Lane Changing and Lane Utilization Behavior for Three Lane Normal Section in Iraq Traffic Sites

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Abstract

Recently, different programs or methods have been produced to solve the traffic problem everywhere in the world. Iraq is one of the countries which suffer from high problems in traffic operation, design and planning. Therefore, to use the sophisticated traffic programs or models such as simulation models there is an urgent need to investigate specified field parameters which correspond to calibrated parameters used in the model under study. This study has focused on studying driver behavior which represents the core stone in a traffic simulation. This behavior represents lane changing (LC) and lane utilization (LU) in normal sections. Three normal sections with three lanes have been selected in different sites in Iraq: two sites in Al-Najaf city and one site in Al-Muthna city. The results of data analysis show that the driver behavior in both LC and LU is similar to the behavior in the UK. The current observed data could be used for the calibration process for any traffic simulation model in order to mimic the reality of Iraqi drivers.

Keywords: Driver Behavior, Lane changing, lane utilization and simulation model.

الخلاصة

مؤخرا ظهرت العديد من البرامجيات والطرق المختلفة التي تم انتاجها لحل المشاكل المرورية في انحاء مختلفة من العالم. العراق واحد من البلدان التي تعاني من الكثير من المشاكل المرورية في الجانب التشغيلي والتصميمي والتخطيطي. العديد من البرامج المتطوره او الموديلات استخدمت مثل موديلات المحاكاة لذلك هناك حاجة ماسة لاكتشاف المعايير العملية والتي تطابق معايير المعايره للبرامج قيد الدراسة. هذه الدراسة ركزت على دراسة سلوك السائق والذي يمثل حجر الزواية لاي برنامج محاكاة مروري. سلوك السائق يمثل تغير الممر واستخدام الممر في المقاطع الاعتيادية. ثلاث مقاطع اعتياديه ذات ثلاث ممرات تم اختيارها في ثلاث مواقع: موقعين في مدينة النجف وموقع واحد في مدينة المثنى. نتائج تحليل البيانات اظهرت بان سلوك السائق لتغيير الممر واستخدام الممر هي مشابه لسلوك السائق في المملكة المتحدة. هذه البيانات يمكن ان تستخدم في معايره نموذج محاكاة مطور للحصول على نموذج محاكاة يمثل سلوك السائق العراقي.

الكلمات المفتاحية : سلوك السائق ، استخدام الممر ونظام المحاكاة.

1. Background

It has been recognized that traffic congestion and traffic safety are the two most important aspects of the transportation network. One of the parameters that affect both traffic congestion and safety is the distribution of traffic to the various lanes of motorway sections (Kyriakidis, 2000).

It is common knowledge that the lane-changing process is the most common phenomenon after the changing of speed. It is also known that the lane-changing process influences the total traffic volume and the capacity of the road, which are strongly related to the safety of the motorway. Therefore, in order to describe the distribution of traffic on the road it is also essential to describe the lane changing process.

Recently, new methods have been developed using the advantage of sophisticated technology such as simulation models and other methods which are interested in the studying driver behavior. It was found that knowing diver behavior is the key to use these new models such as simulation models (Hidas, 2005).

To build a simulation model for Iraqi driver behaviors, there is a need for building that model from the fundamental elements of a traffic simulation model such as car-following model and lane changing model.(Al-Jameel ,2014) developed the first element (car-following model) using safety car-following model. This study has focused on the second element (lane changing model).

2. Lane change

Driver behavior such as lane change and lane utilization has received a lot of attention in order to understand the characteristics of traffic stream (Hidas, 2005). Moreover, the lane utilization factor was also found as one of the important factors which describe how vehicles are distributed among different lanes for the road under study (Hidas, 2005).

Singh (2012) reported that the Lane-changing process has an important role in traffic studies and impact significantly on traffic flow. Lane-changing models first came into existence in the late 1980's. The first lane-changing model was developed by (Gipps ,1986) as micro-simulation tools for a framework with lane changing decisions in urban driving scenarios.   He also modeled the Influence of traffic signals, obstructions, transit lanes and different vehicle types such as heavy vehicles and on drivers' lane selection choice. Gipps' model focuses on the decision-making process considering the potential conflicting goals. However, the developed model suffers from several drawbacks see (Singh ,2012). Recently, different types of models have been developed in order to match the reality of different types of lane changing behavior. The main types of lane changes are Mandatory (MLC) Lane Change and Discretionary (DLC) Lane Change (Hadis, 2002). When the driver must leave the current lane, it is called MLC. This happens due to avoid a lane blockage or to use an exit or to follow their path or to comply with lane use regulations) and he/she will change to the nearest acceptable lane. Whereas, DLC is performed when the driver perceives that driving conditions in the target lane are better, but a lane-change is not imperative.

To interpret several traffic characteristics such as a merge bottleneck due to systematic lane changing activities which creates a bottleneck and decreases capacity, formation and growth of stop-and-go conditions, there is an urgent need to study the LC behavior (Cassidy and Rudjanakanod, 2005; Bertini and Leal, 2005 ; Ahn and Cassidy, 2007).

(Sparmann ,1979) conducted a series of observations on two –lane road section between two German cities and determined the number of lane changing manoeuvres within given time intervals. The result of this study indicates that the lane-changing frequency increases proportionally to the traffic volume increase. This continues until it reaches a maximum value of 600 lane changes per hour per kilometre at a traffic volume of 2000veh/h. then, the frequency of lane changes decreases to the minimum value as the flow reaches maximum value. The author also concluded that the proportion of Heavy Goods Vehicles (HGVs) on the road had a very small effect on the lane-changing frequency and no relationship with speed.

(Singh ,2012) reported that the real time inter-lane variables such as traffic density and lane-changing are fundamental to traffic control and management in urban areas. On many occasions they are used as decision variables to determine strategies for traffic control and management in real time.

A lot of studies have focused on dissecting the driver behavior in terms of lane changing process such as(Singh ,2012; Kukida *et.al.,*2011; Sun ,2010 ; Coifman ,2003). Moreover, the lane changing behaviour also differs from country to country according to the applied regulations in each region as shown in Figure 1.
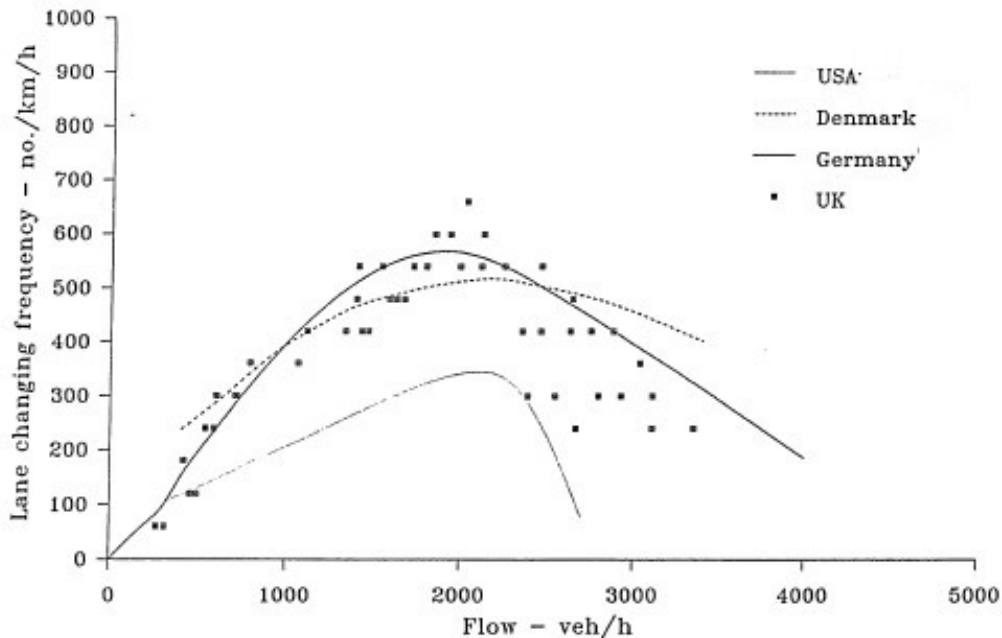
Figure 1 Comparison of lane changing frequency in different countries for 2 lane normal section (Yousif and Hunt, 1995).

In order to provide accurate solutions by using the universal developed models such as the HCM and simulation models here in Iraq, there is an urgent need for studying the driver behavior. Therefore, this study has been devoted to study such behavior (lane change and lane utilization).

The aim of study is to investigate the driver behavior such as lane changing and lane utilization. Then, the collected data of the driver behavior will be used in the calibration process for any simulation model of normal section roads.

3. Lane utilization

(Yousif and Hunt ,1995) attempted to present the lane-utilization as a function of total flow. From field observations at various motorways, they collected the traffic flow data and presented it in five-minute counts. The roadway sections where the data were collected were away from traffic obstructions such as intersections, road works and other influences on the flow. The results were presented in a number of figures where the percentage of vehicles per lane, on two-lane dual carriageways and three-lane sections of motorways was plotted against the total flow.

Yousif and Hunt assumed that 20% of the total flow had been heavy good vehicles. However, the effect of HGVs to the lane utilisation was excluded from the regression procedure.

After the derivation of these regression formulas, Yousif and Hunt found that these relationships were similar in shape to those reported earlier by(Heidemann, 1994 ; Currer ,1974). Finally, the regression curves obtained by Yousif and Hunt were plotted against those curves obtained from similar motorways in Germany as reported by (Hotop ,1975 ; OECD ,1983). The visual comparison that was performed

by Yousif and Hunt, suggested that for two-lane sections similar behaviour is obtained both for the U.K. and Germany. However, for the three-lane sections, the use of the nearside lane (lane 1) is higher in the U.K. than that on German motorways. This corresponds to a lower usage of the offside lane (lane 3) while the middle lane (lane 2) has somewhat similar usage. This could be attributed to differences in drivers' behaviour and the effects of speed limits and their enforcement in the two countries.

(Heidemann ,1994) developed a theoretical model that described and analysed the distribution of traffic to the individual lanes and the frequency of lane changing on two-lane and three-lane unidirectional roadways. Heidemann derived differential equations with which he described the split of the total traffic flow to the individual lanes. Heidemann's model was based on two equations. The first of these equations, contained the condition of equilibrium for the balance of changeovers between two lanes, and the second equation is a differential equation, which describes the change in the proportion of the traffic volume on a single lane as a result of an infinitesimally small growth in the overall traffic volume.

Finally, Heidemann obtained curves from the derived equations and compared these curves with empirical data measurements. Although Heidemann did not include the effect of HGVs and speeds in his equations the results were surprisingly similar to the empirical data with which he made comparisons. The only parameters required were those taking account of the gap acceptance since it was established in the literature that speeds and HGVs hardly affect the lane distribution or the frequency of lane changing,(Heidemann ,1994).

4. Data Collection and Analysis

This section indicates the data collection stage. Data have been collected using video camera. In each case it has been selected the vantage point as a foot bridge. This provides good location in terms of zoom and hiding from drivers' vision. Three different normal sections in Iraq have been included in this study. From the UK, two sites have been selected, too.

4.1 Selected sites

To achieve this study, three sites have been selected. The first location is on the Karbala -Najaf road as shown in Figure 2. The first site from where data were collected was a section on the Karbala -Najaf road. This section has three lanes of traffic for each direction. As in most of the cases, the filming procedure took place on a bridge just above the road.

The figure below indicates the details of the selected section along Karbala - Najaf road. This location has been selected because it is close to normal section behaviour. The vantage point is the foot bridge located on the selected section.

Figure 2 Site1 located on Karbala -Najaf roadway.

Data have been collected using video camera. Then, data have been extracted from the video each five minutes for each lane as shown in Table 1. A section of 250m has been determined using light column existing on the road. The start and the end of the section have been determined on the screen of the laptop using for the analysis. Then, the section understudy has been monitored to capture the vehicles doing LC from lane 1 to lane 2, lane 2 to lane 1 and other LCs activities.

Secondly, the next site that was visited is a three-lane section on the Airport Road. Data have been collected from section Airport Road neighborhood "Al-wafai Quarter". The direction of traffic stream comes from Karbala towards Al-Najaf International Airport. The visit took place on Monday the 17th of November 2014 and the filming procedure took place between 7:40 and 8:50. A video camera was installed on the footbridge crossing this road as shown in Figure 3. A video recording for 50 minutes was obtained from this site as shown in Table 2. This road is characterized by high volume and high speed because it carries a high traffic volume coming from the northern parts of Al-Najaf city in addition to the traffic volumes coming from other provinces such as Karbala, Hilla and Baghdad.

The other direction of Site 2 is the traffic coming from the Airport towards Karbala as shown in Figure 3. The period of video recording is 50minutes. As reported above, data have been collected each five minutes as shown in Table 3.

Time	Flow (veh/hr)			Lane change (LC/hr/km)			
	Lane 1	Lane 2	Lane 3	$1 \rightarrow 2$	$2 \rightarrow 1$	$3 \rightarrow 2$	$2 \rightarrow 3$
7:45-7:50	480	1320	1188	528	288	240	528
7:50-7:55	420	1356	1320	384	336	384	480
7:55-8:00	456	1524	1284	384	192	528	528
8:00-8:05	672	1440	1656	192	480	672	912

Table 1 Data collected from site 1.

The third site is the section of the road at the entrance of Al Muthanna province (through Rumaitha - Samawa). This section was selected because it satisfies the requirements of normal section such as it is far away from intersection and U-turn. Another important reason for this selection is the existing of footbridge crossing this road as a vantage point as shown in Figure 4. Then, the video camera was installed there to capture data for 55 minutes as shown in Table 4.

After the selection of the sites, it was then necessary to collect the necessary data. The recording of the data for each site was completed with the assistance of a video camera. The camera that was used was a Sony video camera, which also had the facility to record time. In each site that was visited, the camera was placed on a high position, usually a bridge above the normal section.

Table 2 Data collected from site 2-A.

Time	Flow (veh/hr)			Lane change (LC/hr/km)			
	Lane 1	Lane 2	Lane 3	$1 \to 2$	$2 \to 1$	$3 \to 2$	$2 \to 3$
7:30-7:35	20	44	26	9	2	3	3
7:35-7:40	12	43	36	4	4	4	7
7:40-7:45	13	39	34	3	0	4	6
7:45-7:50	8	41	34	8	2	2	4
7:50-7:55	12	40	34	8	4	3	5
7:55-8:00	10	35	28	1	1	7	2
8:00-8:05	9	25	22	1	1	3	1
8:05-8:10	27	33	10	1	3	3	4
8:10-8:15	16	24	23	0	5	2	3
8:15-8:20	25	20	18	2	5	2	0

This procedure was followed so that the camera was filming in an angle to the section of the normal section that was below the bridge. In addition to this, it was also very important that the camera would not be visible to the drivers on the motorway - mainly for safety reasons.

Another important objective of the recording procedure was to record the data at both peak and off peak hours. This was based on the necessity to describe the distribution of traffic in general and not just for the specific peak hours of the day. Therefore, it was decided to record each site in the following order: Off peak – Peak – Off peak.

Table 3 Data collected from site 2-B.

Time	Flow (veh/hr)				Lane change (LC/hr/km)				
	Lane 1	Lane 2	Lane 3	Total	$1 \to 2$	$2 \to 1$	$3 \to 2$	$2 \to 3$	Total
7:30-7:35	48	432	216	696	0	0	96	96	192
7:35-7:40	96	468	252	816	0	192	144	192	528
7:40-7:45	84	468	276	828	0	48	144	96	288
7:45-7:50	12	432	168	612	0	96	48	96	240
7:50-7:55	60	372	180	612	48	240	48	0	336
7:55-8:00	48	312	96	456	0	144	0	0	144
8:00-8:05	108	408	228	744	288	0	48	96	432
8:05-8:10	84	384	192	660	336	0	48	48	432
8:10-8:15	84	432	276	792	192	0	96	0	288
8:15-8:20	48	456	300	804	96	0	96	48	240

Table 4 Data collected from site 3.

Time	Flow (veh/hr)				Lane change(LC/hr/km)				
	Lane 1	Lane 2	Lane 3	Total	$1 \to 2$	$2 \to 1$	$3 \to 2$	$2 \to 3$	Total
7:30-7:35	1284	1284	504	3072	672	528	48	192	1440
7:35-7:40	1152	1248	528	2928	768	576	240	144	1728
7:40-7:45	1092	1176	408	2676	528	672	96	240	1536
7:45-7:50	1080	1116	396	2592	672	432	192	96	1392
7:50-7:55	1056	948	372	2376	624	384	144	240	1392
7:55-8:00	1104	1128	540	2772	720	336	240	96	1392
8:00-8:05	840	960	348	2148	528	384	288	48	1248
8:05-8:10	900	936	288	2124	432	528	192	96	1248
8:10-8:15	828	600	264	1692	432	480	144	96	1152
8:15-8:20	948	876	168	1992	576	336	144	48	1104
8:20-8:25	720	756	132	1608	480	432	192	96	1200

Figure 3 Site 2 along Najaf-Karbalaa –Ring road (Airport road).

Figure 4 Site 2 along the entrance of Al Muthanna Province.

4.2 Data Analysis

After analyzing the reordered data (videos), the results of lane changing indicates that the behavior of lane changing for three lane section likewise the reported behavior by other studies such as (Sultan and McDonald ,2001). This means

that the maximum number of LC is around 3000veh/hr for the three lane section. It was found that maximum number of LC for two lane section is around 2000veh/hr.

According to the figure, the maximum number of LC is around 1400 which are corresponding to 3000 veh/hr. Then, the LC decreases with the increase of flow as illustrated in Figure 5.

Another set of lane changing data was collected using video camera installed over a bridge foot located on the three normal section of M60 J1-J2 on the 12th of March 2010. These data were collected by the author when he was in the UK.

Figure 6 indicates the difference between the frequency of LC in the UK and Iraq. This difference is attributed to the existing of MTR (three –wheel vehicle) with low speed that makes the other vehicles do LC in order to avoid blocking by this type of vehicle. Moreover, one of the difficulties that face us in finding such section is that existing of illegal parking vehicle either to get off passengers or pick up. This behavior leads to more unnecessary LC as observed in Figure 6. On the other hand, reaching maximum flow comparing with the UK is difficult because of spreading a lot of numbers of check points which block the traffic flow especially after the checkpoint area. Lane utilization behavior has been demonstrated clearly from the field data as shown in Figure 7. The main behavior of driver in the three lane section here in Iraq could be summarized as:

When the rate of flow is low most of the vehicles concentrate on the second lane. More than 50% of the vehicles occupy the second lane up to 800veh/hr, whereas the occupancy of the first lane is still fluctuated within different rates of flow as shown in Figure 7. The lane utilization for the third lane represents that up to 40% of drivers using this lane during low and moderate flow. Then, most drivers return to concentrate in the third and second lane at high flow.
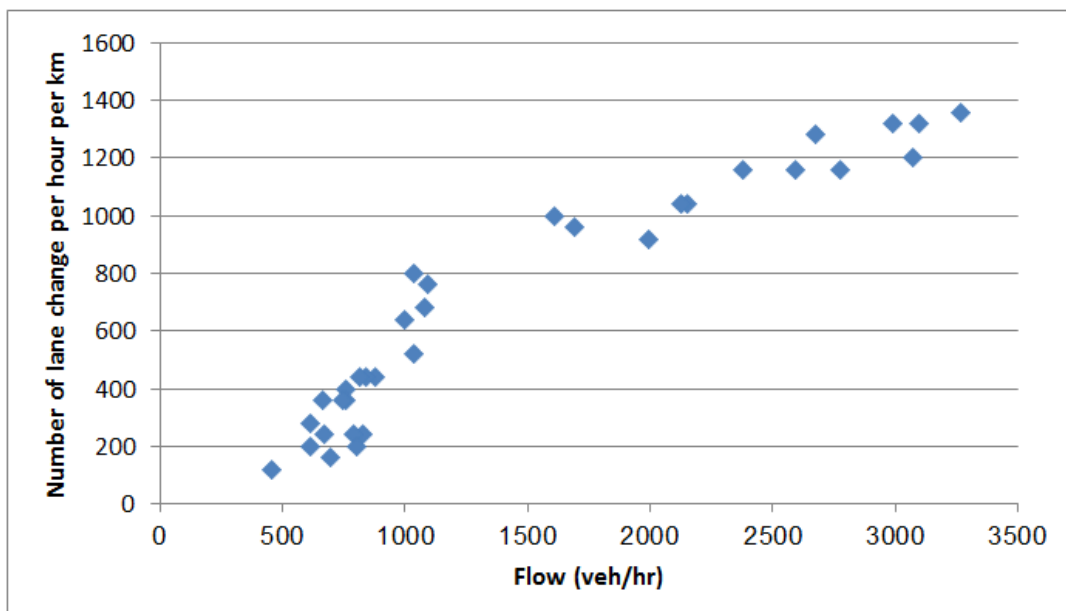
Figure 5 Number of LC with flow for all sites.

Another set of data was collected from loop detectors embedded in the M60 which is a normal section road on the 10th of February 2015. This is a ring road surrounding Manchester city. The results of analysis are indicated in Figure 6. The figure shows different behaviors between the LU in Iraq and in the UK. The difference comes from that the distribution of traffic volumes among the lanes in each section especially in low flow.
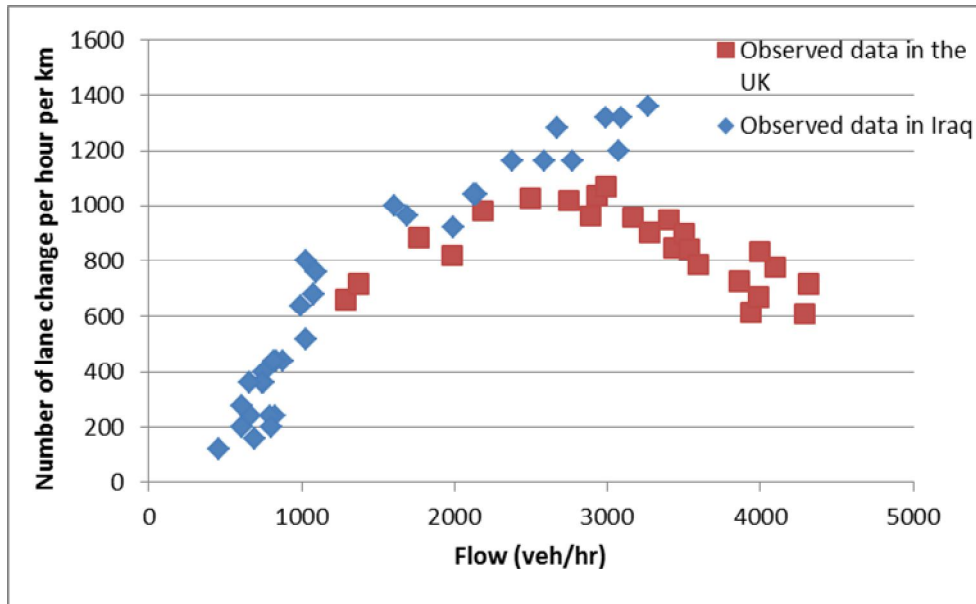

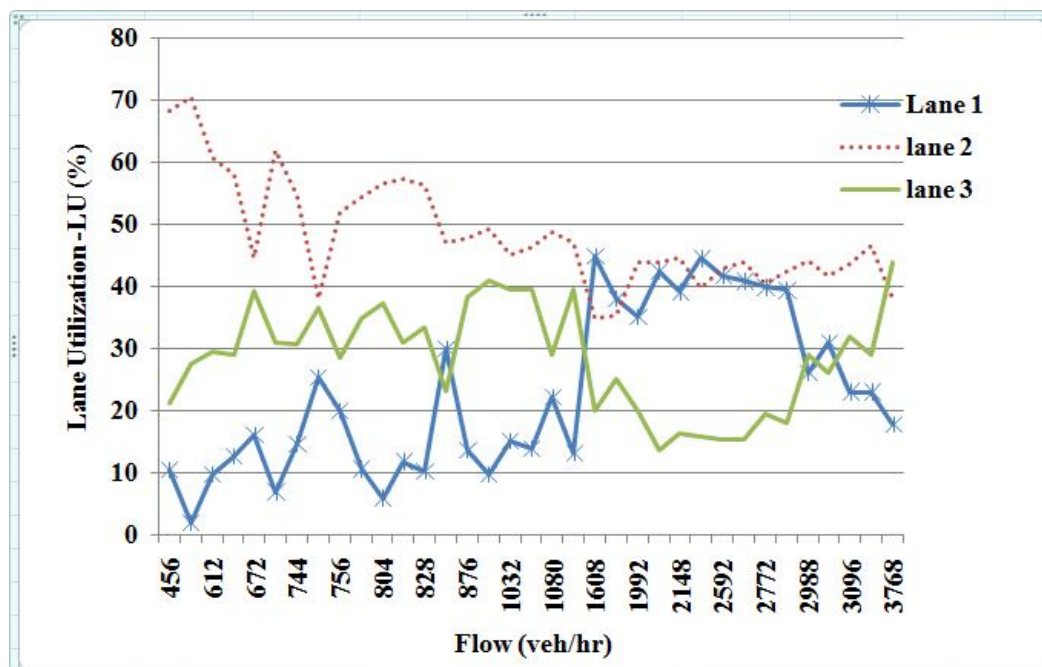**Figure 6 Comparison between lane changing behavior in Iraq and the UK.**

Figure 7 Lane utilization with flow rate for all sites.

Generally, the difference in how traffic distributing among different lanes is due to the same reasons mentioned above for the LC behavior. Almost Iraqi drivers try to be in the second lane to avoid slowing vehicles on the slow lane and to keep the third lane open for passing high speed vehicles during low to moderate flow. As flow

increases from moderate to high flow, the drivers try to return to the first lane due to enough space there up to a specific limit (around 3000 veh/hr) leading to reduction in the lane utilization from about 70% to 45%. Then during high flow, the first lane becomes highly congested; therefore the drivers try to escape from it to the second lane as shown in Figure 7.

The utilization of third lane could be observed as it is less than the second lane under low to moderate flow and higher than the use of the first lane as shown in Figure 7. For the high flow, as shown in Figure 7, the occupancy of third lane by the drivers reduces sharply to the low limit, then increases to be close to the second lane in the percentage of use.

Figure 8 indicates how drivers in the UK distribute themselves among different lane for the three lane normal section. At low flow, the majority of drivers are in the first lane and the minority in the third lane. Whereas, the second lane ranges between the highest value in the first lane and low one in the third lane. As flow increases from low to congested, the lane utilization for the first lane decreases from more than 95% to less than 30%. The inverse behavior for the third lane is observed, i.e. as flow increases from low to high flow, the lane utilization for the third lane increases from 0% to around 40%. Figure 8 also indicate how the lane utilization for the second lane ranges approximately between 50% to 30% under moderate to high flow.
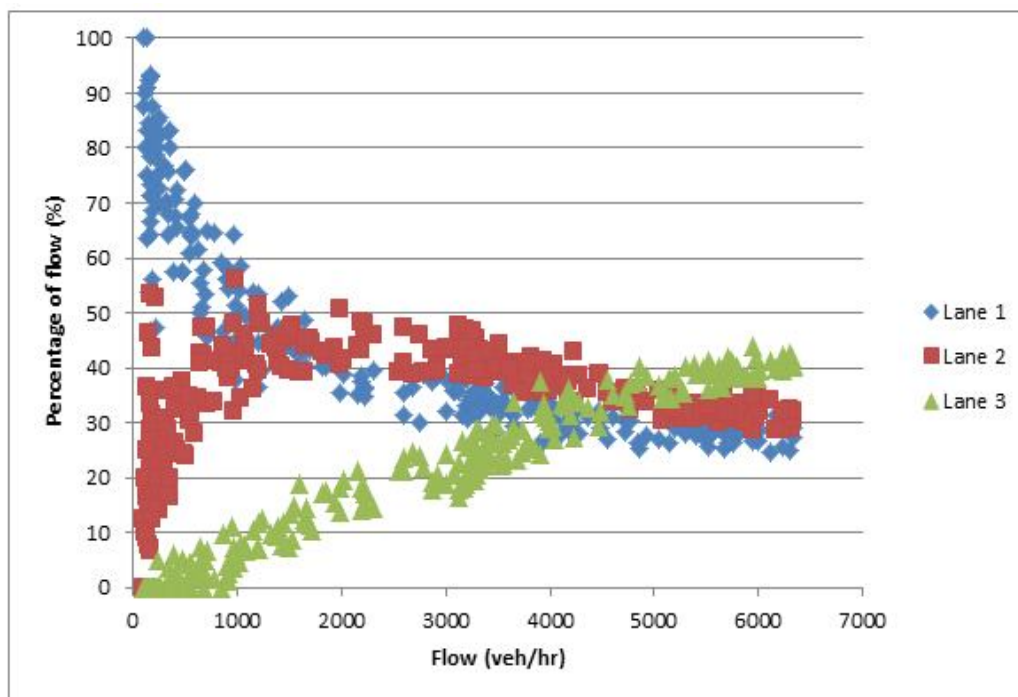
Figure 8 Lane utilization with flow rate from M60 in Manchester City (UK).

The main difference between the lane utilization behavior in Iraq and the UK is clearly observed through Figures 7 and 8. Firstly, the main concentration of driver in Iraq in the second lane whereas in the first lane in the UK. This could easily be attributed to the uncomfortable damaged first lane (slow lane) due to the absence of maintenance. Therefore drivers try to avoid being in the first lane which is not the case in the UK. Accordingly, the observed behavior, regardless the difference in the system of driving, in the UK seems closely to the real behavior for driving. On the other hand, the difference in driving habits in Iraq from the UK and other countries for the lane utilization could be due to less attention that paid for road maintenance.

Knowing the lane utilization behavior could be used as a calibration parameter for developing simulation models. This makes a simulation model capable of representing the traffic reality.

5. Conclusions and Recommendations

The main conclusions could be summarized from this study as follows:

1. Lane changing behavior observed in the field is similar to the lane changing behavior in the UK for the three lane section. However, the number of LC obtaining from field data in Iraq is higher than observed in the UK. This may be attributed to several reasons such as Iraqi drivers are more aggressive in accepting small gaps than the British drivers and existing MTR vehicles (small car with three tires) make motivation for other drives to change lane.

2. There is a clear difference between the utilization behaviors of drivers in the UK and in Iraq in how drivers distribute among other lanes under low to high flow conditions.

3. There is a need for such study for another type of normal sections such as two-lane and four lane sections from Iraq traffic sites.

4. This study represents the core stone for the calibration process of a simulation model in Iraq. The next step of this study is to use these sets of data for calibrating and validating the developed simulation model by the author for LC and LU behavior.

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