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COMPARATIVE EVALUATION OF THE MOVING CAR METHOD FOR TRAFFIC DATA COLLECTION ON MULTILANE HIGHWAYS

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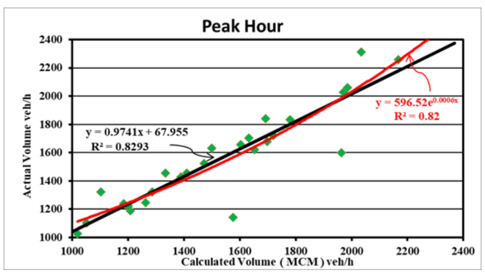
Graphical abstract



Abstract

Collecting traffic flow data is essential for most traffic studies to analyze and evaluate the performance of systems that provide safe trips for people and goods on highways. There are several methods for collecting traffic data. The moving car method (MCM) calculates traffic volume, speed, and travel time simultaneously, while stationary methods, such as camera recordings or radars, observe these data separately. This research aims to use both data collection methods on six segments of urban multi-lane highways to determine the accuracy of the moving car method compared to traditional methods. Additionally, it seeks to model a relationship between these methods to facilitate data collection using MCM for more accurate results. The results indicate no significant difference between the two methods, as the T statistic is less than the critical T in the t-test results. The models show low values of RMSE for the relationships between observed volume, arithmetic and harmonic mean speed, and arithmetic and harmonic means of travel time obtained by stationary methods and these data calculated by MCM. These models can be used with MCM for the study area.

Keywords: Moving car method, traffic volume, Speed, travel time, comparison and modeling

1.0 INTRODUCTION

In the context of current transportation, multi-lane highways are crucial, they serve as vital accesses for the movement of people and goods. In order to guarantee effective and secure mobility, it becomes essential to evaluate the performance of these routes as traffic loads rise and modeling a relationship for essential parameters on studied routs of transportation [1]. The data collection needed for that are traffic volume, speed, density, geometric data, headway and travel time [2, 3, 4], which can be obtained by traditional methods like camera records, speed gun, and site survey or by only moving car method. The increase in population has led to increase in vehicular population [2], and that causes a congestion within urban transport networks, which has been a significant social, economic and environmental issue [4]. Furthermore, as more drivers use the roadway, traffic density increases and speed decreases significantly until the road reaches its capacity [5].

Because of that, the process of gathering data is crucial to obtaining accurate findings for evaluating the quality of the roadways' services and developing a suitable plan [6]. The main objectives of this study are to collect traffic data on multilane highways, including traffic volume, speed, and travel time, using two different methods. The aim is to compare these methods to determine the most efficient one in terms of time, cost, effort, and data quality. Additionally, the study seeks to develop a model that correlates the two data collection methods, providing a simplified approach to calculating traffic data on multilane highways.

In (1954), Wardrop and Charlesworth proposed a technique in England, which they published under the heading "A Method of Estimating Speed and Flow of Traffic from a Moving Vehicle." The Cook County Highway Department looked into this method, focusing solely on traffic flow estimation, to see if it was practical in this nation. In the event that a substantial number of sections need to be sampled, the method seems to be highly beneficial for estimating the total combined volume of all the sections. This is because, although mistakes may be significant in any one section, they seem to be eliminated when the sections are combined [7, 8].

In this method, an observer moving through the traffic stream gathers information on the vehicles he come across, using the "moving car" method of traffic data collection. This technique can be used to gather information on traffic volume, speed, and travel time, among other traffic factors [9]. Wardrop and Charlesworth recognized a number of benefits associated with the moving observer approach (1954), among them are the following:

- Simultaneous collection of flow and speed data is possible, which is very helpful for examining the relationship between the two parameters.
- It is possible to assess the flow rate and average speed of cars, in addition to travel duration along a stretch of road.
- When the moving observer method requires fewer person-hours to attain a specified level of accuracy than stationary counts, it is considered cost-effective [10].
- Vehicles can be categorized, and flow rates can be determined for each category.
- If necessary, other details (such as the locations and reasons for delays) might be noted.

According to O'Flaherty and Simons (1970), the moving observer method has the following drawbacks:

- The number of side streets joining the main route's flow can affect the method's accuracy.
- The method is highly sensitive to variations in the traffic stream. For low traffic flows, achieving a desired level of accuracy may require a large number of test runs, which can be impractical [11].

A study by William J. Mortimer, used this method to estimate traffic volume and speed, For the moving car approach used in this study, a car, a driver, and one or more observers are needed. The amount of information determines how many observers are needed. Since no attempt was made to break down the different types of vehicles, it was determined that one observer was adequate in this investigation. It also shows that the conventional or actual method of gathering traffic data, which entails gathering information at a fixed site using sensors or other devices, is more costly and time-consuming than the moving car method [8].

In 2016, a study in India used the moving car method to observed data such as travel time, delay time, and speed. Next, a comparison of the traffic flow over the course of the three days was shown, along with a graphic representation of the average journey time, average running time, and average delay time for each session each day. The study demonstrates the relationship between traffic flow and travel time delay, demonstrating that while traffic flow grows, travel time delays; conversely, shorter delay times correspond to faster vehicle speeds and shorter travel times [12]. This research will focus on demonstrating the relationship between the same traffic characteristic obtained through two different methods.

Another study looked into the accuracy and viability of applying this technique to New Zealand's rural highways-, many of which have low flow rates. According to the results, for low traffic country routes, the number of trips needed to get an acceptable level of accuracy will be too great to be feasible [11].

The research study in Leeds evaluated the method's efficiency across different traffic conditions, focusing on both peak and off-peak periods. Findings indicated that the method is particularly suitable for peak period traffic situations, on urban radial, ring-road, central city routes, and suburban/rural motorway routes, characterized by long sections (approximately 1 mile) devoid of intersections and traffic-generating developments. Additionally, parking was prohibited along these sections during peak travel periods. These routes contrast with the multi-lane highways which will be examined in this paper [13].

Another study in Malaysia, conducted on six segments of two-lane highways with varying geometric characteristics, implemented the moving car observer (MCO) method for direct field measurement of free-flow speed (FFS). This was compared with FFS estimates based on the Malaysian Highway Capacity Manual (MHCM) model. The results demonstrated that MCO estimates more accurately represent the actual scenario, and a relationship was developed between the two approaches. This paper differs from the study by comparing the arithmetic and harmonic speeds obtained through speed gun measurement with speed obtained from MCO method [14].

In another study conducted in the USA, the accuracy and practicality of the moving car method for data collection were investigated by statistically comparing it with the stationary observer method. The findings revealed that the moving car method yields precise volume and speed estimates compared to the stationary method, particularly for road segments with three lanes per direction, especially when multiple runs are conducted [9].

An analytical comparison between the density of vehicles in the field as determined by the moving car method and the density anticipated by theoretical speed-density models, based on the information gathered, traffic stream parameters including volume, speed, and density were computed. Next, using SPSS, the relevant parameters of the Greenshield, Greenberg, and Underwood models were found by fitting them to the graphical representation of the speed-density relationship. Statistical significance tests and sensitivity analysis of these fitted models are then reported in relation to moving observer data [15].

In this paper, a comparison is made between traffic volume, speed, and travel time data acquired using the moving car method and the stationary method, such as video recordings and radars, to determine how closely the moving car method approximates the traditional method. Additionally, a model will be developed to relate the two methods, aiming to improve the accuracy of data collected using the moving car method. To ensure precise data collection, a camera will be installed inside the test car during the runs. This setup allows data to be reviewed and counted in the laboratory, reducing the need for multiple observers to count various

2.0 METHODOLOGY

The study area for this research comprises six sections (1, 2, 3, 4, 5, and 6) of urban multi-lane highways, each containing two lanes in each direction and spanning approximately two miles in length, as depicted in the Figure 1. To assess and compare between the two methods of data collection.

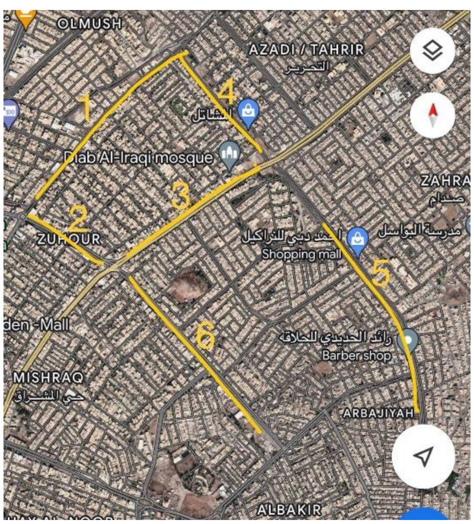


Figure 1 Multi-lane highways of the study area. (google map)

2.1 Traffic Volume Data

Traffic volume data will be calculated by using video records of a fixed cameras, placed on electricity poles on the median of each highway. As shown in the Figure 2, It records the traffic flow in each direction, to calculate the number of cars of approximately ten to twelve hours each day to fully capture the impact of peak hours from 7 a.m. to 7 p.m. of the day, and to determine the peak and off-peak hour [16].

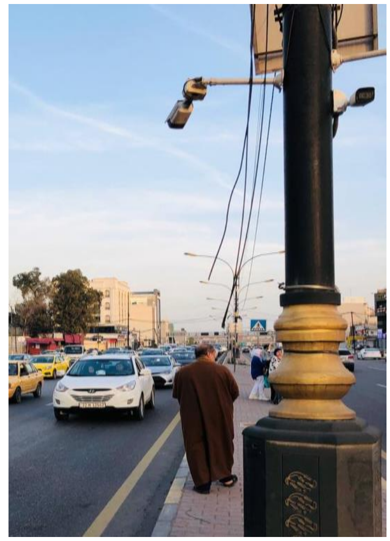


Figure 2 The cameras on the median of the road for traffic data

2.2 Speed Data

A radar speed gun, showed in Figure 3, is used to obtains 100 value of individual car's speeds in each direction of six segments, then using a statistical table to calculate time mean speed TMS, space mean speed SMS, (which have a substantial differences) [17], mode speed, and median speed, with a standard error equal to 1.609 [18].

Figure 3 The speed gun

2.3 Travel Time Data

To estimate travel time, two stationary cameras are placed at the entry and exit points of a road segment. These cameras record the time each observed vehicle takes to travel from the entry to the exit point. This process is repeated for 100 observations in each direction of the segment.

Statistical methods are then used to determine the arithmetic mean, harmonic mean, mode, and median travel times [14, 19].

2.4 Moving Car Method (MCM)

In the moving car method of data collection, multiple runs are performed with a test car that is traveling through both "against" and "with" a one-way traffic stream. The test car observers record the following information for each run:

The number of opposing cars met;

The number of cars overtaking the test car while it was travelling;

The number of cars that the test vehicle overtook;

The distance of the run (or alternatively the journey times of the observer, with and against the stream) [20].

Two equations, that allowed for the computation of the traffic flow rate, and travel time from the gathered data, were developed as shown in Equation (1) for travel time estimation, and Equation (2) for traffic flow estimation [21].

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

$$t_s = t_w - \frac{y}{q} \quad (2)$$

$$v = \frac{L}{t_s} \quad (3)$$

q- is the number of cars in the direction of moving survey car.

x- the number of cars traveling in the opposite direction;

y- is the number of cars that overtaking test vehicle minus that overtaken test vehicle.

ta- is the travel time taken for the journey when vehicle is travelling in opposite stream;

ts- indicates the estimate of mean travel time in the direction of the stream;

tw- Average travel time when vehicle is travelling in the stream;

L- is the length of the highway segment under analysis ;

v- is the speed in the direction of the stream.

3.0 RESULTS AND DISCUSSION

To assess the Moving Car Method and compare the data obtained by it with the data obtained by the stationary methods, t-tests with the values of standard deviation and the Root Mean Squared Error (RMSE) are used as indicators. These measures help determine the proximity of the Moving Car Method data to the actual data.

3.1 Results and Discussion of the Traffic Volume

The traffic volume was calculated for six segments of multi-lane highways in each direction, both for peak and off-peak hours across two times of the day. The results of traffic volumes for one of the segments over a span of 12 hours are shown in Figure 4.

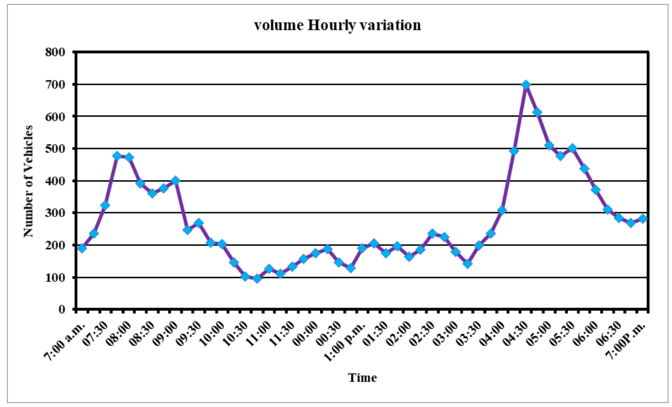


Figure 4 Volume hourly variation for segment 1 of the study area

The peak hours for this segment are depicted in the figure and observed to occur from 7:50 to 8:50 in the morning and from 4:10 to 5:10 in the evening. This methodology was consistently applied across all segments, then the volume data calculated using the Moving Car Method (MCM) for both peak and off-peak hours.

The results demonstrate both linear and exponential relationships between the calculated volume data obtained by the Moving Car Method (MCM) and the actual volume data obtained by video records, specifically for peak hour data, as depicted in Figure 5. Additionally, for off-peak hour data, linear and quadratic relationships are observed, as illustrated in Figure 6. These relationships exhibit high R-square values, signifying a strong regression between the two samples.

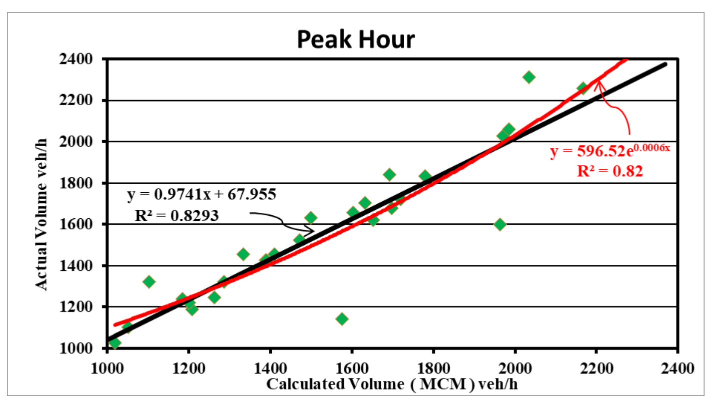


Figure 5 Linear and exponential relationships between peak actual volume and MCM volume data

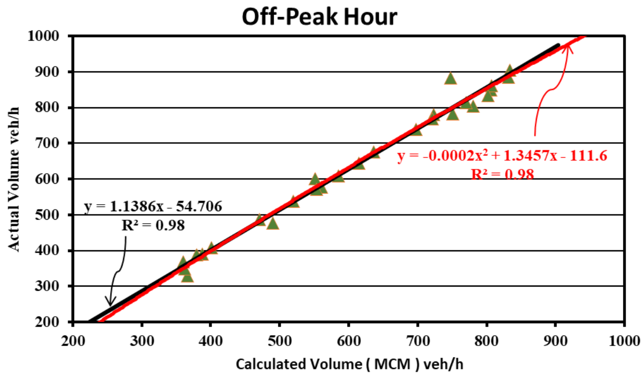


Figure 8 Linear and quadratic relationships between off-peak actual volume and MCM volume data

The statistical calculations for volume data of two methods are presented in Table 1. The Root Mean Squared Error (RMSE) is a key metric for evaluating the performance of a regression model. It quantifies the average discrepancy between the model's predictions and the actual values. Lower RMSE values indicate that the model's predictions are more accurate and closely aligned with the observed data, whereas higher RMSE values suggest larger errors and less precise predictions. This trend is also reflected in the values of R-square, which is 0.98 for the data obtained during off-peak hours of the highway segments, with lower standard deviations.

Table 1 T-test results of the two methods at peak and off-peak hour volumes

Sample Size	SD		RMSE		t-test	
	Peak Hour	Off-Peak Hour	Peak Hour	Off-Peak Hour	Peak Hour	Off-Peak Hour
30	141.80	32.11	134.72	41.32	1.73	1.49

When comparing the statistical T values with the tabled T values at a 95% confidence interval, the results indicate that there is no significant difference between the traffic volume data collected from video records and that collected using the Moving Car Method. Contrary to the study in Leeds, which concluded that MCM is effective for peak period traffic situations, this study demonstrated the efficiency of MCM for off-peak periods. This difference in results may be due to parking being prohibited along the studied sections during peak travel periods in Leeds.

3.2 Results and Discussion of the Traffic Speed and Travel Time

The arithmetic mean, harmonic mean, mode, and median were observed for speed data and travel time separately. Speed values and travel time were then calculated using the equations of the Moving Car Method (MCM) to compare the MCM values with each group of speeds and each group of travel times. Figure 7 shows the variation of each observed speed group—Time Mean Speed (TMS), Space Mean Speed (SMS), mode, and median—obtained by radar speed gun, with the calculated speed obtained by MCM.

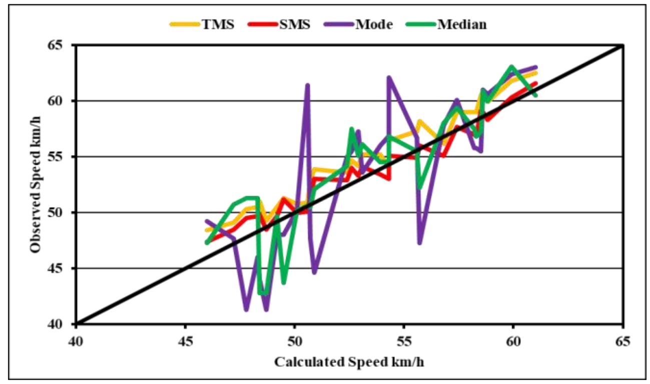


Figure 7 The variation of speed data for both methods

As shown in the figure, the mode and median speed values are significantly different from the MCM (Moving Car Method) speed values. On the other hand, the arithmetic mean and harmonic mean speed values are much closer to the MCM values. The Figure 8 shows the variation of travel time data.

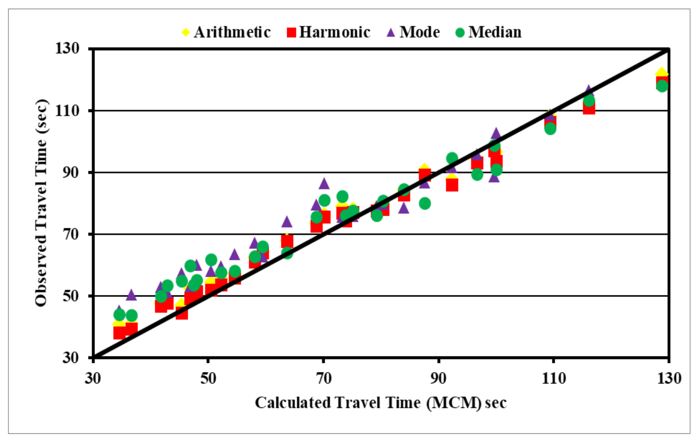


Figure 8 The variation of travel time data for both methods

As shown in the figure, the mode and median travel time values are significantly different from the MCM (Moving Car Method) travel time values. On the other hand, the arithmetic and harmonic means travel time values are much closer to the MCM values. The T-test results with SD and RMSE show in the Table 2.

Table 2 T-test results for the two methods of speed and travel time data

Parameter	Sample Size	SD				RMSE				t-test			
		Arithmetic Mean	Harmonic Mean	Mode	Median	Arithmetic Mean	Harmonic Mean	Mode	Median	Arithmetic Mean	Harmonic Mean	Mode	Median
Speed km/h	30	4.17	3.85	6.58	5.26	1.58	0.55	8.81	3.73	0.87	0.88	4.27*	2.79*
Travel Time sec	30	22.0	21.90	19.11	19.83	4.18	3.92	7.39	7.16	1.84	1.97	3.62*	3.28*

The T-test values for the data collected using the two methods show that the arithmetic and harmonic means of both speed and travel time are less than the critical T values at a 95% confidence interval. This indicates that there is no significant difference between the stationary method and the moving car method in collecting arithmetic and harmonic mean speed and travel time data. Conversely, there is a significant difference in collecting mode and median data.

The RMSE values for the arithmetic and harmonic means are also lower than the RMSE values for the mode and median, for both the stationary and moving car methods. Therefore, the moving car method can be used instead of the stationary method for collecting speed and travel time data as arithmetic and harmonic means, reducing both cost and time for highway analysis in various studies. The models comparing the two methods are shown in Figure 9 for speed data and Figure 10 for travel time data.

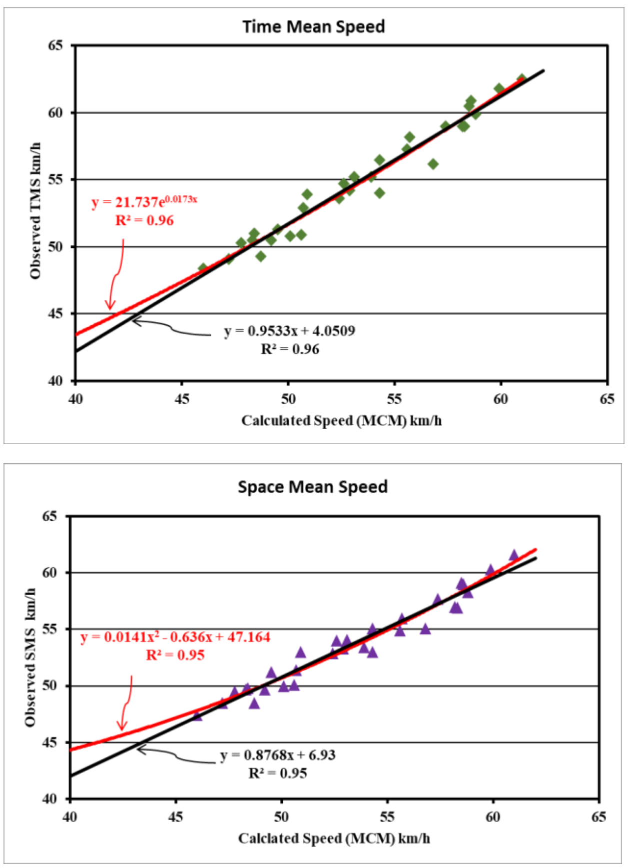


Figure 9 The models of speed data between two methods of data collecting

The models for calculated speed data using the moving car method and observed speed data using a radar speed gun exhibit linear, quadratic, and exponential relationships. The high R-square values indicate a strong regression relationship between the two methods of speed data collection.

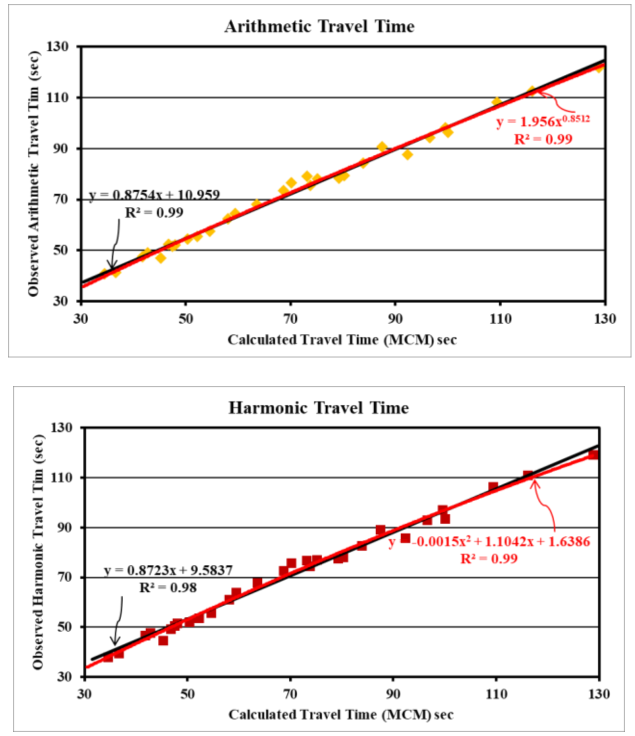


Figure 10 The models of travel time data for two methods of data collecting

The same indications are shown for travel time models, with linear, quadratic, and exponential relationships between the moving car method and video records from two cameras at the entry and exit points of the highway segments. The high R-square values indicate a strong regression relationship between the two methods. This demonstrates the accuracy and efficiency of the Moving Car Method (MCM), as its results closely align with actual traffic data and accurately reflect the conditions of urban multilane highways. This method saves time, money, and effort. Similarly, William J. Mortimer's study concluded that the stationary method is more costly and time-consuming compared to the moving car method.

4.0 CONCLUSION

In this research, a comparison was conducted using T-tests and modeling to collect traffic volume, speed, and travel time data through the stationary method and the moving car method for six segments of urban multi-lane highways during peak and off-peak hours. The results indicate no significant difference between the two data collection methods for traffic volume and for the arithmetic and harmonic means of both speed and travel time. The performance indicators for the regression models, specifically RMSE, which measure the average difference between predicted and actual values, demonstrated low RMSE values. This indicates that the models are accurate and fit the data well. These findings apply to the traffic volume models and the arithmetic and harmonic means of speed and travel time. Consequently, the models developed can be reliably used to collect traffic data using the moving car method for the six highway segments studied, addressing various traffic issues such as congestion and travel time delays on the city's highway network and nationwide. Additionally, these models can be used to gather data for assessing the level of service on multilane highways, enhancing traffic flow quality, or designing new multilane highway routes.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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