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ASSESSMENT LANE CHANGING BEHAVIOR IN LOCAL RURAL ROADS

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Abstract: The lane changing model is one of the most important cornerstone models to build a traffic microscopic simulation model. To build such lane changing model, there is a need to investigate the drivers' characteristics from field data. Accordingly, this study has mainly focused on lane changing behavior of Iraqi drivers. A huge amount of data has been collected from different sites in Iraq using specific type of cameras; these five sites (roads) are: Baghdad–Hilla, Baghdad–Mahmudiyah, Baghdad-Kut, Baghdad–Diyala and Najaf- Karbala roads. In addition, gun-speed has been also used to collect data of desired speeds. Different data have also been collected such as flow, headway, and speeds. The results show that as the flow increases, the frequency of lane changing also increases up to specific range of flow then as flow increases the frequency of lane changing decreases. In addition, this study indicates higher number of lane changing over all observed sites comparing with other countries. Finally, this study also indicates that the violated number of lane change varies with different levels of flow.

Keywords: *lane changing model, simulation model, driver behavior*

تقييم سلوك تغيير الممر في الطرق الريفية المحلية

الخلاصة: نموذج تغيير الممر هو واحد من أهم نماذج حجر الزاوية لبناء نموذج محاكاة للحركة المرور. لبناء هكذا نموذج لتغيير الممر، هناك حاجة لاستكشاف خصائص السائق من البيانات الحقلية. وفقا لذلك، هذه الدراسة ركزت بصورة اساسية على خصائص تغيير الممر للسواق العراقيين. كميات كبيرة من البيانات جمعت من مواقع مختلفة في العراق باستخدام نوع معين من الكاميرات، هذه المواقع الخمسة (الطرق) هي: بغداد - الحلة، بغداد - المحمودية، بغداد - الكوت، بغداد - ديالى والنجف – كربلاء. بالاضافة الى ذلك، تم استخدام مسدس السرعة ايضا لجمع السرع المرغوب بها. بيانات مختلفة تم جمعها كالجريان المروري والفاصل الزمني بين مقدمة مركبة والسرع. النتائج بينت بانه كلما زاد الجريان المروري فان تردد تغيير الممر يزداد ايضا لحد معين من مدى الجريان ثم بعد ذلك كلما يزداد الجريان فان تردد تغيير الممر يقل . مضافا الى ذلك هذه الدراسة بينت عدد تغيير الممرات هو اعلى لكل المواقع مقارنة بالاقطار الاخرى. وفي النهاية، هذه الدراسة بينت ايضا بان عدد تغيير الممر الغير قانوني (المخالف للقانون) يتغيير مع مستويات الجريان المختلفة.

1. Introduction

Understanding the behavior of the driver has a great role in managing traffic and controlling the various types of problems that are caused by the constantly changing conditions on the transport network. Driver behavior varies from one country to another for different cultures, so driver behavior must be studied in a way that reflects a realistic reflection of what actually exists in the country. One of the important concepts that

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directly affect the behavior of the driver is changing the lane, i.e. the process of changing the location of the vehicle from one lane to another (lateral movement) [1].

Lane change (LC) has a clear impact on the performance of the transport network, where the current study focuses primarily on collecting data to understand the mechanism of changing the lane which is so important step to build a hybrid model to represent the process of changing the lane as it is in fact [2].

In Iraq, very few studies which have studied this behavior. Al-Jameel [3] developed a simulation model based on limited data taken from three roads around Al-Najaf city. The authors, Al-Jameel [4], and Al-Jameel and Kadhim [5], also studied the same behavior but for specific types of roads which are three-lane section. Therefore, this study tries to enhance both quantity and quality of such data by increasing the number of observed hours and sites in order to give a comprehensive picture for this behavior.

2. Lane Changing Models

The model of changing lane is considered as the second grade after the model of the car following in its importance in building the microsimulation model, and also has an impact on the evaluation of macroscopic characteristics due to the impact of interference on traffic characteristics [3, 6]. Lane change (LC) is the process of changing the vehicle's position from a lane to another lane for reasons related to the driver's behavior in response to a specific goal or for other reasons forced the driver to change the lane. LC is more complicated because the decision to change lanes depends on several targets, and sometimes some of them may conflict with the others [7]. LC behavior can be affected by several different factors such as driver characteristics, pavement surface characteristics and traffic flow condition, distortions in the surface of the pavement have an effect on the process of changing the lane and vary depending on the driver's age and gender and his/her conditions, and the speed of his/her vehicle [6,8].

The process of LC is linked to the characteristics of both the driver and the vehicle. To understand this process, there is a need to study these characteristics. Several researchers represented the behavior of LC, either through simulation, mathematical analysis or experimental analysis as mentioned by Xu [9] which summarizes the methods and models of analysis of the behavior of LC. The frequency of lane change (FLC) has an impact on safety in the roads. The more FLC leads to more traffic accidents [10]. Figure 1 demonstrates the general structure of LC [11]. Mostly, the driver of the following vehicle depends mainly on the availability of the appropriate gap to change the lane in another direction (either to the right or to the left) [1].

The model of LC was classified as a mandatory lane change (MLC) or a discretionary lane change (DLC) [12]. MLC, it occurs when a driver is obliged to leave the lane or change the lane in order to reach his/her destination, for example, to use an off-ramp [13].

DLC, this is done to improve driving conditions and make them more comfortable and changing the lane is not required or unnecessary in this case [14], for example, change the lane to achieve a higher speed and to exceed the slow leading vehicle or to exceed the following trucks or to stay away from the merger sections in traffic stream.

The classification of MLC into three types namely free, forced, and cooperative [15], and for more details see for example, Choudhury, Ramanujam [16]. And for more information about LC in terms of types and classifications model, see Rahman, Chowdhury [17].

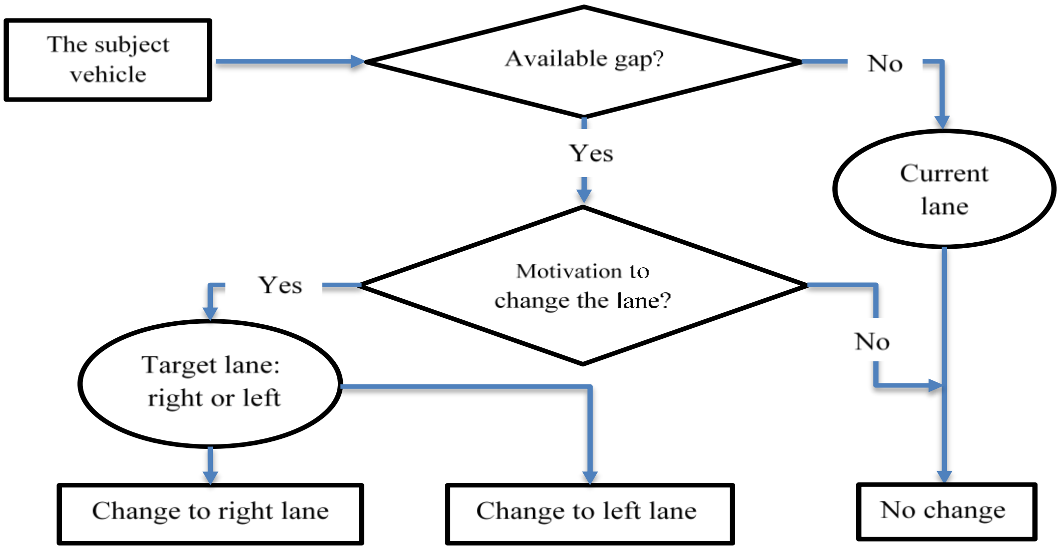

Figure 1. The general structure of lane change [18].

2. Previous studies on the model of LC

Rorbech [19], developed a model to study the effect of LC on the delay in the queue, where to avoid queuing, and the driver of the vehicle lane change to escape from this queue. This model was developed for studying two lane of freeway using the stochastic Markov process, which concludes this process based on data collected from the field. The author found that a vehicle may be in one of four cases; which is the vehicle either to be left or right lane and the traffic condition either free or constrained.

Gipps [20], was the first who developed a model of microsimulation that includes the process of LC. His model covers different situations such as traffic signals, transit lanes, obstacles and the presence of heavy vehicles. The model was based on three main factors: the possibility, necessity and desirability of LC (safety of change). The behavior of LC is governed by two basic considerations: achieving desired speed and selecting the correct lane for conducting maneuvers. The importance of these considerations varies with regard to the distance with the intended turn. Based on this distance, driver behavior is in one of three cases. These are; when the turn is far away, the driver focuses on achieving desired speed and there is no effect to change the lane [20]. When the turn is in the middle of the distance, a driver tends to stay in the lane pair and ignore the increase in speed if this involves changing the lane in the wrong direction. Finally, the turn is close, the driver focuses on maintaining the correct lane and speed is not necessary.

Yousif [21], developed a microsimulation model to represent driver behavior traffic in dual-carriageway roads, under normal conditions and under roadwork conditions. In normal conditions, the driver changes the lane to the faster lane if he/she is faced by a slower vehicle when the slower vehicle speed is less than the value of R. The value of R proposed by Ferrari [22] and shown in Equation 1. However, if the difference in speed for slower vehicle speed is less than the value of R, the driver will remain in the current lane.

$$R = 1040/SP_{Fd} \qquad (1)$$

Where; SP_{Fd} is the desired speed of following vehicle (km/hr).

Yousif [21], obtained a comparison in the behavior of changing the lane between different countries for similar sites (two lane section) and the study was based on the calculation of the FLC in a kilometer per minute. The results show that UK, Germany and Denmark are similar in behavior to LC, but unlike those in USA, as shown in Figure 2 and 3.

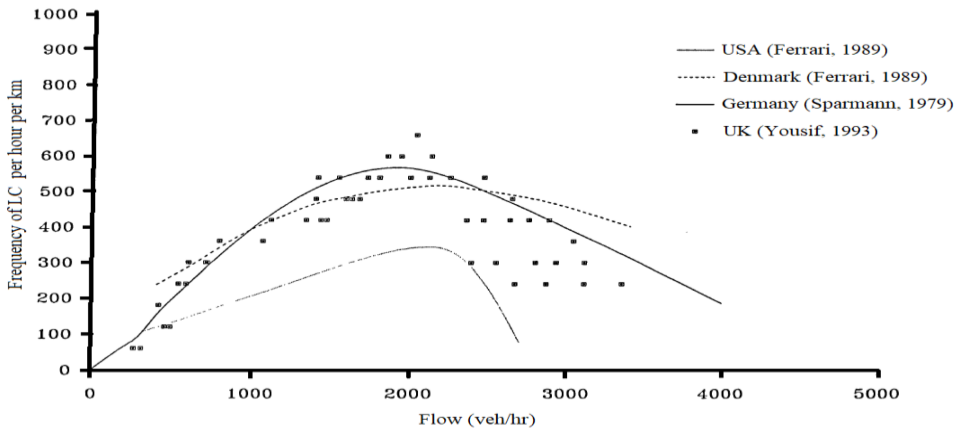

Figure 2. The frequency of LC for different countries for a two-lane section [21].

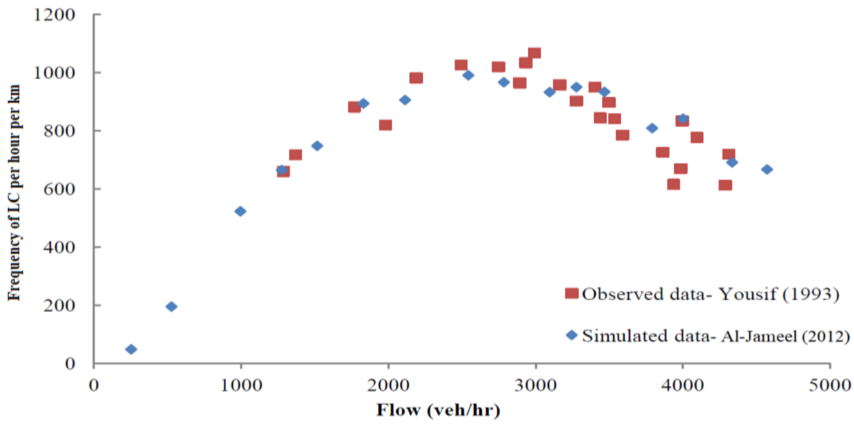

Figure 3 The frequency of LC for different countries for a three-lane section in the UK [7].

Ahmed [23], has modeled the process of lane change of both cases, MLC and DLC, This process is done using three steps: a decision to consider the lane change, choose the target lane, and accept gaps in the target lane. Where it is assumed that the driver can use nearby lane to enhance speed, since the accepted gaps are difficult to reach in the case of traffic congested. Therefore, a forced merging model captures the changing behavior of the forced and developed courtesy yielding. Ahmed [23] used the microscopic traffic simulator laboratory (MITSIMLab) to test and validate the developed model. Toledo[24] and Choudhury [25] followed the same approach as they used MITSIMLab to test and validate the models developed by them.

Many researchers have proposed and developed many models and according to different assumptions designed to represent the behavior of the driver when changing the lane. Therefore, referring will be made to some sources that relate to these models, for example, Yang[26], Halati et al., [27], Hidas [28], Al-Jameel [7], Lv et al., [29], Nassrullah [13], Li and Sun [30].

4. Duration of Lane Change

Duration of lane Change (or time maneuver) is the total time required to make a complete lane change which is the time from starting the vehicle to change direction from the original lane to the target lane [31]. This time is affected by several factors such as the type of vehicle, the direction of change, the speed of the vehicle, and traffic density [11]. Worrall and Bullen [32], mentioned that, the time of maneuvering is divided into two parts: the time of the head and the rear. The importance of time maneuver because of the great influence in the process of LC, There are several researchers have obtained the value of this time and according to different study areas, both inside and outside the city, Table 1 shows different values of duration of LC.

Table1. Summary of studies on the duration of the lane change.

Study	Mean or Median (sec)	Standard Dv. (sec)	Range(sec)	Notes
Worrall and Bullen [32]	Mean=1.25	0.40	-	Head Times
	Mean=1.95	0.50	-	Tail Times
Finnegan and Green [33]	Median = 6.3	-	4.9 to 7.6	Including visual search time
Yousif [21]	Mean= 4.10	1.05	-	Total time maneuver
Chovan [34]	-	-	2.0 to 16	Initial range for Collision Avoidance System
Hetrick [35]	-	-	3.4 to13.6	City and highway segments
Tijerina, Garrott [36]	Mean = 5.00	-	3.5 to 6.5	City streets
	Mean = 5.80	-	3.5 to 8.5	Highway
Hanowski, Wierwille [37]	Mean = 4.80	1.71	1.1 to 16.5	Local short-haul truck drivers, speed <45mph
Salvucci and Liu [38]	Mean= 5.14	0.86		
Lee [39]	Mean= 6.28	2.00		
Toledo and Zohar [11]	Mean= 4.60	2.30	1.0 to 13.3	passenger cars and Heavy vehicles
Thiemann, Treiber [40]	Mean= 4.01	2.31		
Moridpour, Sarvi [41]			1.6 to 16.2	Heavy vehicles
			1.1 to 8.9	Passenger cars
Gurupackiam and Jones Jr [31]	Mean= 4.19	0.81	2.6 to 6.0	
Al-Jameel [7]	Mean= 3.30			average maneuver time
Cao, Young [42]	Mean= 2.54	1.29		

5. Data Description (Data Collection and Analysis)

Where this stage requires data collection, analysis and structure statement, data collection requires the selection of appropriate tools to collect and classify data according to reliable principles. In the current study, the video camera was chosen for collecting the flow of traffic and collecting FLC, time headway and distribution of vehicles on each lane. In addition, the radar (i.e. gun-speed) was used to measure the desired speed of each lane. Data collection was done by selecting several sites of rural highways, including two-lane and three-lane sections. The selection of suitable sites was taken into account; the site is free from curvature and grade, free of any damage affecting the movement of vehicles, and the lack of entrances or exits from and to the main road [1].

Five different sites of rural highways were selected to study the characteristics of driver as shown in Figure 4. Data were collected for different hours of the day in order to obtain the best acceptable results. Table 2 shows the duration and date of collection of data from each site, while Figure 5 shows details of data collection and how cameras are placed.

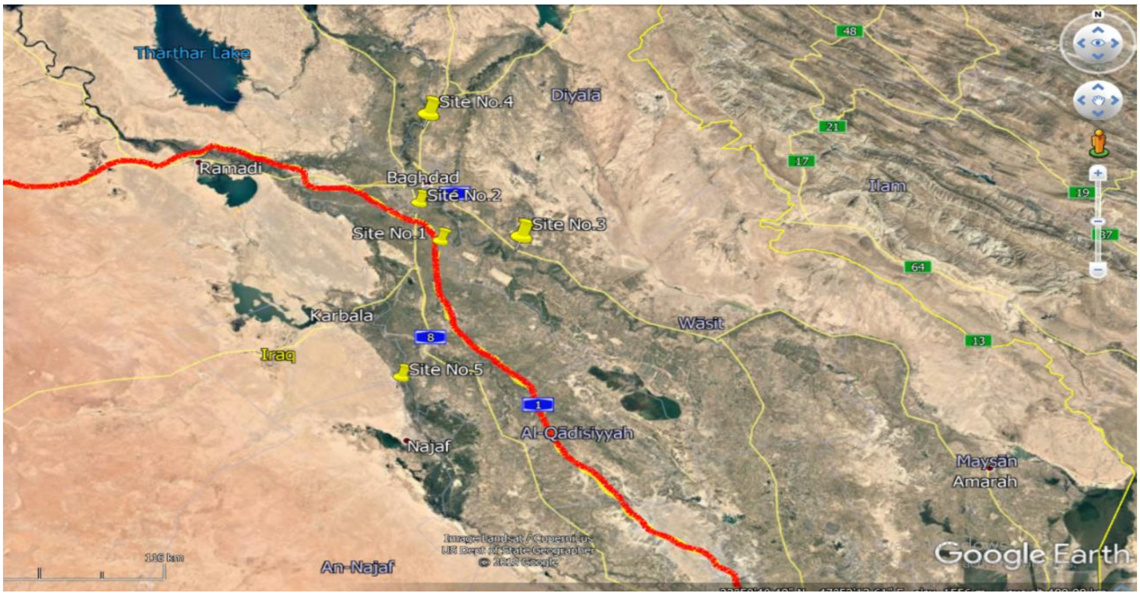

Figure 4. Data collection sites from Iraqi rural highways are shown on the map (Source from Google Earth, 2017).

Table 2. Details of duration and date of data collection from different sites in Iraqi rural highways.

Site No. and No. of lane	Date of data collection	Direction under study	Recording time for two directions
1. Baghdad – Hilla (three lanes)	22-09-2016 23-10-2016 21-06-2017	Both direction	10hr (08:00 AM to 01:00 PM) 7hr and 40 min (06:25 AM to 10:20 AM) 6hr (05:30 AM to 8:30 AM)
2. Baghdad – Mahmudiyah (three lanes)	10-10-2016 17-10-2016 13-02-2017	Both direction	4hr and 30min (06:45 AM to 08:55 AM) 6hr and 30min (1:30 PM to 4:40 PM) 8hr (1:00 PM to 5:00 PM)
3. Baghdad-Kut (two lanes)	27-10-2016 14-05-2017	Both direction	4hr and 40min (08:30 AM to 10:45 AM) 5hr (06:00 AM to 08:30 AM)
4. Baghdad –Diyala (two lanes)	23-01-2017 26-01-2017	Both direction	6hr and 20min (09:50 AM to 01:00 PM) 8hr and 30min (10:20 AM to 2:30 PM)
5. Najaf- Karbala (two lanes)	12-04-2017 22-06-2017	Najaf to Karbala	10hr (07:30 AM to 12:30 PM) 6hr (03:00 PM to 6:00 PM)

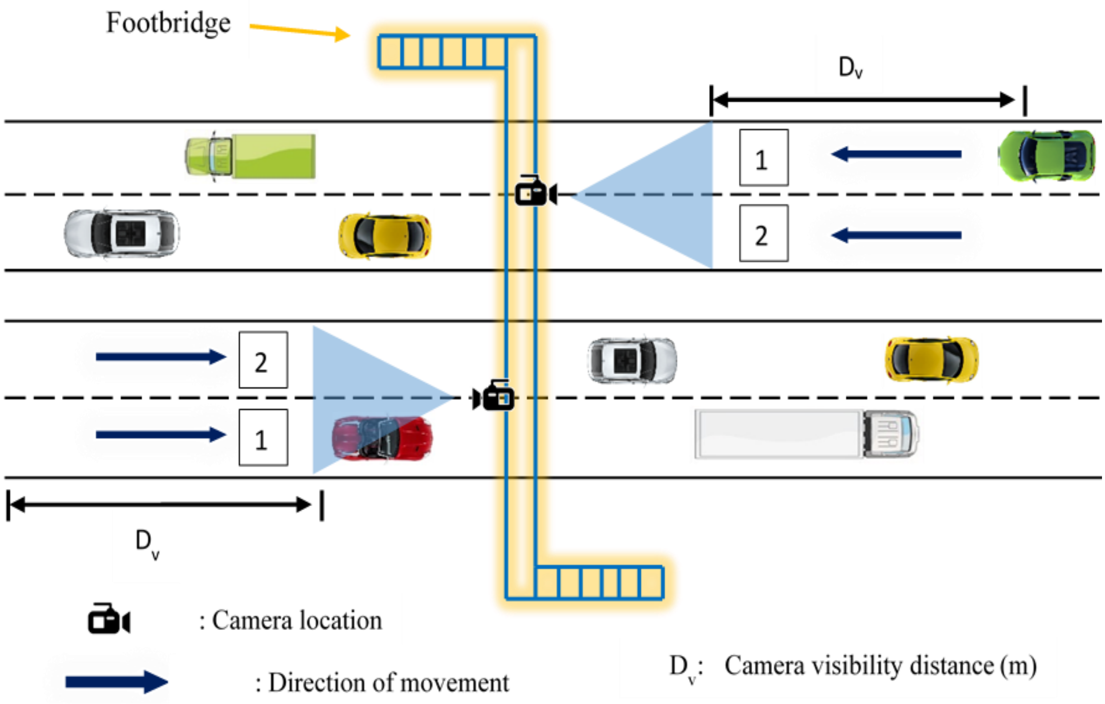

Figure 5. Layout of details for installation of video cameras in the site.

Figure 6 shows the details of some of the sites from which the data were collected. A large-size TV screen was used to display the recorded video for data analysis and by drawing a line on the screen for the flow calculation and vehicle tracking for a specified distance (D_v) to calculate the number of FLC.

Figure 7 indicates the results of traffic flow for the total number of vehicles and the number of Heavy Good Vehicles (HGVs).

Also, using the speed gun, the desired speed for each lane was calculated under ideal traffic conditions, i.e. the volume of traffic is less than 300vehicles/hour [39], and Figure 8 shows the normal distribution of cars and HGVs for the third lane of Site No.1.

Figure 6. Geometric of Site No.2 (in left) and Site No.4 (in right).

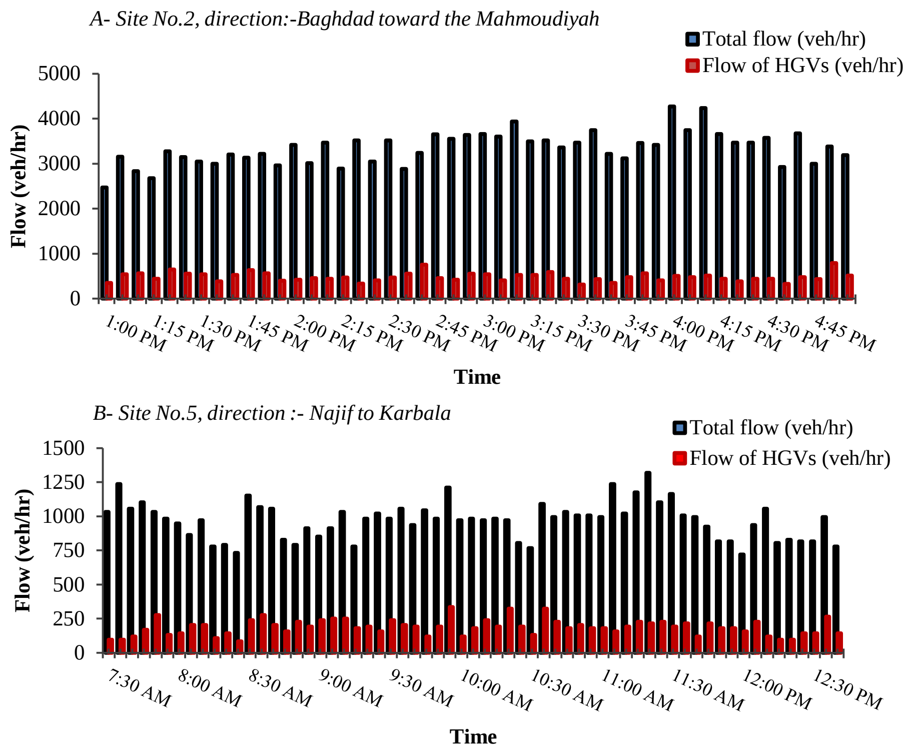

Figure 7. Total flow of vehicles and HGVs (veh/hr) with time.

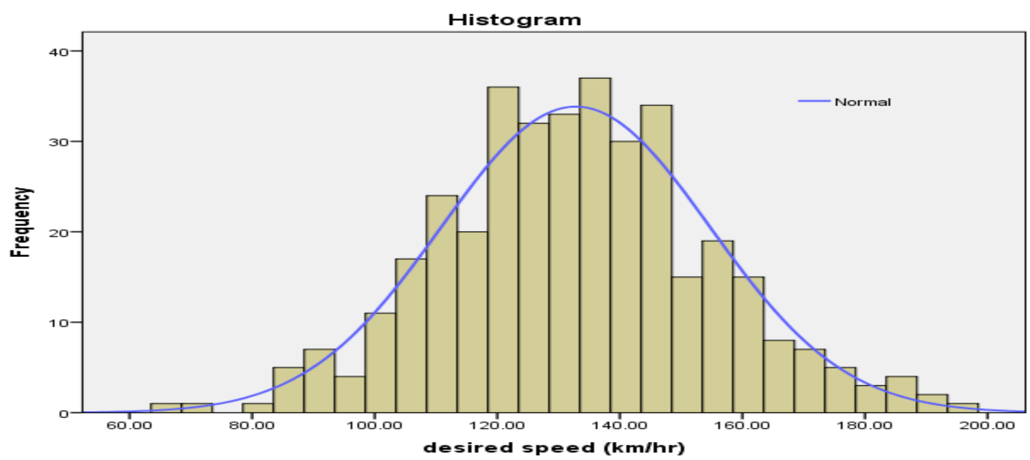

Figure 8. Normal distribution for desired speed for cars from third lane Site No.1

5.1 LC

To determine the behavior of the driver during the process of LC (i.e. when a suitable gap is selected to complete the process of LC), data were collected from all the sites (see Table 2) and analysis of the results by each section (i.e. two lanes and three lanes).

5.2 FLC

The FLC is the number of times drivers change their lanes at a certain distance (this distance is $\mathbf{D_v}$ as shown in Figure 5 and $\mathbf{D_v}$ equal 250m in three lanes and 200m in two lanes). LC depends generally on the vehicle lane-changing speed and the vehicle speed of the leading, as well as traffic density and time headway [21]. Some examples of three lanes and two lanes to the process of changing lanes are described below:

A- Three lanes: From Site No.1 and Site No.2, data were collected for different hours of the day, analyzed by a time interval of 5min [18] and a distance **(D_v)** of 250m (This distance to calculate the number of times during which change the lane), Figure 9 shows the relationship between FLC and the total traffic flow. For three lanes, the peak-hour of traffic flow is 4272veh/hr from Site No.2 as indicated in Figure 10. According to Figure 9, it was found that as flow increases the FLC increases, too, up to 3000veh/hr, then approximately as flow increases the FLC decrease which corresponds to the relations between flow and FLC. However, the FLC (about 1700LC/hr/km) is higher than other countries (see Figure 3) which is about 1100LC/hr/km. This is due to absence pavement marking and violated LC.

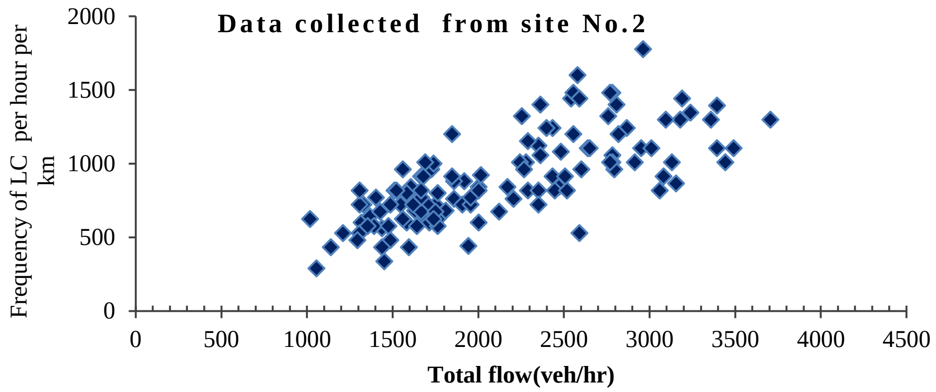

Figure 9. FLC with flow within three lane from Site No.2.

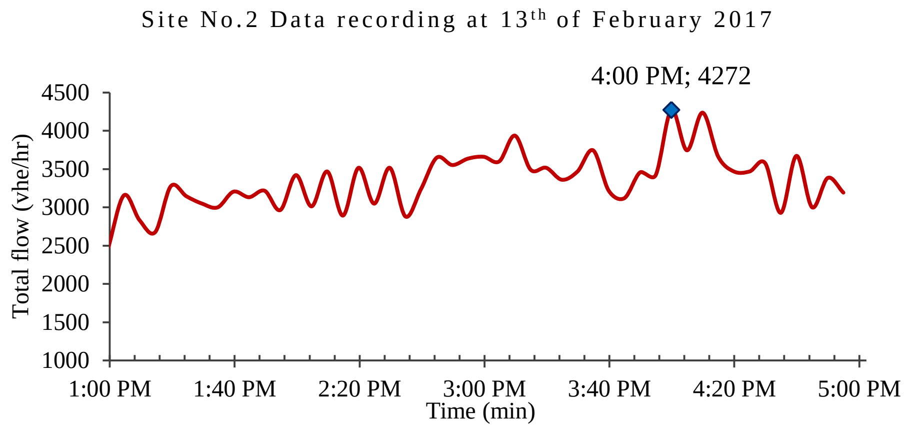

Figure 10. Total flow (veh/hr) with time from Site No.2.

B– Two lane: As in the three-lane sites, where data were collected from the two-lane sites and analyzed by a time interval of 5min and a distance **(D_v)** of 200m, the highest traffic rate obtained is 1980veh/hr in Site No.5 where LC reached its peak, as shown in Figure 11. However, this behavior is different from other behaviors as indicated in Figure 11 which is so high. This could be attributed to the driver behavior and the effect of pavement mainly absence. Therefore, in the Section 5.6 which is a violated LC has been included in this study.

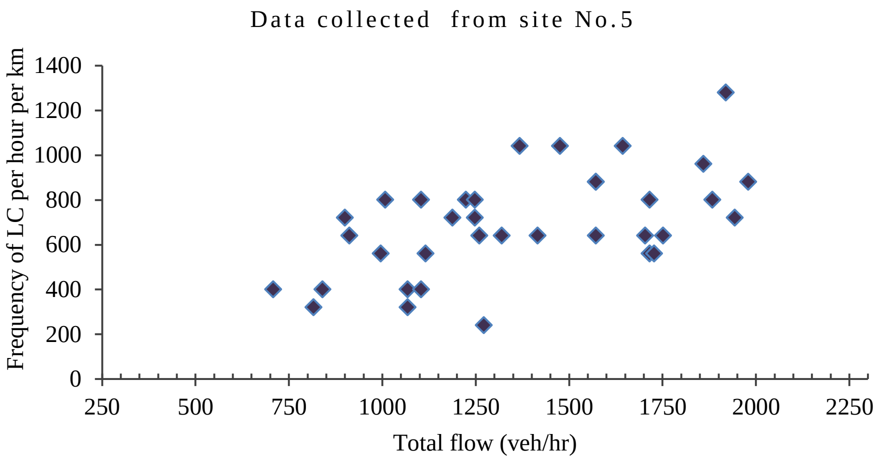

Figure 11. Frequency of LC with flow within two lane from Site No.5.

5.3 Duration of lane Change (time maneuver)

As mentioned in Section 4, the time of maneuver was calculated in this study for each vehicle (i.e. for cars and HGVs) and for both directions (i.e. for vehicles heading towards the right lane or left lane), it was found that the results follow the normal distribution by checking the chi-square test, and the results are shown in Table 3. However, when comparing time maneuver of the current study with the results of previous studies (see Table 1.), the results are close to some researchers such as Hetrick [35] and Al-Jameel [5]. This gives the possibility of using these values as determinants involved in developing the simulation model.

Table 3. Duration of lane change.

Category	Direction of vehicle movement			
	From right to left		From left to right	
	Mean (sec)	St.Dv. (sec)	Mean (sec)	St.Dv. (sec)
Cars	3.05	0.587	3.04	0.583
HGVs	3.69	0.631	3.9	0.731

5.4 Lane change and speed

From Site No.2, data were collected in a 13th of February 2017, analyzing the results in Figure 12, showing the relation of FLC with the speed of each lane. As is evident, an increase in LC leads to reduced speed, thus reducing travel time.

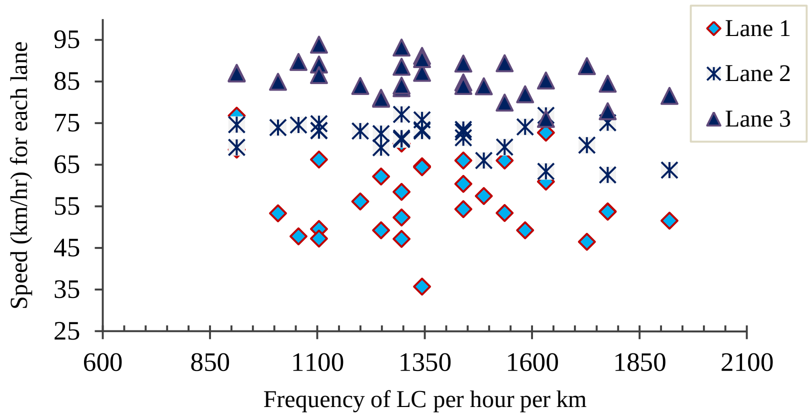

Figure 12. Relation between speed and frequency of LC/hr/km.

5.6 Unsafe Lane Change

The unsafe lane change is a condition that occurs frequently on the road, It occurs when the driver changes direction from left to right, The reason for changing the lane incorrectly is the result of high speed and the presence of a vehicle in front of him slow and free of the right side of vehicles as shown in Figure 13. Also, the driver of the speeding vehicle does not give a signal to the rest of the drivers to change the lane from left to right. This process leads to traffic violations (according to the laws of the country) or crashes. During the current study, the unsafe lane change was calculated for all sites. For example, Site No.2 of the three-lane section was selected and the results are shown in Figure 14.

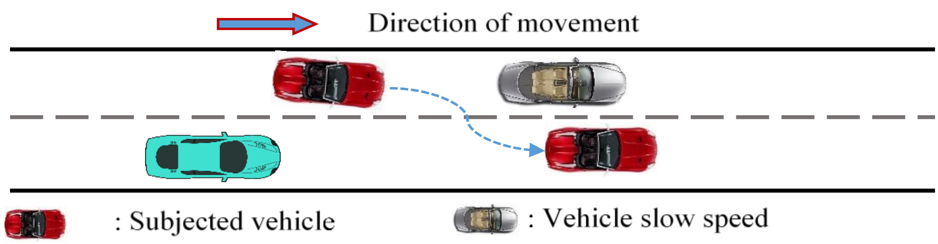

Figure 13. Details of the unsafe lane change status.

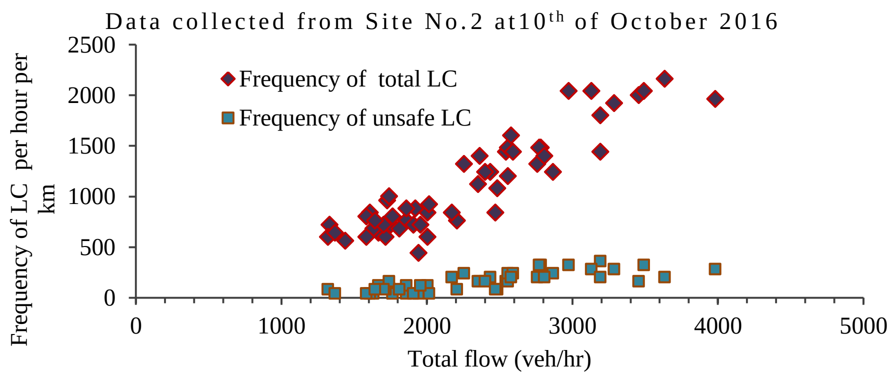

Figure 14. The realtion between unsafe lane change and total flow.

6. Conclusions

The main important points come up with study could be summarized as:

1. The field results indicate that the FLC is higher than other countries by 600 LC/hr/km in case of three lane section. This high LC is due to several reasons such as violated LC, absence of pavement markings and bad surface conditions.
2. The LC for two-lane section was found to be 1040veh/hr which also is higher than other countries for the same reasons mentioning in point 1 above.
3. Also, during the calculation of FLC, it was observed that in some cases an unsafe lane change occurs (ranging from 5% to 25% of the total frequency of LC), i.e. a traffic violation, which could lead to traffic accidents. These violations increase with increasing traffic volume.
4. The Iraqi drivers mainly prefer to stay in the fast lane with doing unsafe LC in some cases.
5. The duration of LC was found to be similar to other countries such as the UK.

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