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Estimating a congested road capacity – headway relationship of a multi-lane highway in an urban area based on lane position

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ABSTRACT

This paper aims to estimate the road capacity based on the headway time to consider the road user behaviour which is the main element in microsystem of traffic analysis. The lane position is considered also in developing the capacity-headway model to reflect the driver behaviour in using each lane. Palestine Street in Baghdad City is chosen as the site study to simulate the urban multilane characteristics of roads. The data representing the roadway characteristics, vehicle volume, and headway time are collected at peak hours to reflect the high traffic flow level. The model is developed using regression analysis. The results show that the lane position affect the driver decision in choosing the lane of movement and affect significantly the capacity values especially the right lane position.

Keywords: Headway Time, Road Capacity; Road User Behaviour, Microsystem Analysis

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1. Introduction

Recently, traffic studies have been conducted based on microscopic analysis to simulate the traffic flow characteristics and assess the driver behaviour [1]. The microscopic characteristic of the traffic flow considers the interaction between individual vehicle-driver and the infrastructure rather than the aggregated characteristics; density, flow, and speed; which are considered in macroscopic analysis [2,3,4]. As the traffic flow is a major parameter in analysing the traffic characteristics in macroscopic level, time headway is a major parameter in analysing the traffic characteristics in microscopic level [4]. This is due to the fact that time headways distribution is essential considered in evaluating the driver behaviour, vehicle characteristics and traffic flow conditions; and also in determining the road capacity [4,5].
Time headway is the difference between the times of any two following vehicles crossing a point on a section of a road. It is measured practically as the time between the passage of a rear bumper of a vehicle and the rear bumper of the next vehicles [2,6,7]. If it is assumed that the time headway (t) of each vehicle is measured, then the total time headways (h) over which flow has been determined as follow [2,6,7]:

$$\sum_{1}^{n_t} h_i = t \tag{1}$$

If the number of vehicles n_t recorded in time t, then,

$$q = \frac{n_t}{t} = \frac{n_t}{\sum_{1}^{n_t} h_i} = \frac{1}{h_{av}} \tag{2}$$

Where, h_{av} is the average headway. Thus average headway is the inverse of flow [2, 6].

1.1. Capacity and headway time

Generally, capacity flow (C) can be found in case of constrained vehicle traffic. Thus, the maximum number of vehicles can occupy a section or pass a point in a section of a lane in a road per hour under prevailing roadway, traffic and control conditions [3,4].

The capacity can be computed using equation 2 by dividing 3600 seconds per hour by the mean headway h_{ave} in congested traffic:

$$C= 3600/h_{ave} \quad (3)$$

Determining accurate capacity of the roads is important for the traffic engineers and road designers to control the traffic delay time issue and optimise the signal timing design in the operational design of intersection [8]. Therefore, the main and sensitive factors affecting the capacity determination and distribution have been addressed. One of these factors is the headway distribution.
The variance in headway distribution within one section of a road has a direct impact on the road capacity. For example, some drivers prefer longer headway time than others belong to same class. As a result, different minimum headway values will be observed [4]. Based on that, two types of capacities are described in previous studies, pre-queue and queue discharge. Each of these has its individual maximum flow distribution. The pre-queue capacity is the maximum flow rate observed just before the traffic jam. The queue discharge flow is the maximum flow rate observed after traffic jam started in the presence of a queue upstream, low speeds and high densities [4]

1.2. Headway distributions

Headway distribution can reflect the driver behaviour in terms of either the traffic flow or road characteristics. In terms of traffic flow level, as traffic flow increase it is expected that drivers will reduce headway to prevent overtaking by beside vehicles [9,10,11]. In this term also it is expected that drivers will increase the headway to avoid any sudden braking which can lead to a crash. In terms of road characteristics, it is expected that the characteristics of urban roads; such as frequent stops, multi-mode of transportation, walking and cycling facilities; may push the vehicle driver to increase the headway time to avoid any expected and unexpected conflict. Other points could be considered in explaining the distribution of headway within one section of roads such as the aggressiveness of driver behaviour and the leading vehicle type [10].

1.3. Effect of lane position

Lane position is one of the factors that should be considered in analysing and modelling the effect of the headway distribution [12]. In characterising and analysing the traffic situation of the un-interrupted multi-lane highways, lane position is considered. Highway Capacity Manual (HCM) [7] considers the lane traffic density per lane is the major measure of performance of this kind of highways. However, the most common used manuals of traffic design and planning assumed that average capacity per lane is uniform while some empirical studies shows that each lane has different average capacity [13]. This can be demonstrated in the microsystem analysis because the lane position affects directly the driver behaviour

2. The main aim of reserch

This research aims to develop a capacity-headway relationship based on lane position for a multi-lane highway in an urban area in medium flow level.
Four objectives need conducting to achieve the aim:

a. To develop a statistical model to estimate the relationship between the headway time and traffic flow on a selected multi-lane highway in high vehicle flow level to simulate the congested traffic situation based on the lane position.
b. To test the validity of the developed headway-flow model.
c. To estimate the capacity of each lane using the developed flow-headway model.
d. To find the difference between the estimated capacity based on the developed model and the estimated capacity based on traditional model.

3. Literatur review

Several studies, which are listed in the study of Faheem and Hashim's [14], addressed the effect of the lane position on traffic stream characteristics and relationships such as vehicle speed and on the road characteristics. On the other hand, many studies were conducted to find the most suitable statistical models of headway distribution based on the traffic flow level or types of vehicles in single-lane and multi-lane highways regardless the lane position effect, such as Al-Ghamdi' study [15], Mei and Bullen[14], Sara [17], Buckley [18], Cowan [19], Sullivan and Troutbeck [20] and other studies listed in Dong et al.'s study [8], Roy and Saha's research [21], Ha et al's study [22] and Jang et al'study [23]. These studies investigated most simple and comprehensive model of headway distribution that can be used for different road classes and different flow rates.

However, a few studies considered the lane position in analysing and modelling time headway distribution. Some examples of these studies are listed below:

a. Semeida conducted two studies [24,25] to address the contribution of the road geometric characteristics of multi-lane highways on the operating speed and road capacity. He found that lane width, median width and side access are the most influential factor.
b. Mei and Bullen [16] and Sadeghhosseini [26] investigated the statistical headway distribution models in different cities based on the lane position of a of four-lane highway in different traffic level. They found that each lane has different distribution.
c. Zwahlen et al. [27] investigated the effect of different traffic volumes on different lanes of a freeway in Ohio on the headway distribution. They found that under same level of hourly volume, the headway distribution is almost the same.
d. Kong and Guo [28] considered lane management on a multi-lane freeway in china with the interaction between different vehicle types. They found that lane position has significant influence on the headway distribution.
e. Faheem and Hashim [14] classified the lanes of rural four-lane highways according to its position into Median Lane (ML) and Shoulder Lane (SL). They based also on the traffic volume level which are classified in this study to low and median level they investigated the impact of lane position aggregated with the traffic volume level on traffic stream relationships and headway characteristics. They concluded that the distribution of headways within lanes has significant variance and recommended to consider the lane position in the further studies of traffic flow characteristics.
f. Abtahi et al [1] investigated the effect of the lane position of a six-lane highway in Iran under heavy traffic volume. They considered the passing lane (the left lane) and the middle lane in their study. They found that most of the drivers on the left lane tend to use very short headway which is considered unsafe headway in this study. Thus, the capacity of the passing lane is higher than of the middle lane.
g. Arasan and Koshy [29] investigated the headway distribution for a divided four-lane in urban area in India. The developed models in this study were the same fir all lanes.
h. Bham and Ancha [26] considered different lane functions as the analysed the time headway on a lane drop and ramp weaving section in a freeway section.

Two studies [31, 32] were conducted to develop a model of headway distribution for a multi-lane highway Baghdad city. Jameel et al [31] developed models to predict the headway distribution in Palestine Street regardless the lane position. Alkaissi [32] developed two statistical models to estimate the headway distribution for two links in Palestine Street to consider the effect of the land use on the fluctuation of headway distribution but she also did not consider the lane position.

4. Methodology of the research

To achieve the aim and objectives of this research, the following steps should be carried out:

a. Selecting the study road based on criteria represented the requirements of this study.
b. Collecting the needed data which are categorised into roadway characteristics and traffic data.
c. Finding the proportion of lane utilisation to reflect the usage of each lane.
d. Selection of the proper statistical techniques to develop the headway-flow relationship.
e. Estimating the road capacity under most frequent headway time using the developed models for each lane.
f. Estimating the capacity under the same condition using the traditional mode, then comparing with the results of the developed models.
g. Finding the difference rate in the estimated capacity obtained in e and f.

5. The study road

The basic points adopted in the selection of the road for the study are identified based on the requirements of this research:

a. The selected road should be multi-lane type in order to consider the lane position factor
b. It should be located in a busy area where high level of traffic flow is observed to simulate the congestion situation.
c. It should be on terrain level, straight, uninterrupted to avoid the effect of geometric and traffic interruption characteristics.

Based on the above and due to the study limited resources, the Palestine Street is chosen. Palestine Arterial Street is located in an important urban area in Baghdad city, Iraq. It is considered a very busy area that has different land use types such as residential, commercial, educational and shopping uses. It has approximately (9.5) km length extending from Maysaloon Square intersection to Al-Mustanseriyah Square intersection passing through two main intersections. Palestine Arterial Street has service roads and considerable distances between its number intersections. It constitutes a major part of ring road number two around Baghdad City [32-36]. Fig. 1 shows the satellite image of selected sections of Palestine Arterial Street.

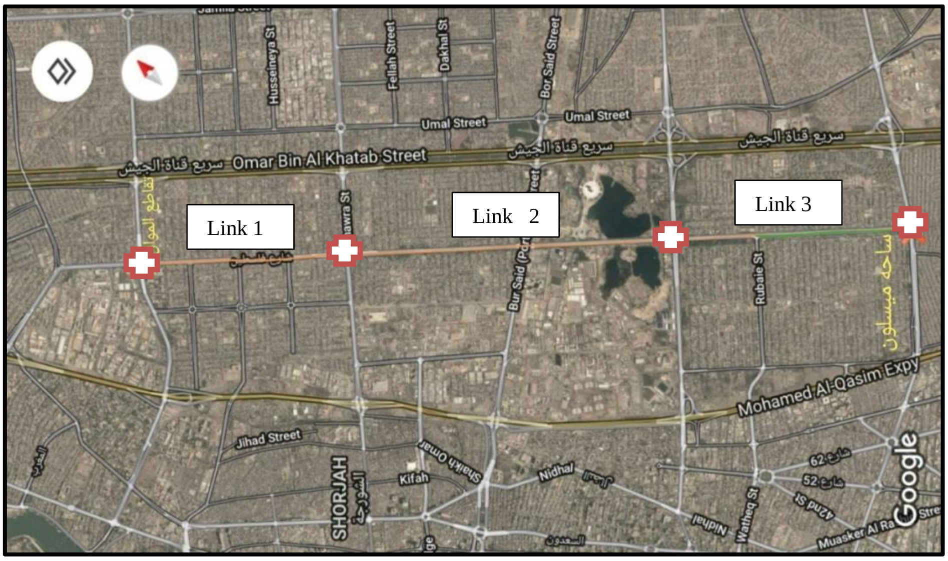

Figure 1. The Satellite Image of Palestine Arterial Street and the Selected Section
“Google Earth 2019"

6. The needed data

The needed data in this study are categorized into: roadway characteristics, traffic volume, and headway time data.

6.1. Roadway characteristics

The general feature of the roadway geometry for Palestine Street is shown in Table 1. The most needed data in this category are the number of lanes and lane width. The lane width is equal for all lanes. Therefore, the lane position is only considered in analysing headway distribution regardless its width. The three lanes in each direction are classified into left, middle, and right lane.

6.2. Traffic volume data

Traffic volume is collected using video recording technique for two hours (from 9:30 to 11:30) when high traffic flow has been observed. This is repeated in three days in three different months; December, January, and February; in which peak flow is observed. To avoid the effect of the interruption in the traffic flow resulted from the existing signalized intersections along Palestine Street; it was divided into three links as shown in Fig. 1. A section of about 100m is selected from each link to collect the data. The traffic volume counts used in this survey are collected on lane basis for each direction in 5-minute intervals for discrete hours

of observations. Fig. 2 shows the aggregated traffic volume for the three lanes.
The traffic volume is classified into four classes, passenger cars, mini bus, bus and truck in order to obtain accurate volume variations by vehicle type. The aggregated traffic composition was presented in the Fig. 3. Heavy vehicle is defined as "any vehicle having more than four tires touching the pavement". To convert the traffic volume to passenger car, passenger car equivalents (PCE) values were taken as (2.0) for buses and trucks for condition of level terrain and 1.8 fo4 mini buses [7].

Table 1. General features of the roadway geometry of Palestine Street

Road Item	Value
Total length	9.5 km
Number of lane	3 Lane/direction
Width of lane	3.9 meter
Median width	6.88 meter
Lateral clearance width	1.38 meter

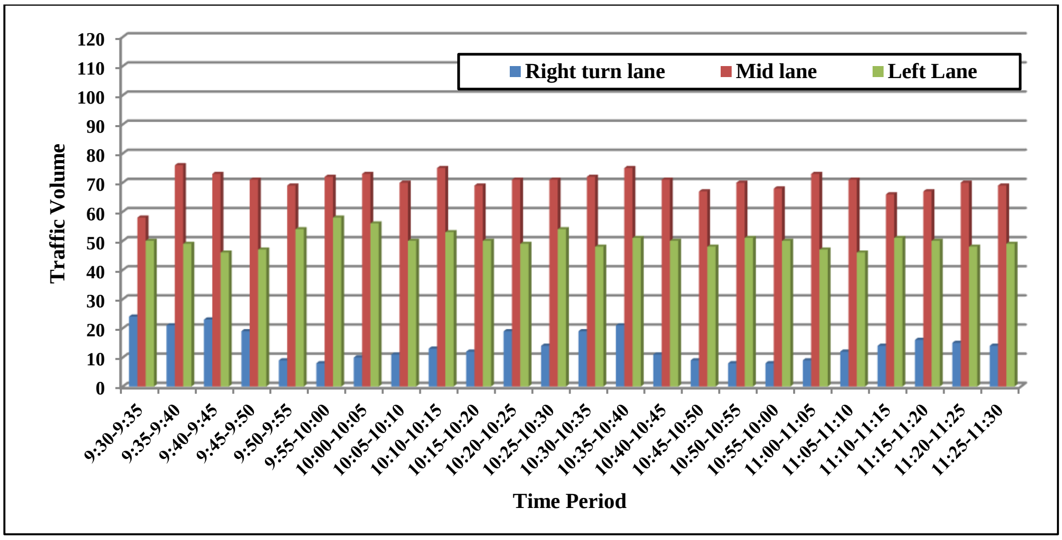

Figure 2. a

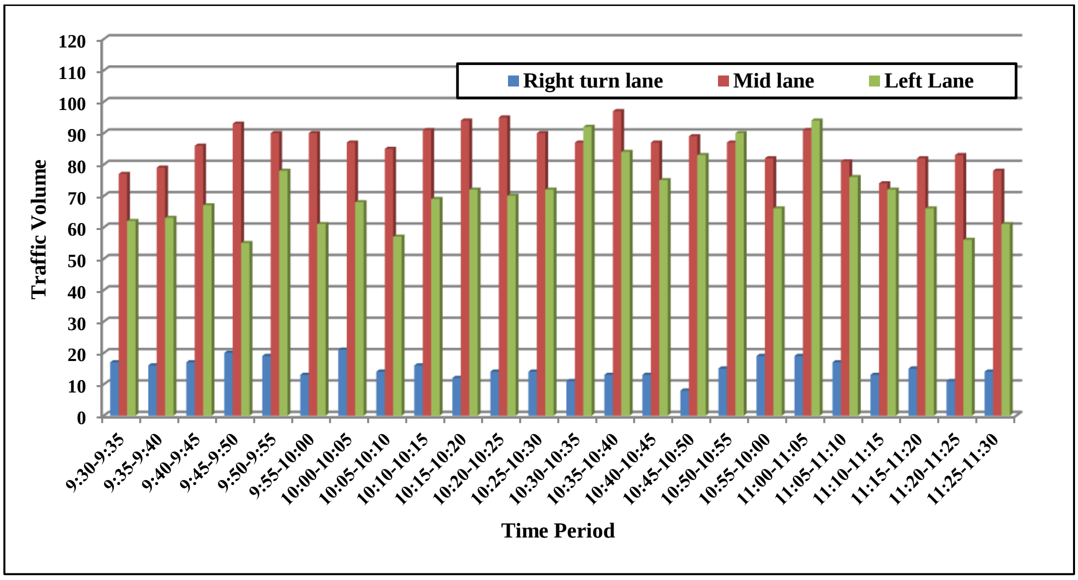

Figure 2. b

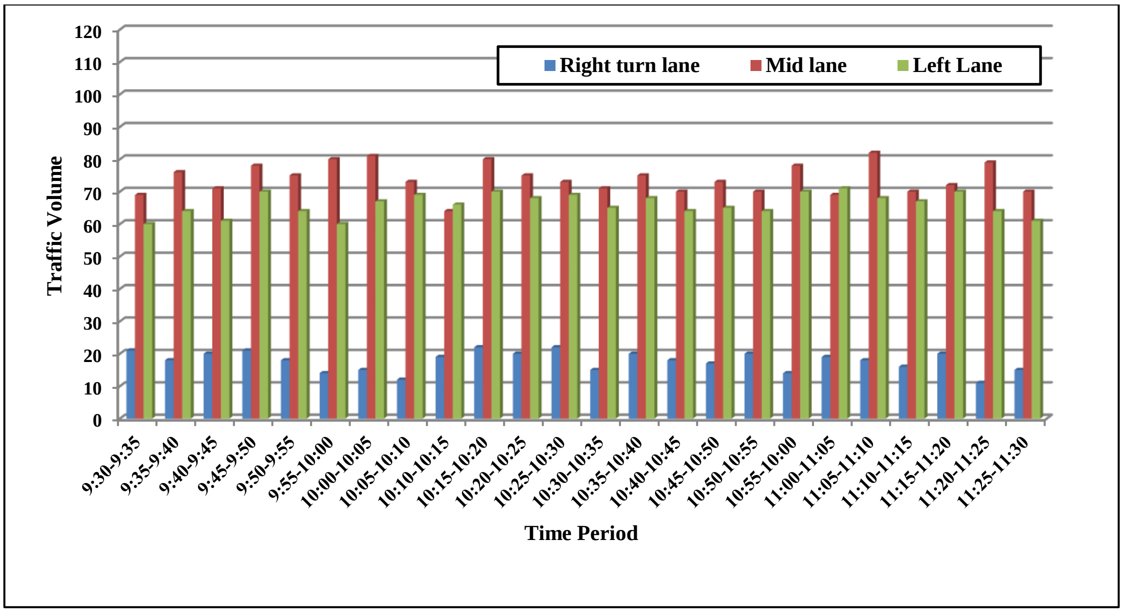

Figure 2. c

Figure 2. The aggregated traffic volume of Palestine Street a. in December, b. in January, c. in February

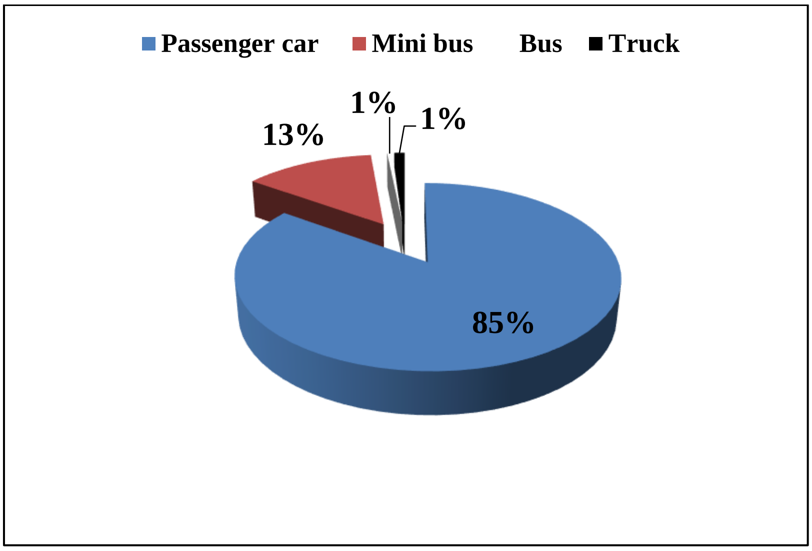

Figure 3. The aggregated traffic composition distribution

6.3. Headway time data

Average time headway between each two following through vehicles has been measured per lane basis in the three selected sections in the same hours of collecting the traffic volume. The most common method of collecting time headway data is the measurement of the time between two vehicles to cross a given point. To measure the time headway from the video film for the selected section, a narrow black tape on the screen is used to represent the indication point that the successive vehicles cross it. Then, the film starts to record the time when each vehicle passed the indication point in each lane then the time between two successive vehicles was determined by calculating the time difference between the passing of leading and following vehicles over the indication point of each lane.

The frequency distributions for time headway with normal curve are estimated using SPSS ver.22 statistical software as shown in Fig. 4.

SPSS 22 software is used to examine the normality of time headway distribution. Table 2 shows that time headway distributions are not normal and skewed to the left according to statistical test (Kolmogorov-

Smirnova and Shapiro-Wilk).

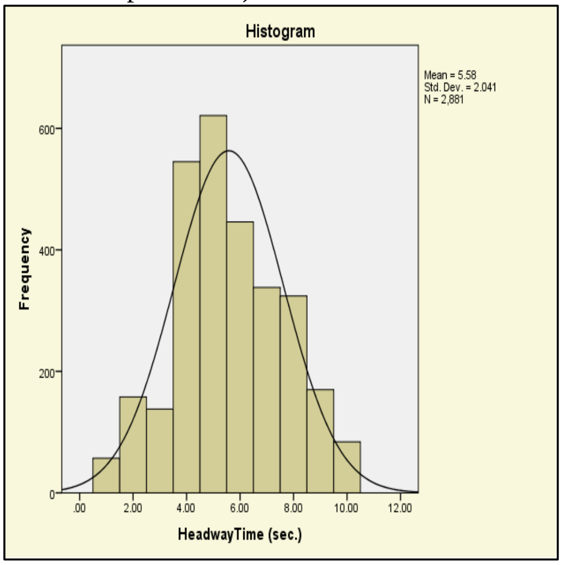

Figure 4.a

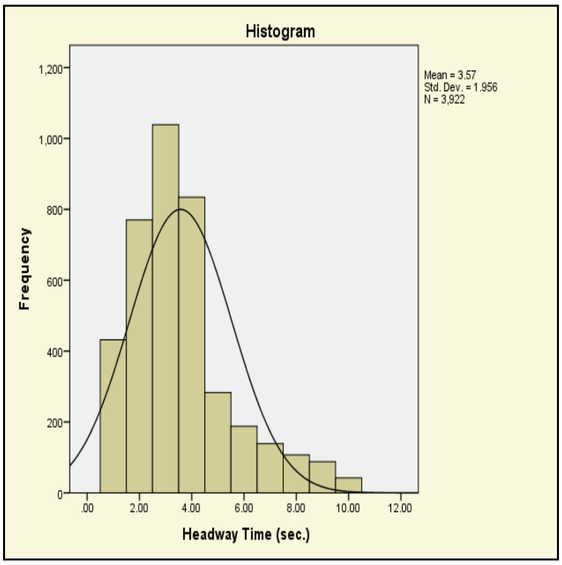

Figure 4.b

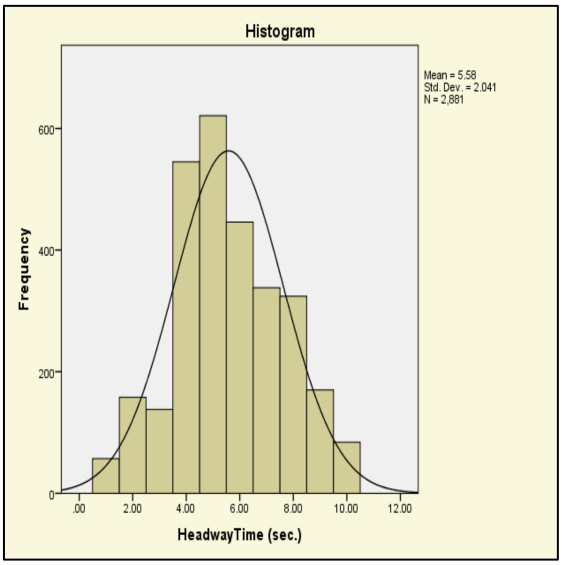

Figure 4.c

Figure 4. Time Headway distribution a. Left lane, b. Middle lane, c. Right Lane

Table 2. Tests of normality of the headway time

Lane	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Right	.194	2882	.000	.887	2882	.000
Mid	.197	3922	.000	.889	3922	.000
Left	.206	3453	.000	.851	3453	.000

7. Lane utilization

Lane utilization is the distribution of the traffic flow to the available lanes per each direction of the highway [7]. To illustrate this distribution, the proportion of the traffic flow per each lane to the total traffic flow per direction is determined for each interval. As shown in Fig. 5, the right lane usage is much less than other lanes. This can be resulted from drivers avoiding to use the right lane because of the random stopping of vehicles and frequent vehicles entering or leaving local streets. While the use of the middle lane is the largest, this is due to it is considered preferable for the drivers. This is because drivers free freedom to travel without interruptions, they can ovoid vehicles using U turn and they can leave the outer lane by overtaking the vehicle in the next lane. However, at high traffic flow (2300-2580) veh/hr, the lane utilization becomes closer to the left lanes. This is due to a fact that traffic at high traffic usually has the same speeds at all lanes and that reduces the need for a lane change.

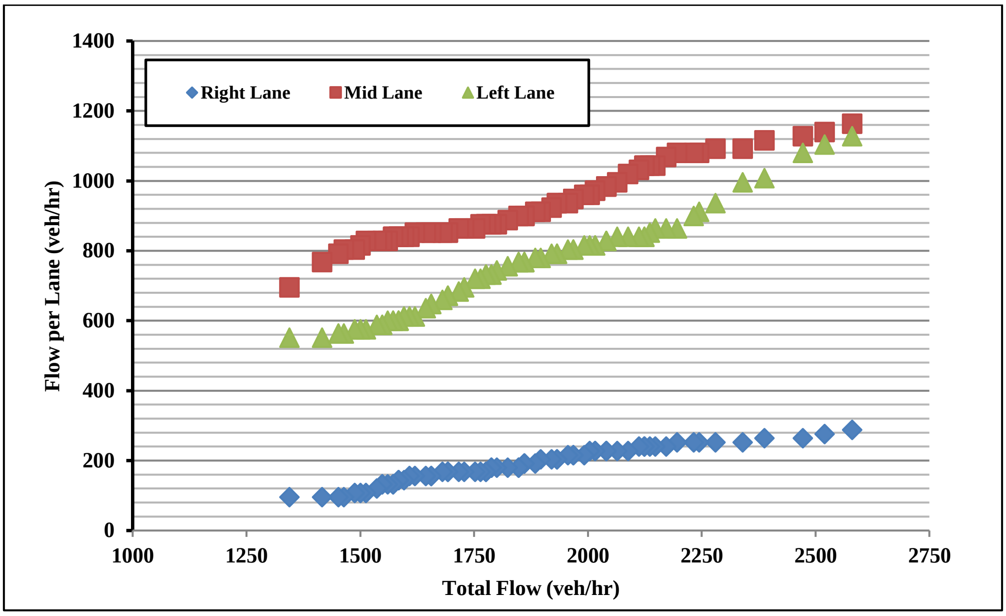

Figure 5. Flow rate per each lane

The proposed models for flow rates at each individual lane with respect to the total flow rates with their coefficient of determinations (R^2) are shown in Table 3. The R^2 values indicated a high correlation. It should be noted here that these models are valid for total flow rates from 1250 to 2850 veh/hr.

Table 3. Proposed model for lane distribution for each lane of Palestine Street

Lane	Model	R^2
Right lane	$U = -9E\text{-}05x^2 + 0.5429x - 495.6$	0.9783
Mid Lane	$U = 4E\text{-}05x^2 + 0.2512x + 331.96$	0.9542
Left Lane	$U = 7E\text{-}05x^2 + 0.2597x + 25.516$	0.9822

According to the traffic flow classification used Ghamdi [15]; in which he classified the traffic flow into low, medium and heavy flow level; and since the minimum observed traffic flow is greater than 1200veh/h; the level of the traffic flow of the case study at the data collection time can be considered high flow level.
To keep the consistency of the range of the collected data with this classification, the minimum and the maximum observed traffic flow, 1250 and 2850 vph respectively, are distributed to the three lanes using the models shown in Table 3. The ranges of the chosen data are determined based on that as shown in Table 4. These ranges will be considered in developing the models in the next steps.

Table 4 The ranges of traffic flow per each lane used in this research

Lane	Minimum flow rate (vphpl)	Maximum flow rate (vphpl)
Right lane	183	766
Mid Lane	646	1048
Left Lane	350	1052

8. Developing of headway time –flow model

Headway time-flow model may be derived using Multiple Regression which is a statistical process used to generate a predictable model at a selected confidence level based on determining the relationship between contributed variables [37, 38]. The SPSS software version 22, curve estimation, is used to develop the model. Several models are generated as shown in Table 5 which all examined using F-test to choose the best model. Probability of F equal to 0.05 is used in the analysis; this corresponds to a value F test of 3.48 [39-43].

Fig. 6 shows the graphical representation of the actual Headway time-Flow relationship for right, middle and left lane of the Palestine Street. In these figures, the ranges of the data chosen to develop the proposed models are identified based on the limits determined in Table 4. From the result of regression process, negative exponential distribution was found to be suitable for modelling headways at different lanes and over the entire range of traffic flows. The headway time–flow adopted models are shown in the Table 6.

Table 5. Model summary and parameter estimates of the generated headway-flow models of the middle lane

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.911	716.216	1	70	.000	8.502	-.005-
Inverse	.955	1480.779	1	70	.000	-1.693-	4789.746
Compound	.953	1427.089	1	70	.000	14.455	.998
Growth	.953	1427.089	1	70	.000	2.671	-.002-
Exponential	.953	1427.089	1	70	.000	14.455	-.002-
Logistic	.953	1427.089	1	70	.000	.069	1.002

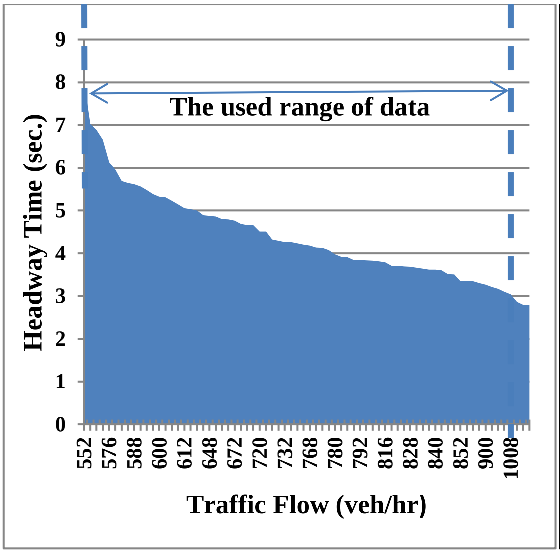

Fig. 6.a

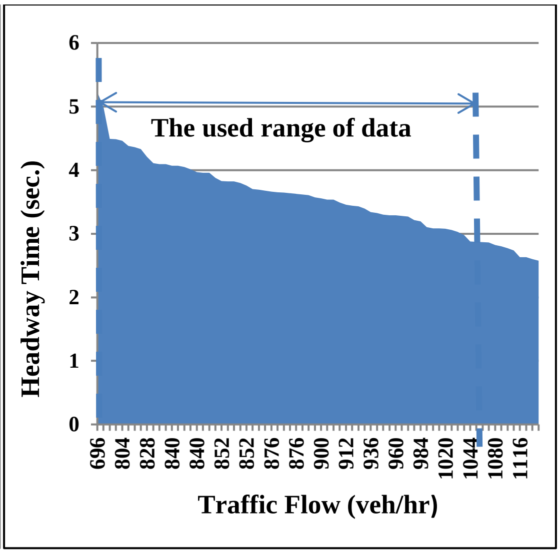

Fig. 6.b

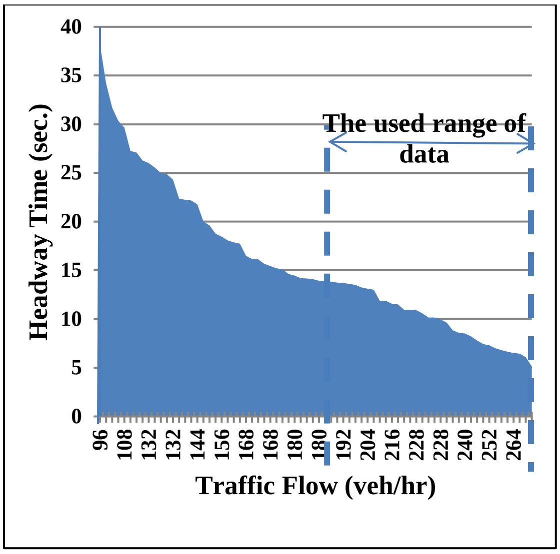

Fig. 6.c

Figure 6. Graphical presentation of the headway time-flow relationship of Palestine Street a. Left Lane, b. Middle lane, c. Right lane

Table 6. Proposed models for headway time -flow for each lane of Palestine Street

Lane	Estimated Models		(R^2)
	h as a function of V	V as a function of h	
Right	$h= 399.87e^{-0.017V}$	EFRL=V=-58.82ln(h)+352.42	0.9088
Middle	$h = 14.455\ e^{-0.002V}$	EFML=V = -500ln(h) + 1335.5	0.953
Left	$h = 14.323\ e^{-0.002V}$	EFLL = V=-500ln(h) + 1327.7	0.908

h = Headway time (sec.), V = Lane traffic flow (v/h/lane), EFRL=estimated flow in the right lane, EFML=estimated flow in the middle lane, EFLL=estimated flow in the left lane.

8.1. Models validation

To test the validity of the model, a new set of data was collected to compare graphically with the results of the developed models and test the correlation between them. Three methods were used to test the correlation: graphical method, coefficient of determination, and Chi-square methods.

The graphical method was done by drawing a relationship between the observed and estimated headway time for each lane as shown in Fig. 7. The points representing the intersecting of the both results should tend to stand nearby the draw line at 45˚ to indicate the closing of the theoretical results of the observed values, then the satisfactory of the developed model. This can be measured statistically by the bivariate Pearson correlation R which is the degree of the relationship between a pair of variables. When R closes to 1, the two variables rise and fall together with perfect correlation [39-43]. The SPSS statistics 22 are used to identify R.

The coefficient of determination R2 is used to measure the rate of variance in the theoretical headway estimated from the developed models to the variance of the observed headway time. Higher R^2 means less difference and more closer to give real assessment [39-43].

To test the goodness of fit of the developed model, the Chi square method was used to explore how the theoretical negative exponential distribution fits the observed distribution for time headway. The results of this test shows that the Chi-square values are less than the critical values, therefore the developed models could be considered accepted as shown in Table 7.

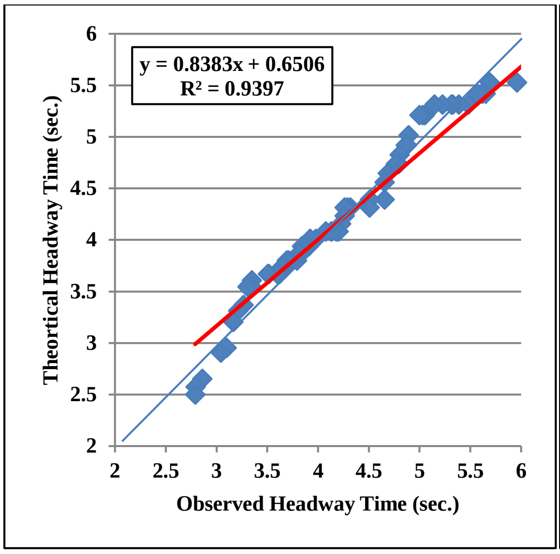

Fig. 7.a

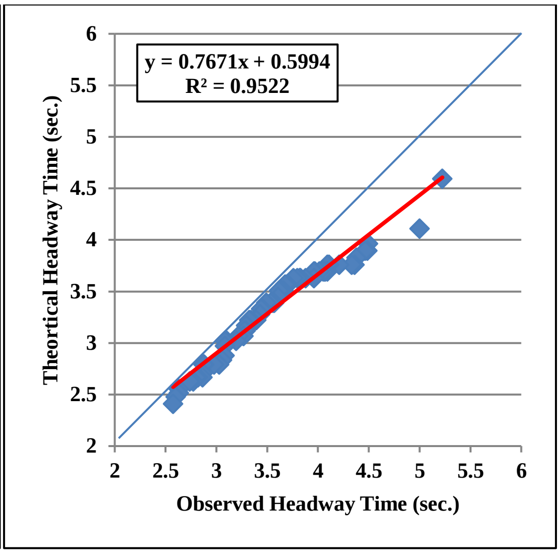

Fig. 7.b

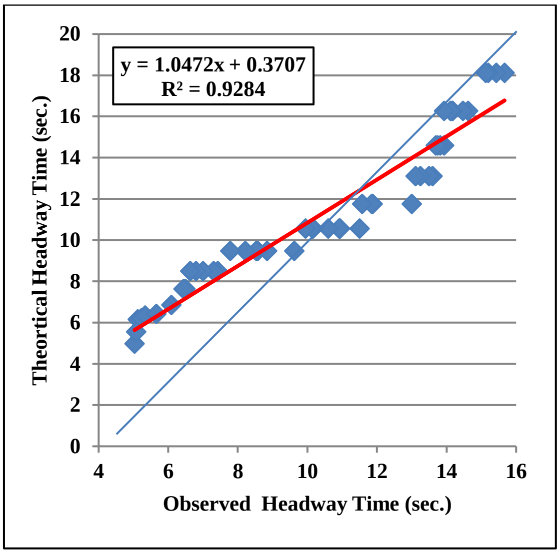

Fig. 7.c

Figure 7. Measured Values of Headway time Versus Regression Predicted Values for a. left lane, b. Middle Lane, c. Right lane

Table 7. Chi Square Goodness of Fit for Each Lane of Palestine Street

Lane	N	Degree of freedom (df)	X^2	X critical
Right lane	21	20	0.577	32.622
Mid lane	16	15	0.356	24.689
Left lane	21	20	0.289	31.785

9. Capacity Estimation

The capacity of the selected sections is estimated based on the microsystem analysis using two models, the traditional models shown in (3) and the developed model in this study which is shown in Table 6. The results are shown in Fig. 8. It can be noted that the capacity estimated using the developed models in this research produced much less values than the capacity estimated by the traditional model. The rate of difference between the estimated capacity values for each (h) is computed.

The average rate of difference is computed by finding the area between the two curves, then divided the area by the difference between the maximum and the minimum headway of each range of used data. For example, the area between the curve of the estimated capacity using the traditional formula and the curve using the developed formula for the right lane is found by the difference between the integration of the both formulas:

$$\int_{h=5}^{14.8} -58.82\ln(h) + 352.42 - \int_{h=5}^{14.8} \frac{3600}{h} = 3906.68 - 2157.72 = 178.5 \text{ vphpl. sec}$$

The results of the remaining lanes are shown in Table 8.

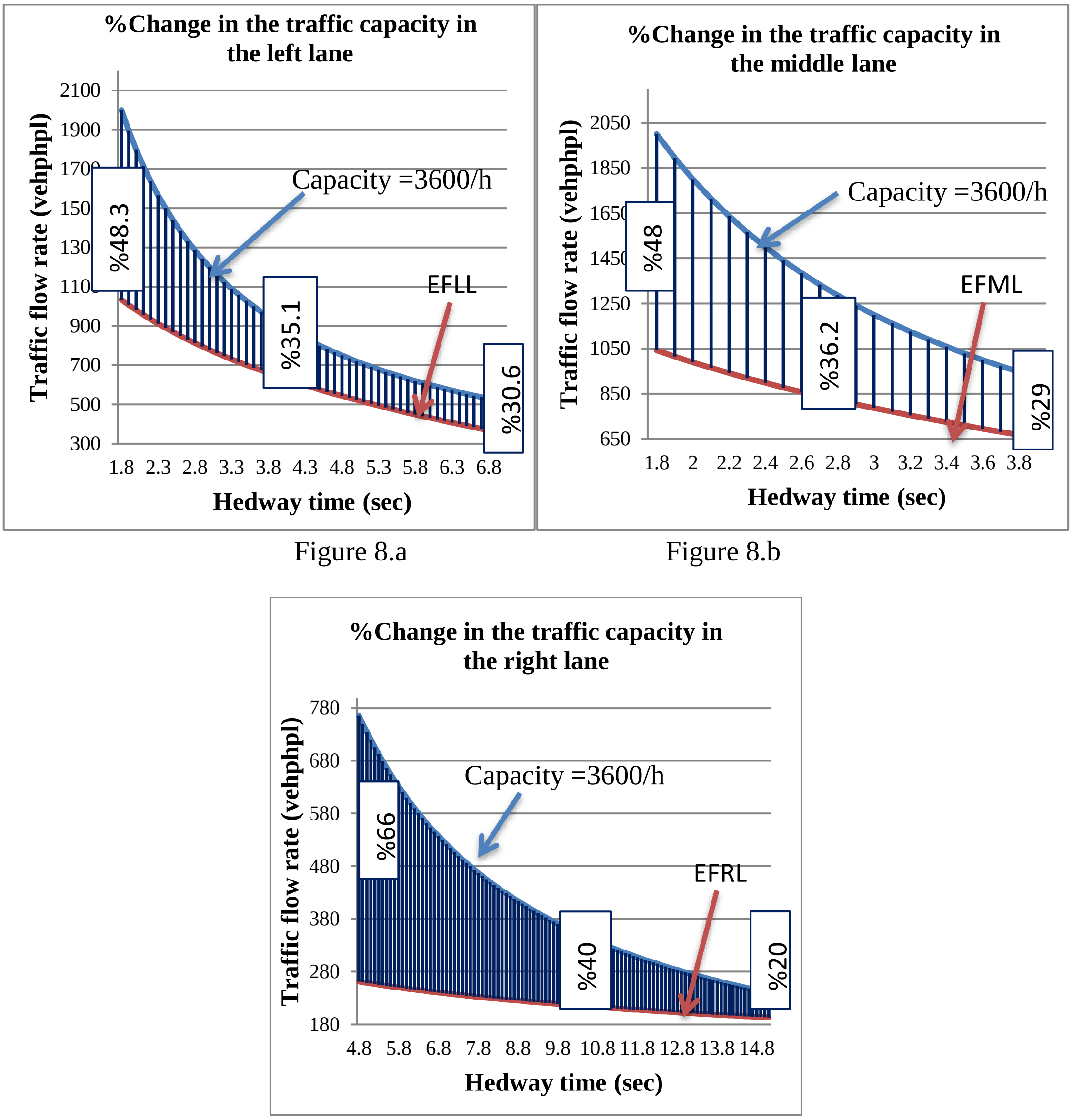

Figure 8.a Figure 8.b

Figure 8.c

Figure 8. the difference rate of capacity values for each lane between the estimated values using the developed model and the traditional modules. A. left lane, b. middle lane, c. right lane

Table 8. The difference values between the two modules

Lane	Area formula between the two curves	Area between the two curves (vphpl.sec)	Average difference (vphpl)	Maximum difference (at h=h_{min}) (vphpl)
Left lane	$\int_{h=3}^{7} \frac{3600}{h} - \int_{h=3}^{7} -500\ln(h) + 1327.7$	902.24	225.56	421
Middle lane	$\int_{h=2.8}^{5} \frac{3600}{h} - \int_{h=2.8}^{5} -500\ln(h) + 1335.5$	631.37	287	465
Right lane	$\int_{h=5}^{14.8} \frac{3600}{h} - \int_{h=5}^{14.8} -58.82\ln(h) + 352.42$	1748.96	178.5	462.25

It can be seen theat he higher difference rae is at the right lane. This may be resulted from the effect of the conditions of the right lane position on the capacity of the lane. The rate of the left and middle lanes are also high. For eah lane, the rate of diiference is higher when the headway time is less.

Based on the difinition of road capacity and the results shown in Fig. 7, the maximum flow can be determined at minimum headwa. The final capacity-hedway modules are shown in Table 9.

Table 9. Estimated capacity at each lane

Lane	Estimated Capacity model	Estimated capacity (vphpl)
Right	ECRL=-58.82ln(h_{min})+352.42	295.2
Middle	ECML=-500ln(h_{min}) + 1335.5	836.5
Left	ECLL=-500ln(h_{min}) + 1327.7	828.8

10. Comparing the estimated capacity with the supplied road capacity

The supplied road capacity it can be defined here as the road characteristics that represent the design characteristics of the roads provided to bear the maximum forecasted vehicle flow. It can be determined using Highway Capacity Models (HCM) [7] for multilane highways at free flow speed less than or equal 60vph. The free flow speed at the selected road is chosen as the vehicle speed at minimum traffic density in urban roads determined in previous study [34]. Then the supplied capacity is [7]:

$$Supplied\ capacity = base\ capacity\ \times F_{HV} = 1000 + 20(FFS) \times F_{HV} \tag{4}$$

Where: FFS= free flow speed vph=60vph
F_{HV} = the adjustment for heavy vehciles = 0.938 when the percentage of the heavey vehcile is 13%.
Then the supplied capacity of eah lane = (1000+20(60))×0.938=2065.73vphpl.

the supplied capacity is much greater than the estimated traffic capcity shown in Table 9 per each lane. This means that the maximum traffic flow at the congestion level is under capacity and the road is desined to accommodate the most common driver behaviour which is reflected by the mode headwqy time.

11. Discussion

The results obtained in this study will be discussed here. Mainly it will focus on lane utilisation, traffic flow level, headway distribution per lane, the developed models, and the comparison between the estimated capacity results.

1. Lane utilisation: the usage of the three lanes by vehicles' drivers was not uniform. The difference between the usage of the left and the middle lane was not significant and it goes to the minimum when the vehicle flow is higher. On the other hand, the usage of the right lane is much less because the drivers prefers to avoid the frequent enter and access points to the collector streets on the right side of the street. The usage of the right lane as parking by some drivers make it is not preference for movement. In addition, the existing of shopping centres on the right side leads to random stopping of vehicles which drivers trying to avoid. This point enhances the effect of the driver behaviour on the lane choosing and the effect of lane position on the driver movement.
2. The traffic flow:

- The traffic flow level when collecting the data can be classified as high level. This is required to simulate the congestion situation.
- To keep the consistency in the parts of this study, the developed models of lane utilisation shown in Table 3 was used to find the minimum and the maximum limits of the flow and headway data used in the modelling step as shown in Table 4. Based on that, not all the collected was used, the data out of the identified range was excluded as shown in Fig. 6.

3. The headway time data.

- It is noted that the mean and median headway time in the left and middle lanes was shorter than in the right lane because they more occupied by vehicles than right lane.
- Within one lane, the time headway is going to be shorter when the traffic flow increase. This may reflect the high lane occupancy which push the driver to reduce the gab to the in front vehicle. However, this should be conducted in further research and consider other factors such as space headway and speed.
- The statistical description of the headway data shows that the median headway time is less than the mean headway. This means that more than half of the drivers tend to use headway less than the mean value.

4. The flow-headway model.

- Three flow-headway models were developed for each lane using regression analysis as shown in Table 6. Several methods are tested using coefficient of determination (R^2) and it was found that the negative exponential is the most suitable method.
- The constants of model of the left and the middle lanes (EFLL and EFML) were almost the same but they are different the constant of the right lane model (EFRL).
- Three methods are used to test the validation of the developed models and the results show that the three models have the three methods give the same results. The results demonstrate the validity of the developed models to express the relationship between the flow and the headway time.

5. Estimation capacity.

- The developed models in this study can be used to estimate the capacity of each lane by defining the limits of the headway time. The minimum headway time in ach lane produces higher traffic flow. This can be considered the capacity of the lane under high traffic flow.
- The estimated capacity in this research per each lane was compared with the estimated capacity using the traditional model as shown in Fig. 7. The results show that the traditional method produced much higher values than the developed model produce. The difference rate between the two estimated values is quiet significant, about %48, in the middle and left lanes and about %66 in the right lane. This means that the traditional method is not valid in determining the capacity per lane and produces overestimated values.
- The estimated capacity per each lane is compared with estimated road capacity using HCM model. The results show that the HCM capacity model produces overestimation capacity since it does not consider the

driver behaviour which is considered in this research using headway time. In addition, the HCM methods assumes that the average capacity is equal for all lanes while the results of this research show that the lane position affect the capacity value.

12. Conclusion

1. The effect of lane position on the headway times and traffic flow is significant. This enhances the significant role of the driver behaviour in terms of deciding the lane of movement on the distribution of traffic flow, headway times, and then the maximum capacity.
2. The usage of the right lane is not significant in the area of study. Therefore, the conditions of area; such as the land use, existing access points, and illegal parking usage; should be considered in further studies.
3. The traditional model of estimating the capacity based on the headway time is not valid to estimate the capacity of each lane.

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