	135	133	0.11	403	**588**
16	24	2	131	137	0.10	349	**603**
17	15	2	130	139	0.06	228	**634**
18	75	4	129	132	0.30	1090	**680**
19	49	2	133	131	0.19	695	**593**
20	53	3	132	133	0.21	761	**679**
21	35	1	131	132	0.14	493	**678**
22	37	2	131	131	0.15	536	**720**
23	34	4	132	138	0.14	507	**733**
24	42	1	135	137	0.16	569	**755**
25	86	4	134	134	0.34	1209	**783**
26	49	7	134	133	0.21	755	**704**
27	53	2	133	132	0.21	747	**689**
28	41	4	132	134	0.17	609	**672**
29	45	2	133	130	0.18	643	**677**
30	49	4	131	129	0.20	734	**734**
31	52	1	130	130	0.20	734	**785**
32	49	0	130	134	0.19	668	**797**
33	48	1	139	134	0.18	646	**814**
34	49	0	135	141	0.18	639	**823**
35	68	4	132	131	0.27	986	**829**
36	74	2	133	131	0.29	1036	**776**
37	56	4	132	135	0.22	809	**720**
38	55	1	131	132	0.21	767	
39	49	3	134	133	0.19	701	
40	50	1	134	139	0.19	673	
41	45	4	133	129	0.19	673	
42	47	4	135	129	0.19	695	

Table 2 presents the traffic flow results of the manual counting approach at the five locations of driveways and intersections by the team of field observers. Each row shows the result of the vehicles counted for one duration of cycle (vehicle/ three minutes) for all the five persons. Subsequently, the average traffic flow (q) was calculated for these five results as the mean per three minutes (vehicles per three minutes). Finally, this mean value was converted to its equivalent number of vehicles per hour (veh/h) as shown in the last column of the Table. This was repeated for each row, which represent the number of cycles over the entire duration of the study period (90-minutes).

TABLE II. RESULTS OF TRAFFIC FLOW VOLUME COUNTED MANUALLY BY IVE PERSONS.

Cycle No.	Per.1	Per. 2	Per.3	Per.4	Per.5	q Avg. Team (veh/three minutes)	q Avg. Team (veh/h)
1	24	45	39	37	22	36.40	**728**
2	19	42	37	28	22	32.60	**652**
3	19	42	47	46	31	40.00	**800**
4	19	39	44	24	25	33.20	**664**
5	17	37	54	26	29	35.60	**712**
6	16	43	46	28	30	35.60	**712**
7	14	68	44	20	24	37.00	**740**
8	13	44	35	19	29	31.00	**620**
9	10	44	38	45	21	34.60	**692**
10	17	38	48	48	20	37.20	**744**
11	19	40	41	42	21	35.60	**712**
12	18	35	48	38	24	35.60	**712**
13	20	48	4	54	33	34.80	**696**
14	22	42	38	41	25	36.60	**732**
15	19	44	42	35	40	39.00	**780**
16	15	41	37	34	41	36.60	**732**
17	18	48	38	38	21	35.60	**712**
18	19	37	37	48	23	35.80	**716**
19	17	35	48	43	29	37.40	**748**
20	16	42	50	38	31	38.40	**768**
21	17	37	39	35	28	34.20	**684**
22	16	46	35	50	29	38.20	**764**
23	14	48	47	46	25	39.00	**780**
24	14	47	39	46	25	37.20	**744**
25	13	48	40	45	25	37.20	**744**
26	14	48	42	45	25	37.80	**756**
27	14	49	44	44	25	38.20	**764**
28	14	49	46	49	24	39.40	**788**
29	14	44	44	49	24	38.00	**760**
30	14	43	45	48	24	37.80	**756**

The final column represents the final average traffic flow in vehicles per hour (veh/h) for all the five persons generated from urban road segment, which represent the final result based on manual approach (TF-Manual). These estimates of traffic flow were then compared with those traffic flow using MOM (TF-MOM) presented in the last column of Table 1. As shown in the two results presented in Tables 1 and 2, the number of rows based on the manual count approach was 30, whereas those of the MOM was 42. This is due to the relative difference in the duration used to count the vehicles using MOM being lesser than the cycle duration (three-minutes) as predefined to count the vehicles manually by the team.

IV. STATISTICAL ANALYSIS

With regard to the aim of this study, the accuracy of the traffic flow estimate relied on the extent of difference between the traffic flow results derived from the two different methods. These two types are TF-MOM and TF-Manual. These two results were calculated as average values which derived from the number of trial tests. Therefore, these two average values fluctuated depending on these trial test values. However, each of the estimates from the two methods follow a normal distribution as depicted in Figures 3 and 4. Moreover, Table 3 presents the descriptive statistics of these two independent populations of the average traffic flows, which were found to follow normal distribution.

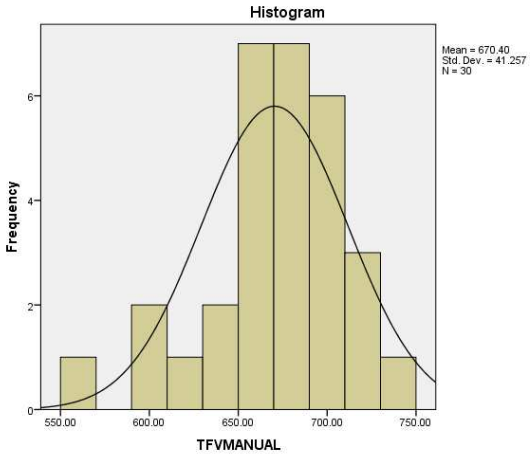

Fig. 3. Normal Distribution Histogram for TF-Manual

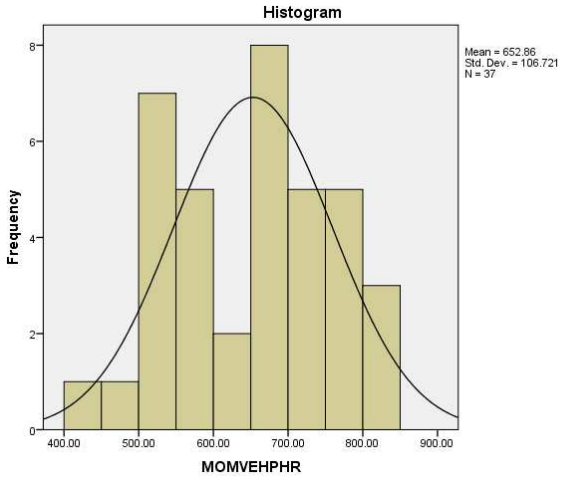

Fig. 4. Normal Distribution Histogram for TF-MOM

TABLE III. DESCRIPTIVE STATISTICS OF AVERAGE TFV FOR TWO TYPES OF MEASURING

Population Group	Number of Points, N	Mean (μ)	Variance (σ^2)	Standard Dev. (σ)	Max. Value	Min. Value
TFV-Manual (1)	30	670.4	1702.18	41.25	740	560
TFV-MOM (2)	37	652.8	11389	106.7	829	429

The statistical test for the difference between the average of the two populations N_1 (*TFV Manual*) ~ [μ_1, σ_1^2], and N_2 (*TF-MOM*) ~ [μ_2, σ_2^2], could be drawn on the basis of the theory stated Khalid, et al. [18] as follows:

Let $x_{11}, x_{12}, \ldots\ldots\ldots x_{1n1}$ be a random sample of size n_1 from the population 1 (*TF-Manual*), and $x_{21}, x_{22}, \ldots\ldots\ldots x_{2n2}$ be a random sample of size n_2 from the population 2 (*TF-MOM*). Suppose the two populations represented by X_1 and X_2 are independent and normally distributed with parameters $X_1 \sim N(\mu_1, \sigma_1^2)$ and $X_2 \sim N(\mu_2, \sigma_2^2)$ respectively. Then, the statistical test was applied for the hypothesis (with Equation 4 as the null hypothesis, while Equation 5 as the alternate hypothesis) as follows:

$$H_0: \mu_1 = \mu_2 \rightleftharpoons \mu_1 - \mu_2 = 0 \quad (4)$$

$$H_1: \mu_1 \neq \mu_2 \rightleftharpoons \mu_1 - \mu_2 \neq 0 \quad (5)$$

And the equation for statistical test of these two hypotheses was written as the following:

$$Z_c = \frac{(\overline{X_1} - \overline{X_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \quad (6)$$

As it was reported earlier, for empirical traffic studies an error of around 10% could accepted [10, 11]. This is means that the level of confidence is based on 90% (α/2 = 0.05). According to the Z-tables, the critical value of this confidence level (+α/2 = +0.05, and -α/2 = -0.05) is (1.645, and -1.645), respectively in both sides. Therefore, the rejection zone area of the Z-test is as shown Figure 5.

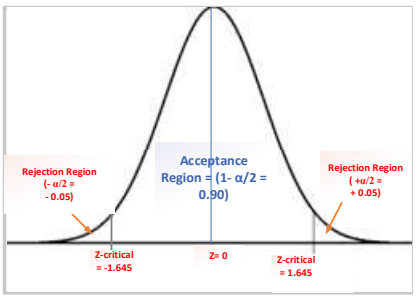

Fig. 5. Acceptance and Rejection areas of Z-standard normal distribution at 90 % Confidence Level

The value of this test Z_C in Equation 6 is usually compared with the Z-critical (±1.645) in Figure 5. If the sampling distribution of the difference between two populations of the average traffic flows is statistically zero, the accuracy is then statistically significant at the 90% level of confidence. Conversely, if this sampling distribution of the difference between two populations is statistically not zero, this implies that the accuracy is statistically not significant at 90% level of confidence. By substituting the value in Equation 6, the Z_C was calculated as shown in Equation 7.

$$Z_c = \frac{(670.4 - 652.8) - (0)}{\sqrt{\frac{(41.25)^2}{30} + \frac{(106.72)^2}{37}}} = \frac{17.6}{19.1} = 0.921 \quad (7)$$

This statistical value of 0.921 is smaller than the Z-critical value of 1.645 at the 90 % confidence level. This implies that it occurs on the acceptance zone of Figure 5. As a result, the null-hypothesis (Equation 4) of assuming significant difference between the TFV-MOM and TFV-Manual was rejected. Accordingly, the accuracy of MOM for measurement of traffic flow on urban roads has normal fluctuation due to limited number of access points, hence, it is statistically accepted at 90% level of confidence.

V. CONCLUSIONS

Based on the study conducted and the main objective of this study put forth to actualize, which is evaluating the accuracy level of MOM for measuring traffic flow on urban road segment. Statistical test was performed to evaluate the extent of difference between the two populations of average traffic flow measured using MOM and manual count approach based on stationary observation. The statistical test results showed that there is no statistically significant difference between the two estimates of average traffic flows determined from the two methods at 90% level of confidence.

However, a key distinction of this evaluation is that it was established that the difference between two average values of traffic flow was as a result of traffic fluctuation over the period used for measuring the traffic flow. This ensures the accuracy of the "Moving Observer Method" when collecting traffic data in urban roads with realistic traffic flow fluctuations. However, the results affirmed that the MOM is well suited alternative traffic flow measuring approach to manual count technique, even during conditions of fluctuation in traffic flow. Therefore, finding from this study increases the potential and advantages of MOM application for measuring traffic flow parameters on urban roads.

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