https://doi.org/10.33261/jaaru.2023.30.02.002 *Association of Arab Universities Journal of Engineering Sciences (2023)30 (2): 07–16*

Association of Arab Universities Journal of Engineering Sciences
مجلة اتحاد الجامعات العربية للدراسات والبحوث الهندسية

Prediction Model of Lane Change Frequency based on Traffic Characteristics of Urban Street

Zainab Ahmed Alkaissi[1]*, Ayman Ismael[2], and Ali Wissam[3]

[1] *Department of Highway and Transportation, College of Engineering, Mustansiriyah University, Baghdad, Iraq, dr.zainabalkaissi77@uomustansiriyah.edu.iq*

[2] *Department of Highway and Transportation, College of Engineering, Mustansiriyah University, Baghdad, Iraq.*

[3] *Department of Highway and Transportation, College of Engineering, Mstansiriyah University, Baghdad, Iraq.*

**Corresponding author: Zainab Ahmed Alkaissi, dr.zainabalkaissi77@uomustansiriyah.edu.iq*

Published online: 30 June 2023

Abstract –The understanding of traffic characteristics and operation mechanisms of driving behaviors is important for management and traffic operation strategies and planning for the future. This research focused on investigating and predicting the effect of lane change on surrounding traffic characteristics. A Multiple regression model of R^2=0.636 was developed to estimate the frequency of lane change as a function of traffic speed and flow rate variables. Lane change frequency (LC) was the dependent variable whereas the traffic speed (Speed) and flow rate (Flow) were the independent variables for the model. Traffic speed influenced the rate of lane changing more than other variables. The analysis showed a better prediction of operational capacity depending on local and lane change frequency increasing the operational capacity by 10%. The rate of lane changing increased as the traffic flow rate increased, and these increments were accompanied by an increase in vehicle density with a peak lane change frequency of (1000 LC/km/hr) at a flow rate of (1501 veh/hr) and beyond this value of flow rate the frequency decreased significantly.

Keywords –Lane Change, Traffic characteristics, Prediction model, Flow rate, Traffic speed, Urban street, Multiple regression.

1. Introduction

Due to congestion problems that cause impatience and inconvenience among vehicle drivers, it is expected that driver behavior and lane change varies during traveling and finding suitable lanes for completing their trips with minimum delay. The lane change influenced traffic stream characteristics in terms of flow, speed, and density due to internal and side inference that induced impedance on surrounding vehicles. The state of traffic congestion is considered the main reason for lane change maneuvers for drivers to seek the shortest path rather than car following. Lane change can be explained in terms of three sequences stages:

- Motivation to change lane.
- Selection of lane to change into target lane.
- Execution of lane change and completing maneuvers.

The impediment effect of lane change is more significant during the maneuver of lane changing of heavy vehicles. Although their smaller percentages of vehicular traffic flow, the heavy vehicle is considered an important effect on traffic flow [1].

Park and Rictchie (2004) [7] investigated the relationship between traffic speed and lane change. They proposed a statistical regression model based on their measured field data of lane-changing behavior, including vehicle types, the difference between upstream and downstream traffic flow, and speed. Lane change was found to affect speed more than other variables such as differences between upstream and downstream traffic flow.

For weaving maneuvers (woven and non-weaving) lanes, a specific method [5] is given for the expressway. The rate of lane change is explained for interwoven lanes but the relationship between speed and lane change behavior is not analyzed. Jin W. (2010) [9] stated that lane change behavior impacted the capacity of the traffic stream. It introduced a factor of lane changing behavior to adjust the three parameters of traffic density, traffic flow rate, and speed.

Jongsang et al. (2018) [8] applied a deep auto encoding network to estimate a multiple variables model of lane-changing decisions. Utmost studies were based on human behavior, and are similar to human behavior models. Compared to these models, autonomous vehicle models used more accurate information when entering mixed traffic and were naturally influenced by human-driving vehicles; therefore more factors are considered when changing lanes and making decisions.

For mixed traffic, autonomous vehicles will influence traffic speed and minimize the occurrence of lane change behavior [2] and [10].

Zheng, et.al (2019) [4] stated that the motive of lane change was from both horizontal and vertical aspects and used speed as the motive for safety requirements and predicting the lane change behavior.

Xie, et.al. (2022) [3] studied the relationship between rates of lane change and traffic speed under mixed traffic conditions. An empirical data used to establish the corresponding simulation models of road with penetration rate of autonomous vehicles of (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%). It was found the effect of lane change of each lane on traffic speed since it's considered an important parameter to predict traffic state.

The understanding of traffic characteristics and operation mechanisms of driving behaviors is important for management and traffic operation strategies and planning for the future.

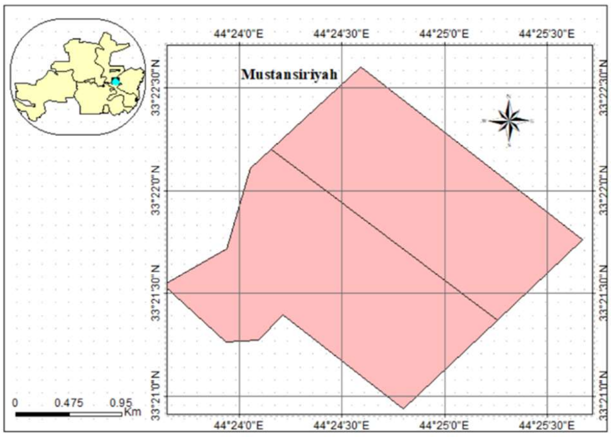
This paper investigates and analyzes the effect of lane change on surrounding traffic characteristics. The relationship between lane change and speed rate, and traffic flow rate is important to estimate their effect on the capacity of urban streets. An empirical method is utilized to better describe the lane change relationship between speed and traffic flow of the urban street with different traffic flow rates. The study relationships are needed to understand the traffic operation of traffic flow in the urban street.

2. Case Study

A Palestine urban street in Baghdad city is a major Arterial Street consisting of three lanes in both directions with geometric design characteristics presented in Table 1. The different mixed land uses surrounded the urban street; residential, educational, and commercial induced potential pressure of daily trips (production and attraction). The selected case study area suffered from delays and straffic congestion during peak periods (Alkaissi, 2017).The se lected segment of Palestine Street for the study is located in the East of Baghdad between Mustansiriyah University and Al-Nakhala Intersection of (1.03 km) length as depicted in Fig. 1. The selected segment of Palestine Street was considered in this research to detect various rates of lane-change maneuvers that affect the traffic stream characteristics due to impedance of driver behavior and on-street parking vehicles since all these factors influence the capacity of the street.

Table 1: Geometric Characteristics of Studied Street Segment

Palestine Arterial Street (From Mustansiriyah University to Al-Nakhala Intersection)				
	Movement	No. of lanes	Average lane width (m)	Average Median Width (m)
North direction	Right-Turn	1	3.9	7
	Through	1		
	Left- Turn	1		
South direction	Right-Turn	1	3.9	7
	Through	1		
	Left- Turn	1		



a) Map Area of Selected Case Study.

b) Location of Palestine Arterial Street.

Figure 1: Coordinated Map of Case Study a) Map Area of Selected Case Study b) Location of Palestine Arterial Street.

2.1 *Data Collection*

The field data collected for the study segment from Mustansiriyah University to the Al-Nakhala intersection include the traffic volume for every 15 minutes and average traffic speed for every 5 minutes based on typical weekdays (Monday 3/1/2021), (20/12/2021) (10/1/2022) under clear weather conditions for 5 hours from (9:00 a.m. to 1:00 p.m.) (These selected days represented normal conditions for traffic flow, and chose different periods within study period for November (20/12/2021) and January (3/1/2021 and 10/1/2021)). The manual method was adopted for the collection of traffic volume data because of the following:

- Difficult Iraqi facilities for permissions to utilize and set Video Cameras at the location of the case study.
- The absence of detectors and intelligent transportation systems (ITS).

Short periods to the start of lane change maneuverers and after several minutes until it is completed were detected to study and analyze the effect of lane changing on traffic characteristics. For speed data collection, a Speed Gun, Bushnell Velocity Speed Gun type (Auto Racing: Speed range from 10-200 MPH up to 1,500 feet.) was used to estimate traffic speed at the field as shown in Fig.2. The location of the study segment was along mixed land uses with higher activity observed despite the existence of a designated bus stop but vehicles stopping anywhere along the segment of study linked to load and unload passengers were observed and such conditions caused a high rate of lane change for drivers to overtake the stopped cars.

Figure 2: Speed Gun, Bushnell Velocity Speed Gun used for Speed Data Collection.

3. Results Analysis and Discussions

The lane change of vehicles influences the operational performance and characteristics of the traffic stream significantly. Analysis of lane change frequency was done by depicting the collected field data for traffic characteristics; speed (km/hr) and flow rate (veh/hr) as per field observation during the peak and near-peak periods within a day to explore the impact of heavy and low traffic state conditions. The fieldwork estimated the frequency of lane change in terms of maneuver number for 100 m distance and time interval is 5 minute then the data were standardized and converted to distance length 1km and time interval 1hr [5]. So the unit was per unit kilometer per hour (No./km/hr) for the direction of travel and explored the lane change from both rights to middle and middle to left lane of a case study.

3.1 *Relationship between Density and lane Change Frequency*

To seek the relationship between frequency of lane change and traffic density, Fig. 3 illustrated the number of lane change maneuvers (per kilometer per hour) as a function of density. High frequency of lane change (1000 LC/km/hr) was obtained at a low to moderate traffic density of (20 veh/km) due to available spaces within traffic streams which tend to offer maneuvers for lane change of vehicles then decreased gradually with density increased and start to reduce significantly at (50 veh/km) traffic density. When the density increased, showed the relationship between frequency of lane change and traffic density a clear linear relationship. In the case of urban streets selected in this research, where the bus stop and mixed land surrounded the area as stated in previous research [6] make the vehicles tend to change lanes and avoid stopping and delayed vehicles.

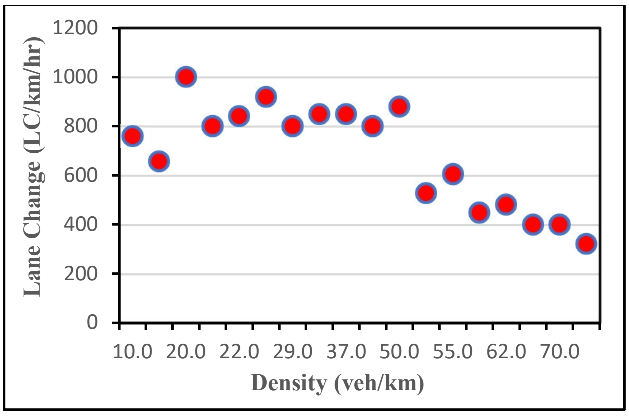


Figure 3: Relationships of Lane Change Frequency and Traffic Density.

3.2 *Relationship between Traffic Flow and Lane Change Frequency*

Fig. 4 shows the plot of the relationship between lane change frequency and traffic flow rate. And the variation of lane change from the right lane to the middle lane and from the middle lane to the left lane is explained. A general observation was obtained which stated that at low to medium traffic flow levels, the frequency of lane changing increased as the traffic flow rate increased, and these increments were accompanied by the increase of vehicle density and concentration as shown in Fig. 3, which intern reduced the probability of lane change frequency. The results showed a peak lane change frequency of (1000 LC/km/hr) at a flow rate of (1501 veh/hr) and beyond this value of flow rate the frequency decreased significantly due to the high concentration of vehicles that limit the probability of changing lanes. Another interesting feature obtained from Fig. 4 is that changing lanes from right to middle lane most frequently than changing lanes from middle to left lane due to the concentration of bus stops, slow-moving vehicles, and on-street parked vehicles along the curbside lane (right lane).

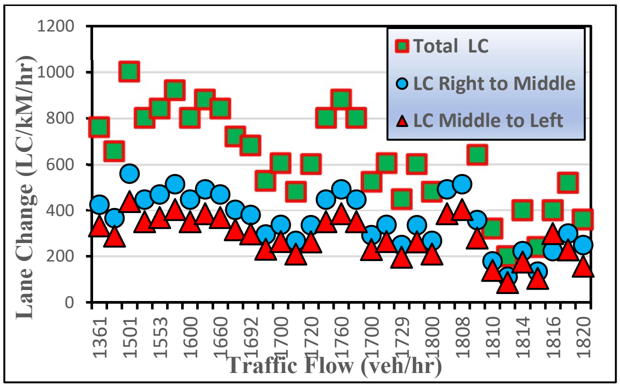


Figure 4: Relationships of Lane Change Frequency and Traffic Flow.

3.3 *Relationship between Traffic Speed and Lane Change Frequency*

The relationship between the frequency of changing lanes and the speed of the traffic stream is presented in Fig. 5. It is observed that the increase in traffic speed increases the frequency of lane change and a positive relation was obtained because the higher traffic speed offers the probability of overtaking maneuverers. The measured lane change frequency results were plotted with speed rate as depicted in Fig. 6. Overall, the obtained results help to characterize and quantify the effect of significant speed rate (which represents the change in traffic speed) on lane change frequency that induced a higher frequency of lane change as the speed rate increased.

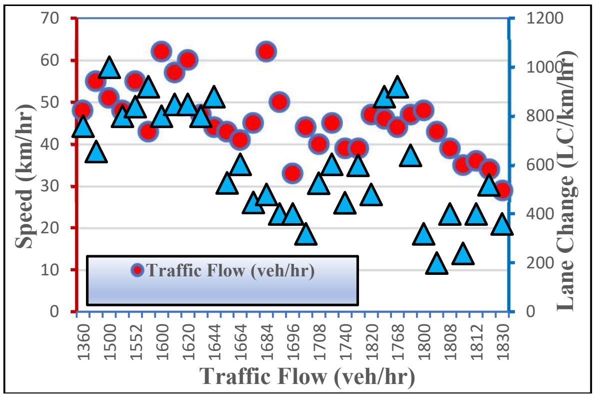


Figure 5: Relationships of Lane Change Frequency and Traffic Flow with Speed.

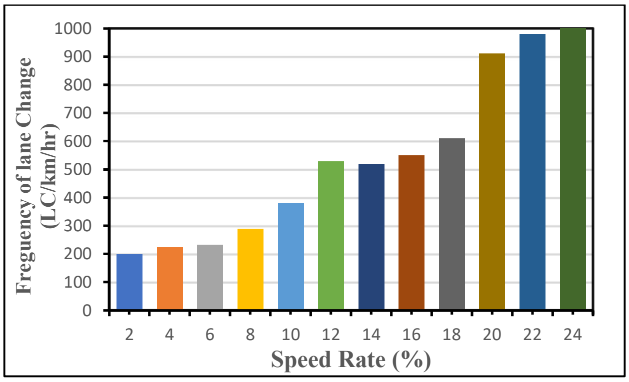


Figure 6: Effect of Speed Rate on Frequency of lane Change.

3.4 *Effect of Lane Change Frequency on Capacity*

The speed–flow density relations were analyzed to explore the effect of lane changing frequency and estimate the capacity of an urban street. The traffic flow and speed were estimated based on 5 min. period as shown in Fig. 7. , the speed decreased from (62km/hr) to (29 km/hr) with a rate increment of traffic flow. The flocculation of speed results reduced when reaching the sustained capacity. The speed-density relation is presented in Fig. 8 which is expressed based on aggregated data for 5 min. the period at midblock to explore the traffic state characteristics of the urban street before reaching the operational capacity of the road. One of the aims of this research is to investigate the effect of lane change on the operational capacity of urban streets and this was implemented based on collected field data for speed –flow –density relationships depicted in Fig. 7 and Fig. 8 for speed–density and speed –flow relations respectively. The empirical analysis of results provided a better prediction of operational capacity depending on local traffic conditions. The maximum operational flow rate in the direction of travel was (1820 veh/hr) as shown in Fig. 7 and represented the capacity magnitude under the local traffic conditions of a case study. For detecting the effect of lane change, a comparison with an estimated theoretical capacity of (1660 veh/hr) based on the headway distribution of vehicles at congested periods (Alkaissi, 2019) is illustrated in Fig. 9. It can be realized that the effect of lane change frequency might be increased the operational capacity by 10%.

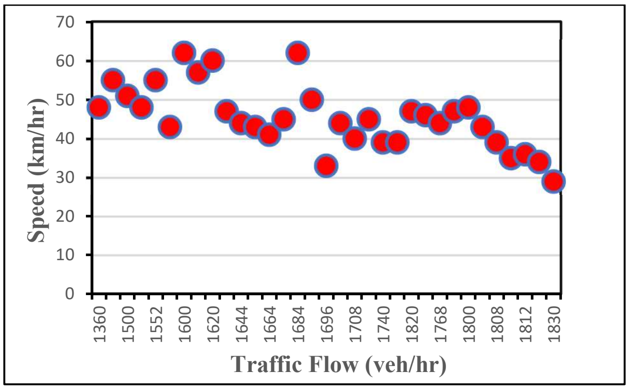


Figure 7: Flow –speed Relationship.

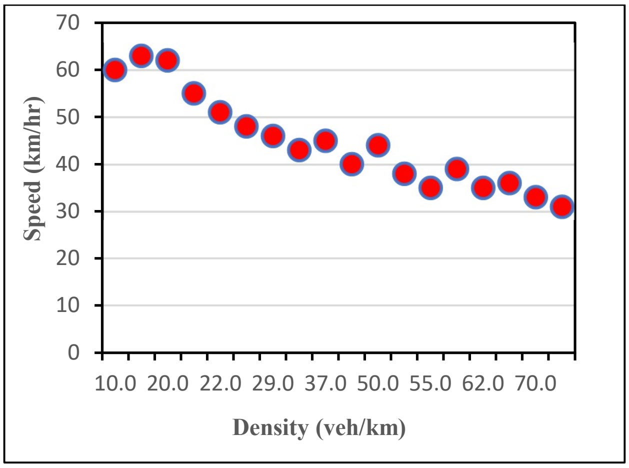


Figure 8: Speed–Density Relationship.

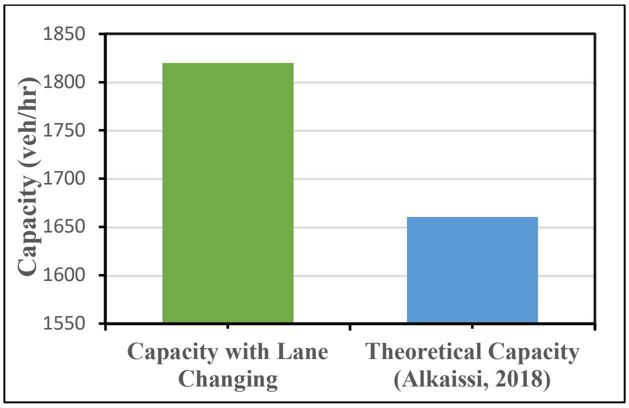


Figure 9: Effect of Lane Change Frequency on Operational Capacity.

3.5 *Statistical Model and Correlation Analysis*

A statistical technique was adopted to explore the relations and effects of various traffic characteristics on the frequency of lane change. A multiple regression model was developed to estimate the frequency of lane change as a function of traffic speed and flow rate variables using SPSS (software ver.26). Lane change frequency (LC) is the dependent variable whereas the traffic speed (Speed) and flow rate (Flow) are the independent variables.

The multiple linear equations of the predicted model have the following form in Eq.1 and are presented with details of R-square in Table 2 and standardized and unstandardized confidence in Table 3:

$$LC = 891.384 + 10.928\,Speed - 0.198\,Flow \quad (1)$$

R^2 =0.636

Where:

LC: Frequency of lane change (No./km/hr).

Speed: Traffic speed (km/hr).

Flow: traffic flow rate (veh/hr).

The R-square of 0.636 was obtained for the multiple linear models which indicates that 63.6% of the variability in the frequency of lane change can be explained by traffic characteristics of speed and flow rate in the regression model. The coefficients of correlation of independent variables are presented in Table 4. The speed was correlated with lane change frequency with a positive relationship and with (0.433 km/hr) standard error of coefficient. However, the flow rate was correlated with a negative relationship and with (0.46 veh/hr) standard error of coefficient. These contributed to the increased frequency of lane change with high traffic speed and low traffic flow rate, hence these variables were significant in the predicted model. The unfamiliar driver behavior was not considered in the analysis of the regression model, hence the reliability of applying this model is limited by the unfamiliar effect of driver behavior. Fig. 10 shows the P-P plot that compares the empirical distribution of the standardized residual of the dependent variable to the expected normal distribution. This presented strength of the difference between expected and observed values of lane change frequency. The descriptive statistics and test of normality for independent variables are presented in Tables 5 and 6 respectively. It is clear from the normality test for speed and traffic flow are normally distributed according to Shapiro –Wilk and Kolmogorov – Smirrnove tests, also looking for the Q-Q plot in Figs. 11 and 12 for traffic flow and speed variables, a close point and match the line with small deviations.

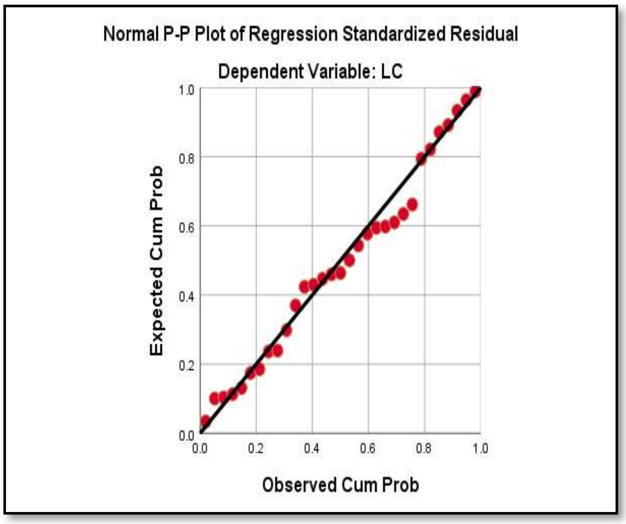


Figure 10: P-P Plot of Regression Standardized Residual Depended Variable; Lane Change Frequency.

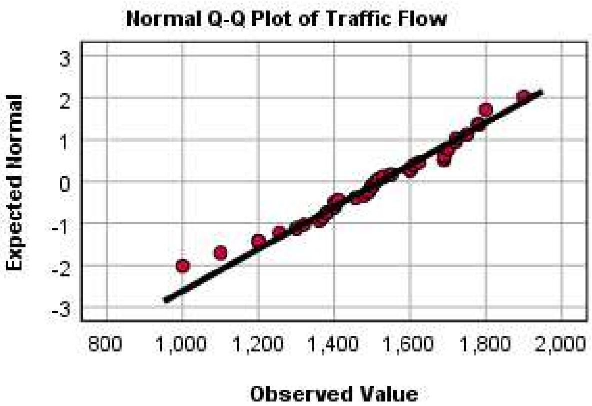


Figure 11: Q-Q Plot of Traffic Flow Variable.

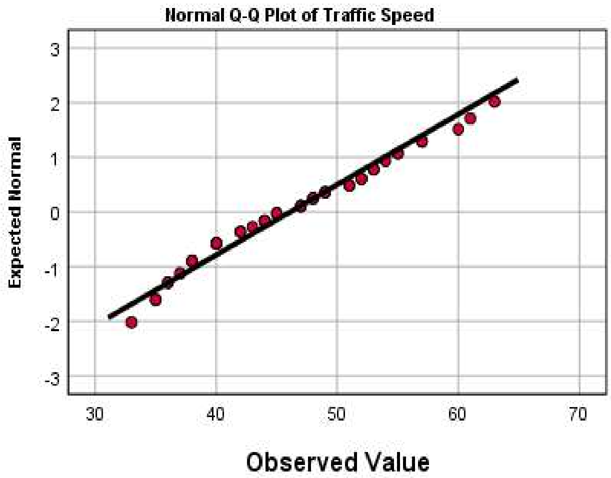


Figure 12: Q-Q Plot of Traffic Speed Variable.

3.6 *Model Validation*

To confirm that the model achieves acceptable accuracy and is predictive with good performance 75% and 25% splitting strategy was used. The chi-square test was used to check the goodness of fit for the developed model against the field data as presented in Table 7, ($\chi^2 < \chi_{Critical}$) which indicated there are no significant differences between the developed model and real-field data.

The scatter plot for comparison is depicted in Fig. 13 and the predicted model of lane change frequency is considered to be valid for outputs of the predictive model and is acceptable with regards to the survey field data and can offer a relatively accurate estimation of field data.

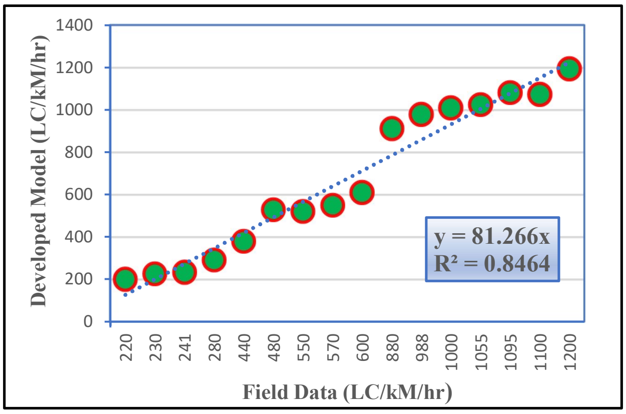


Figure 13: Developed Model Outputs versus Field Data of Lane Change Frequency.

Table 2: Regression Model Summary.

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. An error in the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.798[a]	.636	.618	122.47177	.636	34.964	2	40	.000	1.506

a. Predictors: (Constant), Speed, Flow

b. Dependent Variable: LC

Table 3: Standardized and Unstandardized Coefficients of Regression Model.

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	891.384	87.028		10.243	.000	715.495	1067.274			
	Flow	-.198	.051	-.460	-3.868	.000	-.301	-.094	-.718	-.522	-.369
	Speed	10.928	3.004	.433	3.638	.001	4.856	16.999	.707	.499	.347

a. Dependent Variable: LC

Table 4: Correlation Coefficients between Lane Change Frequency, Speed, and Flow Rate Components.

Correlations

		LC	Flow	Speed
Pearson Correlation	LC	1.000	-.718	.707
	Flow	-.718	1.000	-.597
	Speed	.707	-.597	1.000
Sig. (1-tailed)	LC	.	.000	.000
	Flow	.000	.	.000
	Speed	.000	.000	.
N	LC	43	43	43
	Flow	43	43	43
	Speed	43	43	43

Table 5: Descriptive Statistics for independent variables.

Descriptives

			Statistic	Std. Error
Traffic Flow	Mean		1520.6889	29.66775
	95% Confidence Interval for Mean	Lower Bound	1460.8975	
		Upper Bound	1580.4803	
	5% Trimmed Mean		1528.0494	
	Median		1510.0000	
	Variance		39607.901	
	Std. Deviation		199.01734	
	Minimum		1000.00	
	Maximum		1900.00	
	Range		900.00	
	Interquartile Range		305.00	
	Skewness		-.445	.354
	Kurtosis		-.063	.695
Traffic Speed	Mean		46.1111	1.15873
	95% Confidence Interval for Mean	Lower Bound	43.7758	
		Upper Bound	48.4464	
	5% Trimmed Mean		45.9074	
	Median		45.0000	
	Variance		60.419	
	Std. Deviation		7.77298	
	Minimum		33.00	
	Maximum		63.00	
	Range		30.00	
	Interquartile Range		12.50	
	Skewness		.287	.354
	Kurtosis		-.822	.695

Table 6: Test of normality for Independent Variables.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Flow	.112	45	.193	.974	45	.409
SP	.117	45	.137	.967	45	.223

a. Lilliefors Significance Correction

Table 7. Chi-Square test for Model Validation.

Developed Model	χ^2	Critical χ
Frequency of Lane Change	21	23.68
N=16, df=14, Significant level α=5%		

4. Conclusions

The following concluding remarks can be drawn:

1. High frequency of lane change (1000 LC/km/hr) was obtained at low to moderate traffic density of (20 veh/km) due to available spaces within traffic streams then decreased gradually as density increased and start to reduce significantly at (50 veh/km) traffic density.
2. The rate of lane changing increased as the traffic flow rate increased, and these increments were accompanied by the increase of vehicle density with a peak lane change frequency of (1000 LC/km/hr) at a flow rate of (1501 veh/hr) and beyond this value of flow rate the frequency decreased significantly.
3. The increase in traffic speed increased the frequency of lane change and a positive relation was obtained because the higher traffic speed offers the probability of overtaking maneuverers.
4. The frequency of lane change increased as the speed rate increased.
5. The empirical analysis shows a better prediction of operational capacity depending on local traffic conditions. The maximum flow rate in the direction of travel was (1820 veh/hr).
6. Effect of lane change frequency increased the operational capacity by 10%.
7. A Multiple regression model was developed to estimate the frequency of lane change as a function of traffic speed and flow rate variables. Lane change frequency (LC) is the dependent variable whereas the traffic speed (Speed) and flow rate (Flow) are the independent variables as presented in Eq.2 with R^2=0.636

$$\text{LC} = 891.384 + 10.928\ \text{Speed} - 0.198\ \text{Flow} \quad \text{eq. 2}$$

Acknowledgments

The authors would like to express their thanks to Mustansiriyah University in Baghdad, Iraq, for supporting the present paper.

References

[1] A. F. Al-Kaisy, F.L. Hall and E. S. Reisman, "Developing Passenger Car Equivalents for Heavy Vehicles on Freeways during Queue Discharge Flow." Transp. Res. A vol. 36, no.8, pp.725–742, 2002.

[2] C. Wang, Q. Sun, Z. Li, H. Zhang, and K. Ruan, “Cognitive competence improvement for autonomous vehicles: a lane change identification model for distant preceding vehicles,” IEEE Access, vol. 7, pp. 83229–83242, 2019.

[3] H. Xie; Q. Ren and Z. Lei, Influence of Lane-Changing Behavior on Traffic Flow Velocity in Mixed Traffic Environment, Journal of Advanced Transportation, Vol. 2022, Article ID 8150617, 26 pages, 2022.

[4] H. Zheng, J. Zhou, Q. Shao, and Y. Wang, “Investigation of a longitudinal and lateral lane-changing motion planning model for intelligent vehicles in dynamical driving environments,” IEEE Access, vol. 7, pp. 44783–44802, 2019.

[5] Transportation Research Board (TRB). "Highway Capacity Manual: HCM 2000". TRB, Washington, DC, USA, 2000.

[6] M. AL-Anbari and Z.A. Alkaissi, “Assessment of Sustainable Indicators for Road Transportation: A Case Study of Palestine Arterial Street”. International Journal of Science and Research (IJSR) ISSN (Online), pp. 2319-7064, 2017.

[7] S. Park and S. G. Ritchie, “Exploring the relationship between freeway speed variance, lane changing and vehicle heterogeneity[R],” in Proceedings of the 83rd Annual Meeting of the Transportation Research Board, Washington D. C.UCI-ITSTS-WP-04-4, Washington D. C., 2004.

[8] S. Jongsang, C. Heungseok, and Y. Kyongsu, “Stochastic model-predictive control for lane change decision of automated driving vehicles,” IEEE Transactions on Vehicular Technology, vol. 67, no. 6, pp. 4771–4782, 2018.

[9] W.L. Jin, “A kinematic wave theory of lane-changing traffic flow,” Transportation Research Part B: Methodological, vol. 44, no. 8-9, pp. 1001–1021, 2010.

[10] Y. S. Jiang, R. Hu, Z. H. Yao, P. C. Wu, and X. L. Luo, “Stability and safety analysis for heterogeneous traffic flow composed of intelligent and connected vehicles,” Journal of Beijing Jiaotong University, vol. 44, no. 01, pp. 27–33, 2020.

[11] Z. A. Alkaissi, " Analytical Study of Headway Time Distribution on Congested Arterial: A Case Study Palestine Road in Baghdad City", Proceedings of the 2nd GeoMEast International Congress and Exhibition on Sustainable Civil Infrastructures, Egypt 2018 – The Official International Congress of the Soil-Structure Interaction Group in Egypt (SSIGE). 10.1007/978-3-030-01911-2_8, 2019.

[12] Z.A. Alkaissi, "Travel Time Prediction Models and Reliability Indices for Palestine Urban Road in Baghdad City". Al-Khwarizmi Engineering Journal (Alkej), 13(3), 120–130, 2017.

نموذج التنبؤ لتكرار تغيير المسار بناءأ على الخصائص المرورية في الشوارع الحضرية

زينب احمد القيسي[1*]، أيمن اسماعيل[2]، علي وسام [3]

[1] *قسم الطرق والنقل، كلية الهندسة ، الجامعة المستنصرية، العراق ، بغداد، dr.zainabalkaissi77@uomustansiriyah.edu.iq*

[2] *قسم الطرق والنقل، كلية الهندسة ، الجامعة المستنصرية ، العراق ،بغداد.*

[3] *قسم الطرق والنقل، كلية الهندسة ، الجامعة المستنصرية، العراق ، بغداد.*

[*] *الباحث الممثل : زينب احمد القيسي، dr.zainabalkaissi77@uomustansiriyah.edu.iq*

نشر في: 30 حزيران 2023

الخلاصة – ان فهم الخصائص المرورية وأليات التشغيل المروري للسلوكيات القيادة يعتبر أمرا مهما في إستراتيجيات الإدارة والتخطيط في المستقبل.ركز هذا البحث على التحري لتاثير تغيير المسار على الخصائص المرورية المحيطة. تم تطوير موديل الانحدار الاحصائي متعدد المتغيرات $R^2=0.636$ لحساب تكرار تغيير المسار بدلالة السرعة المرورية ومعدل التدفق المروري كمتغيرات. كان تكرار تغيير المسار المتغير التابع بينما اعتبرت السرعة المرورية ومعدل التدفق المروري المتغيران المستقلان للنموذج. أثرت السرعة المرورية على معدل تغيير المسار أكثر من المتغيرات الاخرى. أظهر التحليل تنبؤًا أفضل بالسعة التشغيلية اعتمادًا على تكرارتغيير المسارمحليا ، مما أدى إلى زيادة السعة التشغيلية بنسبة 10 ٪. زاد معدل تغيير المسار مع زيادة معدل تدفق حركة المرور ، وكانت هذه الزيادة مصحوبة بزيادة في الكثافة المرورية مع اعلى تكرار لتغيير المسار (1000 لتر / كم / ساعة) بمعدل تدفق (1510 مركبة / ساعة) وبعد هذه القيمة لمعدل التدفق ، انخفض معدل التكرار بشكل ملحوظ.

الكلمات الرئيسية – الخصائص المرورية، نموذج التنبؤ، معدل التدفق، السرعة المرورية، شوارع حضرية، الانحدار المتعدد.