ASSESSMENT OF TRAVEL SPEED FOR URBAN STREETS USING GLOBAL POSITIONING SYSTEM

*Sumayah T. Ayob¹

Zainab A. Alkaissi¹

1) Highway and Transportation Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

Abstract: The travel speeds selected and trusted by the driver vary according to his behavior and the surrounding environment. Accordingly, this paper studies the change of the free-flow speed, influences on it, of the route linking Al-Bayaa and Bab Al mudam sectors. A GPS device was used to collect data during 60 rounds for three periods (morning, day, and night), 50 of them during the off-peak time and 10 during peak time with drivers of both genders and different ages. The results showed a variation of the FFS values at off-evening peak time, also noting the posted speed limits corresponding to the statistically calculated 85, which was 69km/hr. along the route. The emergence of a significant impact of the security checkpoints in link 3, causing a general defect in the traffic accounts. Also, there was an increase in the speed with an increase in lane width by 13% and a decrease in the speed with an increase in the number of lanes by 45.18% and 18.6% between 2 and 4 lanes and 2 and 3 lanes respectively. It should be noted that male is bolder and more reckless in choosing speeds by 26.32% than female and that groups of 50 and below years old choose less speed by 13.52% of ages 35 and below years old who are more confident and familiar in dealing with roads and choosing the appropriate speed.

Keywords: *travel speed, FFS, PSL, GPS, driver chrematistics, operation speed.*

1. Introduction

The great development of urban cities like Baghdad, diversity of land uses, tendency for private mode Caused an increase in traffic

volumes[1], drivers' behavior to the roads has changed, and the side parking[2], all these reasons led to an imbalance in traffic in general, as they affected the flow of free speeds. It is necessary to survey, review these urban rout and to show the influence of these factors on them.

1.1. Travel Speed

In its simplest definition, the travel speed can be defined as the distance traveled between two points on a road divided by the travel time. Which differs from the running speed, including the times of stops and reactions. Thus, any convergence between the two-speed values indicates the smoothness and comfort of the movement [3].

1.2. Free-Flow Speed FFS

Free-flow speed (FFS), is known as the free-running speed that the driver operates for a certain section of roads which are far from traffic control and traffic congestion area, under free-flowing, ideal weather conditions [4,5]. There are many ways for calculate free-flow speed, can be calculated as the post speed limits by adding 5 mph (8 km / h) or from the field geometric features of the road as indicated in the highway capacity manual [4], Nicholas J. Garber third

*Corresponding Author: EDMA035@uomustansiriyah.edu.iq

edition in 2002 and HCM 2010 indicate that space means speed represents the harmonic mean for a set of vehicle speed is in an inverse relationship with traffic flow, as it became clear that in the case where flows are low, there is less interaction between vehicles, causes the vehicle to travel in a free state and at the maximum possible speed [4,6]. Similarly, the harmonic mean is used to find FFS [7].

1.3. Factor Affecting the Free-Flow Speed

Highway capacity manual indicates the factors that directly affecting free-flow speed Which can be summarized as (number and width of the lane, access point, lateral clearance, median type, posted speed limit, horizontal and vertical alignment), A study conducted in Nigeria 2016 [8], showed the presence of additional factors that affect the free flow speed such as weather, vehicle and pedestrian characteristics. And in another study conducted in India [9], it was shown the effect of geometric properties such as horizontal and vertical curves on the selection of free-flow speed ,another local research proves this [10]. Moreover, in a study conducted on several drivers of different ages and from both-genders, it revealed the extent of the impact of these two characteristics to reduce the operating speed of the road [11].

1.4. Posted Speed Limits PSL and the Relationship with FFS

It is the speed declared on the sides of the road, which mainly depends on the 85th percentile speed [12], most drivers make reasonable and wise estimates of appropriate road speeds, which are often consistent with the design geometric features of the road. The MUTCD [13] shows the relationship between the posted speed and the FFS. When the speed limit is declared, it should be within 5MPH of the 85th percentile speed in the case of the traffic being in a state of free flow.

1.5. 85th Percentile Speed and the Relation with Posted Speed Limit PSL

It is the speed that most vehicles travel on a road under perfect and free-flow traffic conditions without the influence of the weather, abnormal and slow traffic movements. This speed is chosen by the drivers, considering that it is the safest speed, therefore 85th percentile speed is the main indicator for choosing speed limits for the nearest 5 miles (10 km\hr.) [14].

1.6. Road Classification

The road network of urban cities has a great diversity in terms of the engineering design on which the road is designed based and in terms of the actual functional classification of the road. For various previous studies, the methods were functionally classified into four categories: (principal arterial, minor arterial, and collector, local) [15, 16]. This is what the federal highway administration FHWA has indicated and it was agreed with AASHTO. However, this classification does not give a clear indication of the roads because the classification is based on traffic volumes, the number of miles served by the road, and the nature of the service it provides in terms of mobility and accessibility. Highway capacity manual HCM (2010) clarified this problem and gave other, more precise criteria for classification through the different categories based on design and function to give a more realistic classification for the road [4]. This classification, which the HCM has followed, takes the free flow speed FFS as the basis for knowing the class of road.

1.7. The Utilize of GPS Technique in Data Collection

Finding values for the speeds operated by driver on a particular road with great accuracy and abundance of data, in addition to the use of modern technology methods such as the global positioning system GPS which saves effort and

time, GPS technique is used. Recently published research [17, 18]. Demonstrated this fact. Moreover, other researchers use the GPS technique mainly to calculate travel speeds [19] With the development of data extracted from it, it became the most common method for collecting research data [20 & 21].

2. Objective of the Research

- Extrapolation of a method for calculating the free flow speed along a path based on the acquired data.
- Investigate the impact of the driver's characteristics in terms of age and gender, the number of lanes, and the width of each lane on the free-flow speed.
- Explore the functional classification of some urban street in Baghdad city, which have major activities and different land uses.

3. Methodology

To understand the FFS nature in the city of Baghdad, it is logical to resort the roads that serve different traffic-generating regions with different land uses, in addition to different geometric features used by a large variety of drivers to demonstrate the effect of the aforementioned factors on changing the values of travel speed patterns. Given this, the path linking two vital areas in Baghdad was chosen, namely Bab al-Muadam and al-Bayaa areas in both directions, which in turn connects the two sectors of Baghdad al-Karkh and Al-Rusafa with a total length of 11,532 km "Image .1". This path passes through 14 links. Each link has different engineering characteristics from the other and has widely different land uses on both sides of the road, as explained in "Table. 1".

In this research, determining free-flow speed requires knowledge of the case in which the flow is free. Accordingly, the route was studied at the times of the morning, afternoon, and evening off-peak in the period of (9:00 am – 12:30 pm), (3:00 pm – 5:30 pm), (7:30 pm – 10:00 pm) respectively, on Mondays, Tuesdays, and Wednesdays of every week during which traffic is uniform, for 4 weeks (December /2020) To extract 60 sample size 30 for each direction, which represents the minimum speeds sample size to be normally distributed [22]. These periods were determined based on a test tour throughout the whole day for the study area and also after reviewing some local studies of some links that confirmed the validity of choosing times for off-peak periods.

Image 1. Aerial photo of the study area

Table 1. Link characteristics

link	Name	Length (meter)	No. of a lane (One direction)		Lane width (meter)		Posted speed limits (PSL)	
			north	south	north	south	north	south
1	Mumtaz street	1940	3	3	3.4	3.4	60	60
2	Jinub street	390	2	2	3	3	50	50
3	Al Yarmouk Street I	650	3	4	3.4	3.6	40	60
4	Al Yarmouk bridge	470	2	2	3	3	60	60
5	Al Yarmouk street II	930	3	3	3.6	3.6	40	40
6	Damascus street	1530	3	3	3.6	3.6	60	60
7	Damascus street	1390	3	3	3.6	3.6	60	60
8	Al Allawi I	560	3	3	3.6	3.6	40	40
9	Al Allawi II	200	4	4	3.4	3.4	40	40
10	Al Nasser Street	760	6	6	3.4	3	60	60
11	Haifa street	1532	3	3	3.4	3.4	60	60
12	Bab Almada bridge	900	2	2	3	3	60	60
13	Bab almudam I	80	3	3	3	3	60	60
14	Bab almudam II	200	3	3	3	3	60	60

Moving vehicle technology was used to compute traffic flow rate during the periods mentioned above. The headway was also deduced, which represents the inverted free-flow [23]. The first researcher implemented this method is John Glen Wardrop, 1954 [24]. A study from William J. Mortimer [25] came after that showed how close this method of estimation is to reality. At the same time, GPS was used to calculate the speeds. It was connected with the vehicle. Then, the control bottom was activated when entering the route of the study, shown in "Image. 2" and the results of the device appear from the device to the server, which gives the vehicle's movement details every 10 seconds, with the location and coordinates "Image. 3 " as shown in Tables:

Image 2. GPS device **Image 2.** GPS device output

Table 2. Outcomes for the morning off-peak period (9:00 am - 12:30 pm)

link	north			South		
	Operation speed (km\hr.)	Flow rate (veh\hr.)	headway (sec.)	Operation speed (km\hr.)	Flow rate (veh.\hr.)	headway (sec.)
1	59	1239	3	67	1317	3
2	52	495	7	58	474	8
3	18	1125	3	53	1102	7
4	53	398	9	59	427	8
5	56	903	4	57	892	4
6	48	969	4	55	1047	3
7	47	1110	4	41	532	5
8	39	1384	3	31	1090	3
9	46	1500	2	41	1531	2
10	52	909	4	43	838	4
11	51	958	4	50	1013	4
12	56	829	4	53	852	4
13	32	629	6	32	657	6
14	18	719	5	17	704	5

Table 3. Outcomes for the afternoon off-peak period (3:00 pm- 5:30 pm)

link	north			south		
	Operation speed (km\hr.)	Flow rate (veh.\hr.)	headway (sec.)	Operation speed (km\hr.)	Flow rate (veh.\hr.)	headway (sec.)
1	56	1141	3	62	1097	3
2	60	413	9	56	451	8
3	45	1227	3	49	1158	3
4	61	494	7	63	496	7
5	59	950	4	56	918	4
6	55	801	5	49	815	4
7	51	766	9	38	699	5
8	49	986	4	28	1207	3
9	49	1521	2	38	1451	2
10	57	469	8	38	435	8
11	56	967	4	57	949	4
12	61	701	5	63	671	5
13	38	598	6	41	530	7
14	48	576	6	49	625	6

Table 4. Outcomes for the evening off-peak period (7:00 pm -10:00 pm)

link	north			south		
	Operation speed (km\hr.)	Flow rate (veh.\hr.)	headway (sec.)	Operation speed (km\hr.)	Flow rate (veh.\hr.)	headway (sec.)
1	73	384	10	77	401	9
2	61	363	10	64	354	10
3	48	432	8	56	428	8
4	62	363	10	63	355	10
5	61	1014	4	55	1030	3
6	62	1092	3	61	1016	4
7	68	1234	3	67	1253	3
8	57	893	4	53	754	8
9	57	472	8	58	423	9
10	62	389	9	51	381	9
11	61	461	8	62	455	8
12	62	346	10	63	329	11
13	59	338	11	63	348	10
14	60	282	13	62	315	12

These data represent the arithmetic average for a total of 50 samples for the speed, 18 test runs for each of the morning and evening off-peak periods, and the rest 14 test runs for Off-peak daytime. As for the traffic flow rate, flow samples were taken at the same times as the speed samples, but more broadly, as four samples were taken for one test run in each link, meaning a total of 72 samples per run per period. After that, other samples were taken for 5 drivers of different ages and both-genders "Table.5" And Additional data set were collected to know the effect of the road characteristics (lane width and the number of lanes) on the operating speed of the driver at times of free traffic flow.

Table 5. Driver characteristics

driver	Gender	age
A	male	50
B	male	41
C	male	35
D	Male	32
F	Female	25

4. Results and Discussions

The results of the data extracted from the GPS showed in "Table .4", that the free-flow status is achieved at the time of the evening when the traffic flow is less than 500 vehicles per hour, and the headway is greater than 7 seconds [3].

"Fig .1" exhibits an almost seamless form of operational speed profile along the path.

Figure 1. Operation speed profile

Accordingly, the calculation of the free-flow speed of each link is by converting the GPS data that represents the speed during a specific period (time mean speed.) into space mean speed by taking the variance depending on the relationship between them as explained by Garber third edition in 2002:

$$\bar{u}_t = \bar{u}_s + \frac{\sigma}{\bar{u}_s} \quad (1)$$

$$\bar{u}_t = \frac{\bar{u}_s^2 - \sigma}{\bar{u}_s} \quad (2)$$

$$\bar{u}_s^2 - \bar{u}_t \bar{u}_s + \sigma = 0 \quad (3)$$

Where:

$\bar{u}_s$: Space mean speed

$\bar{u}_t$: Time mean speed

σ : Variance

Table 6. Free-flow speed

link	evening period					
	North			south		
	$\bar{u}_t$	s^2	$\bar{u}_s$	$\bar{u}_t$	s^2	$\bar{u}_s$
1	73	17.361	72.8	77	30.44	76.6
2	61	20.54	60.7	64	25.944	63.6
3	48	372.19	38.3	56	59.2	54.9
4	62	44.278	61.3	63	31.944	62.5
5	61	40.027	60.3	55	37	54.3
6	62	46	61.2	61	34.694	60.4
7	68	19.44	67.7	67	25.75	66.6
8	57	81.694	55.5	53	39.25	52.2
9	57	27.25	56.5	58	11	57.8
10	62	17.25	61.7	51	5.527	50.9
11	61	8.194	60.9	62	47.5	61.2
12	62	17.25	61.7	63	29.5	62.5
13	59	37.0278	58.4	63	10.6944	62.8
14	60	15.02	59.7	62	20.5	61.7

By conducting a statistical analysis of the output data from the GPS device for each link using Statistical Package for the Social Sciences SPSS, the values of 85th percentile

speed, 95th percentile speed, and other descriptive statistical characteristics were calculated as shown in “Table. 7”.

Table 7. Statical analysis

link	Mean	Median	Mode	Std. Deviation	Variance	85 th percentile speed	95 th percentile speed
1	66.06	65.5	64	9.63711	92.874	75	81.8
2	58.56	60	60	6.42749	41.313	64	70
3	43.81	48	56	17.30042	299.305	60	65
4	60.29	61	60	9.15112	83.743	68	75
5	57.6	56.5	48	7.29271	53.184	64	70.9
6	55.2	58	56	12.27574	150.694	65.35	69.45
7	52.58	53	48	14.78843	218.698	70	73.45
8	43.14	43.5	32	14.39389	207.184	60	62.45
9	48.6	49	48	9.9857	99.714	59.35	61.9
10	50.88	52	48	9.12559	83.276	60	65.5
11	56	56	56	6.50902	42.367	63.35	66.45
12	59.41	60	60	6.43855	41.455	66.5	68
13	44.72	40	30	13.41343	179.92	63.35	67
14	41.92	48.5	15	19.59783	384.075	61	67.45

The result shows the effect of the characteristics of the driver and the road in choose the operating speed along the path. The bar chart "Fig. 2" shows the variation of the operating speed for different ages of drivers along the route and at the same time, where it is noticed that the drivers are in the age period between 35-50 years old are more familiar with the roads and gutsier in running vehicles at high speed on each link. Similar to older drivers, who are more rational and wiser in choosing their speeds, younger ages are usually unfamiliar with road handling. "Fig. 3" shows that Women are less daring and more cautious than men this is normal, due to the physiological nature of the women.

Figure 2. Operating speed variation with driver age

Figure 3. Operating speed variation with driver gender

At the other side, it can be found that the geometrical properties of the links also have a high impact as they are placed in "Fig. 4" & "Fig. 5".

Figure 4. Operating speed variation with lane width

Figure 5. Operating speed variation with no. of lanes

Accordingly, the free-flowing speed was calculated during the off-peak evening time shows in "Table .6", was functionally reclassified using the aforementioned determinants in highway capacity manual 2010 appeared that a clear difference was evident between the resulting classification and the classification adopted by the Municipality of the capital, Baghdad "Table.8".

Table 8. Functional classification of links according to HCM

Link NO.	Functional category	Design category	FFS	Urban street class
1	Principle arterial	Intermediate	76.6	I
2	Minor arterial	Suburban	63.6	II
3	Minor arterial	Urban	54.9	IV
4	Minor arterial	Intermediate	62.5	II
5	Minor arterial	Intermediate	54.3	III
6	Principle arterial	Intermediate	60.4	II
7	Principle arterial	Intermediate	66.6	II
8	Principle arterial	Urban	52.2	III
9	Principle arterial	Urban	57.8	III
10	Minor arterial	intermediate	50.9	III
11	Principle arterial	Intermediate	61.2	II
12	Principle arterial	Intermediate	62.5	II
13	Principle arterial	Urban	62.8	III
14	Principle arterial	Urban	61.7	III

Table 9. Comparison classification

Link no.	Functional classification of Iraq Municipality	Functional classification of HCM
1	Principle distribution TSO1	Principle arterial class I
2	Principle distribution TSO1	Minor arterial class II
3	Principle distribution TSO1	Minor arterial class IV
4	Principle distribution TSO1	Minor arterial class II
5	Principle distribution TSO1	Minor arterial class III
6	Principle distribution TSO1	Principle arterial class II
7	Principle distribution TSO1	Principle arterial class II
8	Principle distribution TSO1	Principle arterial class III
9	Principle distribution TSO1	Principle arterial class III
10	Principle distribution TSO1	Minor arterial class III
11	Principle distribution TSO1	Principle arterial class II
12	Principle distribution TSO1	Principle arterial class II
13	Principle distribution TSO1	Principle arterial class III
14	Principle distribution TSO1	Principle arterial class III

From the results mentioned above, some observations must be explained:

- The presence of a fixed security checkpoint at Link 3 towards the north. This condition causes an abnormal traffic situation, and this disruption is evident in the data.
Link 10 has 6 lanes. The clarification of this is that traffic has been banned in two directions and that the whole northern link serves one-way traffic for security provisions, whereas, roads with 6 lanes

are usually highways or expressways which is not available in urban cities.

- Link 5, 6 and 7 are concentrated in areas with diverse and vital land uses, such as the presence of health, educational, and government institutions that generate high demand at times of the day. In addition, the presence of entertainment centers, shopping centers generate traffic jams. So, these links are not subject to a state of free flow throughout the day and this is what was shown in the presented results.

- There is a noticeable effect of the side parking of most links on the operating speed. Thereby, the number of lanes of the road is reduced, which negatively affects its operation.
- In areas with a number of two lanes where the driver is restricted to movement within the lane without overtaking the adjacent lane, provides a stable operating speed and safety along the road that differs from what has been noticed on roads where the 3 or 4 lanes with 3.6m width, in which the driver exceeds the adjacent lane so that the 3-lane road becomes occupied by 4 vehicles.
- From "Fig. 5", a decrease in operational speeds is observed when the number of lanes is increased. This effect is due to on – street parking [2] that are available in the links with a number of 3-lanes or more, which often distract the driver and affect the reaction time. This feature is devoid of the 2-lane links.
- The results show that the vehicles operate at a faster speed under the control of males than in females, at a rate of 26.32%.
- The travel speed for drivers aged between 50-35 years is 13.52% less than ages 25-35 and more by 8.37% from 25 years and below.
- The speed increases with the increase in the lane width by 13% when comparing a 3 meter and a 3.6-meter lane width.
- The bar charts showed a decrease in the rate of speed by increasing the number of lanes by 45.18% between 2 and 4 lanes and by 18.6 % between 2 and 3 lanes.
- Damascus Street does not reach a state of free traffic throughout the day.
- The statistical analysis showed that there is a high dispersion between the data of the links, and there was also a correlation between the design speed and the 85-percentile speed which is 69 km\hr. at evening peak period along the total selected route.
- The average speed of the southern direction is higher than the northern direction, as the north direction represented in Bab al-Moadham sector, which represents the CBD of Baghdad city, with high attraction rate for travel compared to Al- Bayaa sector.
- From what was previously noted, preventing illegal On-side parking, encouraging people to use public transportation and distributing various activities in separate areas within the city, all of these proposals help to significantly improve the traffic situation in the city of Baghdad.

5. Conclusion and Recommendation

Depending on the results obtained from the field study:

- The last classification of roads in Baghdad, done by Scott Wilson Kirkpatrick and partners in 1980, is different from the classification that the results indicated as shown in (junub St., Al Yarmouk I &II streets, Al Yarmouk Bridge, Al Allawi I&II streets, AL Nasser St., Bab Almudam I &II streets).
- Notice that there is a slight discrepancy between the free-flow speed of the links between the northern and southern directions, except for link number 3, which contains a security checkpoint in the northern direction.

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Conflict of Interest

The authors confirm that the publication of this article causes no conflict of interest.

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