STUDYING RURAL ROAD CHARACTERISTICS USING THE DEVELOPED SIMULATION MODEL AND S-PARAMICS

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Abstract - This study has mainly focused on studying the characteristics of selected rural roads in Iraq using the developed simulation model and S-Paramics in order to enrich the area of developing such traffic simulation model calibrated with field data. Thus, several sites, such as Baghdad-Hilla, Baghdad-Mahmudiyah, Baghdad-Kut, Baghdad-Diyala and Najaf-Kerbala, have been investigated such as two and three-lane sections. This paper has three objectives; first, to investigate driver behavior mostly according to collected data of lane changing, lane utilization, flow and time headway. The second objective is to develop simulation model starting from car-flowing and ending with the process of calibrating it graphically and statistically with field data. The third objective is to calibrate the well-known S-Paramics model with field data and comparing it with the developed model. More than 80hrs have been collected using video cameras placed on footbridges as vantage points. The graphical and statistical analyses demonstrate more accurate for the developed model with field data than S-Paramics model. This model may be considered as the first step towards modeling driver behavior in Iraqi rural roads and enhance this model to represent different behaviors according to the collected data.

Index Terms - Simulation model, rural roads, S-Paramics, lane changing, lane utilization.

I. INTRODUCTION

In recent years, the microsimulation method has been used to evaluate and solve most of the traffic problems that occur at a microscopic level, for example at intersections, weaving area or merge area. This evaluation can be enlarged to reflect problems on a wider level of the road or network (i.e. macroscopic or mesoscopic level) (Zhang, 2004).

The process of building a traffic simulation model requires some algorithms as a basis on which sub-models control the movement of vehicles such as the car-following model (CF). Mostly, there are many divisions of CF models and for more details on such models see Kayvan (2013). One of the most important models of CF is the safe distance model. This model was developed to represent several cases of longitudinal movement. It is based on collision avoidance between vehicles by keeping a separate distance (buffer space (Bufs)) between the vehicles in all movement situations (Yousif, 1993 and Al-Jameel, 2011). As for the lateral movement, it is controlled by the model of the lane change (LC) and the gap acceptance (GA) model where the hybrid model has been built to change the lane based on assumptions from previous studies or rules obtained from field data according to driver behavior and vehicle characteristics.

The process of changing the lane takes place when an accepted gap is available. GA Model ensures safety in the process of changing the lane (Bi et al., 2016). Figure 1 indicates GA, the time headway, and the process of LC.

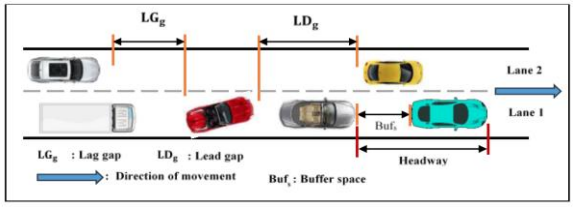


Fig. 1. The process of changing the lane.

II. METHODOLOGY OF DATA COLLECTION AND ANALYSIS

There are various tools used to collect data from the field, for example, cameras, loop detectors, and radars. The camera is one of the most widely used to collect data with different parameters, which are used in the calculation of traffic volume (flow), frequency of lane change (FLC), time headway and speed. The speed gun was also used to measure the desired speed for each lane. In the data analysis stage, a large screen (TV) was used to display recorded video and split the screen by line until the flow and time headway were calculated.
The chosen section is a normal section of a rural highway (two lanes and three lanes for each direction). These sites were chosen according to several criteria, including flat road, an absence of surface distortions, and no entrances or exits from secondary roads. Where more than 60hours were collected by two cameras placed away from the driver's field of vision (camera for each direction). Table 1 and 2 demonstrate the duration and date of data collection as well as Figure 2 shows the sites selected on the map.During the data analysis stage of the recorded videos, the vehicles were classified into two groups, namely cars and HGVs, where vehicles that have more than four wheels

touching the pavement are classified within the group of HGVs (according to HCM, (2000)). Figure 3 indicates the total traffic volume and the traffic volume of HGVs, and by calculating the traffic volume of all the sites mentioned in Table 3, the proportion of vehicles of the total traffic volume is equal to 20%. Furthermore, in order to know how vehicles are distributed on the available lanes, equations were extracted from data as shown in Table 3 (see also Figure 4 which shows the lane utilization for each lane) using the Excel program. These equations are so important because they are responsible for the distribution of the vehicles on each lane in the developed model system, where the model system begins to operate by input the total volume of flow and the desired speed of each lane. Table 4 shows the desired speed measurement for each lane by speed radar (speed gun) while the desired speed is measured when the traffic volume is less than 300veh/hr as mentioned by Duncan (1995).

Table 1 Details of data collection from different sites in rural highways of Iraq (three lane section).

Site No.	Direction under study	Recording time for two directions	Date
One: Baghdad- Hilla	Both direction	10hr (08:00 AM to 01:00 PM)	22/9/2016
		7hr and 40 min (06:25 AM to 10:20 AM)	23/10/2016
		6hr (05:30 AM to 8:30 AM)	21/06/2017
Two: Baghdad-Mahmudiyah	Both direction	4hr and 30min (06:45 AM to 08:55 AM)	10/10/2016
		6hr and 30min (1:30 PM to 4:40 PM)	17/10/2016
		8hr (1:00 PM to 5:00 PM)	13/02/2017

Table 2 Details of data collection from different sites in rural highways of Iraq (two lane section).

Site No.	Direction under study	Recording time for two directions	Date
Three: Baghdad-Kut	Both direction	4hr and 40min (08:30 AM to 10:45 AM)	27/10/2016
		5hr (06:00 AM to 08:30 AM)	14/05/2017
Four: Baghdad -Diyala	Both direction	6hr and 20min (09:50 AM to 01:00 PM)	23/01/2017
		8hr and 30min (10:20 AM to 2:30 PM)	26/01/2017
Five: Najaf- Karbala	Najaf to Karbala	10hr (07:30 AM to 12:30 PM)	12/04/2017
		6hr (03:00 PM to 6:00 PM)	22/06/2017

The time headway distribution of the field data is obtained, and the theoretical distribution of time headway was determined through these data. Consequently, the shift negative exponential distribution was found mostly the appropriate one that matching with the field data. Generally, Equation 1 is responsible for generating the vehicles into the simulation model system. Table 5 shows Kolmogorov-Smirnov (K-S) test to confirm that the theoretical distribution matches the field distribution of the data.

$$Ht=shift-[1/q-shift]\ln(RND) \quad (1)$$

Where; Ht: the time headway (sec).

Shift: the additional time such as 0.25, 0.5 and 1 in sec.

RND: the random number generated by sub-program, and

q: flow rate (veh/hr).

Table 3 Estimated equations for the distribution of vehicles on each lane.

Section type	Equation	R2
Three lanes	Qlane-1= Qtotal - Qlane -2 - Qlane-3	---
	Qlane-2 =0.2864* Qtotal +210.85 for Qtotal $\geq$ 315veh/hr	0.93
	Qlane-3 =0.63495* Qtotal -242.5 for Qtotal $\geq$ 385veh/hr	0.97
Two lanes	Qlane-1= Qtotal -Qlane -2	---
	Qlane -2=0.0001* Qtotal2 +0.342* Qtotal +124.1	0.90

Table 4 Desired speed for each lane (measured by speed gun) from Site No.1.

Category	Lane-1		Lane-2		Lane-3	
	Mean (km/hr)	St.Dv. (km/hr)	Mean (km/hr)	St.Dv. (km/hr)	Mean (km/hr)	St.Dv. (km/hr)
Cars	88.9	18.2	118	24	132.8	22.0
HGVs	78.2	16.0	90.4	16.3	94.7	16.4

Table 5 K-S results for testing the time headway distribution(with shift value).

K-S test	Site No.2		
	Lane-1	Lane-2	Lane-3
Flow (veh/hr)	349	1203	1651
Dmax (shift negative exponential distribution)	0.042 *	0.051 *	0.040 *
Shift value (best value)	0.8	0.5	0.37
Dcr (Critical value)	0.103	0.057	0.048

*Dmax< Dcr (acceptable)

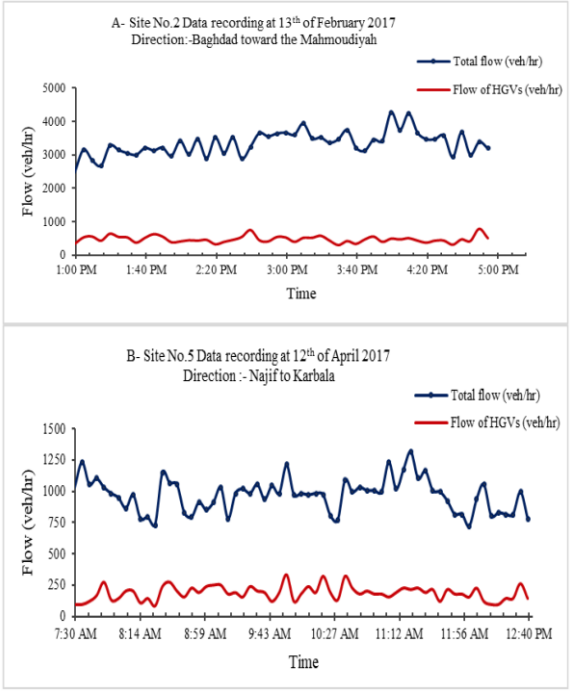
III. MODEL DEVELOPMENT

In this study, two models have been developed to simulate traffic in rural highways where the first model is developed based on the algorithms mentioned in Section 2 (CF, LC, and GA). The second model relies on the S-Paramics software package which has been calibrated with current field data.

A. SIMRIH model

SIMRIH (SImulation Model for the Rural Iraqi Highway) is a model developed based on a model developed by Al-Jameel (2012) on the British roads. The code was rewritten in Compaq Visual FORTRAN (Version 6.6). In brief, the simulation model relies mainly on the control of vehicle traffic management on the three sub-models (i.e. CF, LC, and GA). For the CF sub-model, the model developed by Al-Jameel (2014) was adopted with some modifications to become is proportional to the Iraqi reality (right hand driving system). As for the sub-model of LC, a hybrid model was developed based on some assumptions from previous studies in addition to the assumptions derived from the actual data.

The GA model is responsible for changing the lane within the limits of safety. It is based on what Al-Jameel (2012) developed with several corrections (calibration and validation, see Equation 2 and 3) with field data in order to achieve the best match between the field data and simulation model results, and Figure 5 shows a flowchart of the general structure of the simulation model. For more information on developing the model (SIMRIH), see Al-Jameel and Kadhim (2017).



LDgmin= β1[(SPL2/MDCLvt)–(SPLCv2/MDCLCv)] + β2(Rtime) SPLCV) (2)

LGgmin = β3[(SPLCv2 / MDCLCv) – (SPF2 / MDCF)] + β4(Rtime) SPF (3)

Where; SPF is the speed (m/sec) of following vehicle.

SPL is the speed (m/sec) of leader vehicle.

SPLCv is the speed (m/sec) of lane change vehicle.

β1, β2, β3, and β4 are parameters of calibration.

MDCF is the maximum deceleration (m/sec2) for the following vehicle .

MDCLCv is the maximum deceleration (m/sec2) for the lane changing vehicle.

MDCLvt is the maximum deceleration (m/sec2) for the leading vehicle in the target lane, and Rtime is the reaction time (sec).

In addition to the basic sub-model, there are several parameters and assumptions involved in building the simulation model:

Time headway distribution where it is based on Equation 3.

Lane utilization or the distribution of vehicles available lanes, where the reliance on the equations mentioned in Table 3, which were derived from field data.

Scan time (Δt) is equal to 0.5sec, according to Yousif (1993). The first 600sec (i.e. warm-up time) of running the simulation model and the last 600sec (i.e. warm-off

time) before the end of the modeling are neglected from the calculations. It also leaves a warm-up distance of 1000m and a cool-off distance of 1000m, where the calculations are neglected in these distances to avoid errors in running the model.

B. S-Paramics model

S-Paramics is a micro-simulation package developed in the UK and developed back to the 1990s. It is the software that has the ability to represent the individual and inter-vehicular traffic interactions and has multiple advantages in the design and analysis of road networks at a microscopic level.

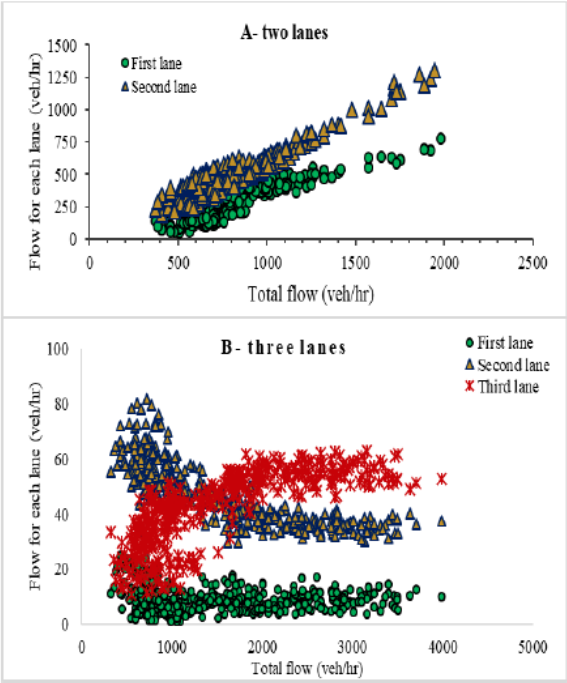


Fig. 4. Distribution of vehicles on each lane in: A-Two lanes, and B-Three lanes.

S-Paramics consists of nodes, links, and zones. Each node has different characteristics, for example, sight distance. The links include the characteristics of the geometric design and the direction of motion (e.g. speed, number of lanes, the width of the lane, grade, and direction of motion, and other characteristics). The zone contains characteristics of vehicle generation and quantity, i.e. the characteristics of the traffic flow and the network supply of vehicles. These characteristics give S-Paramics the capability to design different geometric sections of the road.

Therefore, the geometric design of a road section consists of two or three lanes in each direction, Lane width is 3.65m and the length of the section is equal to 5km. Some of the hypotheses listed below were adopted:

Two types of vehicles: cars and HGVs were used to suit the development of SIMRIH.

The first 30min and the last 30min of the runtime of the model were considered the warm-up time and cool off-time.

Neglect of the calculations at the beginning of the section for the distance of warm-up by 1000m and at the end of the section for the cool-off distance also 1000m.

The total time to run the model is 3hours.

The scanning time (Δt) is 0.5seconds, according to Alterawi (2014).

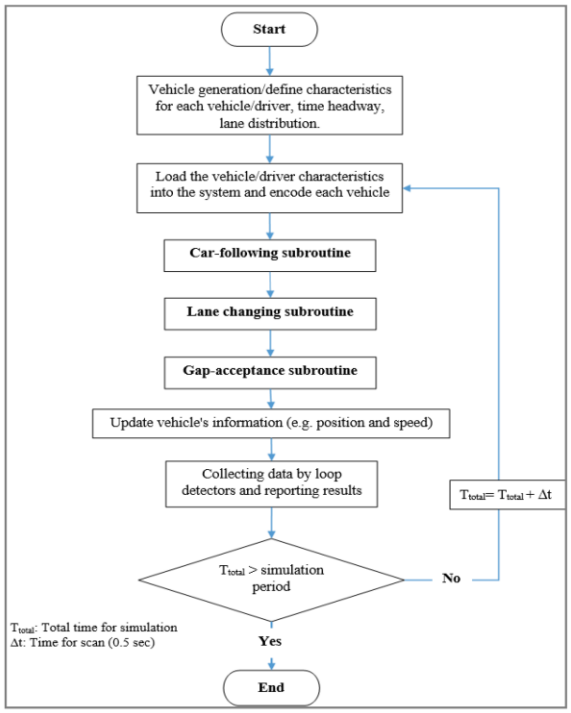


Fig. 5. General flowchart for model development.

IV. CALIBRATION OF THE DEVELOPED MODELS

After completion of model development, it became necessary to perform the calibration process through a set of data. Consequently, after completing the calibration, the verification phase begins and it is mostly performed by another set of data. Calibration is a process in which model variables and parameters are evaluated and modified to achieve the best possible performance of the model (Ciuffo et al., 2012). Validation is an additional process that is done through the use of another data set to ensure that the model is capable of representing the reality of traffic (Ni et al., 2004). Using statistical tests, it is ascertained that the results of the model correspond to the field data as in Equations 4 and 5.

$$\mathbf{RMSEP} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\frac{(o_i - m_i)^2}{o_i}} \quad (4)$$

$$\mathbf{GEH} = \sqrt{\frac{2(m-o)^2}{m+o}} \quad (5)$$

The value of RMSEP is acceptable when it is less than or equal 15, and if GEH value is less than to 5, it is

satisfactory (as mentioned by Alterawi (2014)).
Where; n is the number of time intervals.

o_i is the observed data at time interval i ,and

m_i is the modeled data at time interval i.

Table 6 describes the dataset applied in the calibration and validation process of the model.

Table 6 Dataset for the process of calibration.

Site No.	Recording time (two direction)	Date of data collection	Purpose
2	6hr and 30min (1:30 PM to 4:40 PM)	17-10-2016	Calibraition (LC)
2	8hr (1:00 PM to 5:00 PM)	13-02-2017	Calibraition (Flow)
4	8hr and 30 min (10:20 AM to 2:30 PM)	26-01-2017	Calibraition (Flow)
5	3hr (03:00 PM to 6:00 PM) (Najaf to Karbala)	22-06-2017	Calibraition (LC)

A. Calibration of SIMRIH

For SIMRIH, the calibration process was done by using traffic flow, and the lane change model was calibrated by changing GA parameters ((i.e.β1,β2,β3 and β4) (see Equation 2 and 3). Figure 6 shows the results of the simulation model and its compatibility with the field data and Table 7 confirms that the results of the modeling are consistent with the real data by statistical tests.

Table 7 Calibration statistics for the simulation model (whole section).

Section	Statistical test	
	RMSEP% <15%*	GEH <5*
Three lanes	1.11	0.89
Two lanes	1.55	1.30

*acceptable

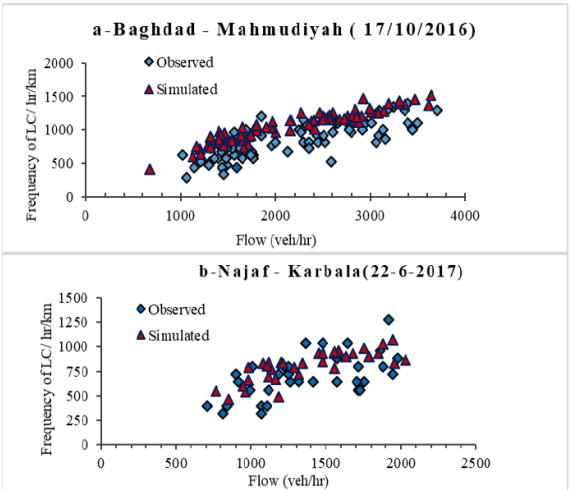


Fig. 6. Comparison of FLC of simulation model results with the field data, a-Site No.2 (three lanes), and b-Site No.5 (two lanes).

Where the traffic flow was used for the whole section. There are determinants such as time headway and buffer space (see Figure 1) to be adjusted until the traffic flow of the field data coincides with the results of the model (note that the results of the model are collected from the section by the virtual loop detectors installed in it) and Figure 7 shows the comparison between the results of the field data (flow) and the modeling results of SIMRIH model, where the best value for the buffer distance is 1.7m.

B. Calibration of S-Paramics

For the purpose of calibration, there are several parameters in the S-Paramics that can be changed to achieve the best match between the simulation results and the field data, of these parameters such as mean headway, minimum gap, and others. This process is performed using arbitrary values within logical limits and close to reality, and the process of changing and modifying parameters within a structured context and not randomly. Figure 7 shows a comparison between simulation results and field data for two lanes and three lanes. This is the result of several times of run and each run changes the values of the parameters to reach the best matching values. Table 8 also shows good acceptance values for some statistical tests.

As a note, the calibration process was carried out on seven seeds to achieve multiple cases of the random number which are close to the traffic reality, i.e. the heterogeneity that occurs in the traffic flow over a certain period of time (WisDOT's, 2014).

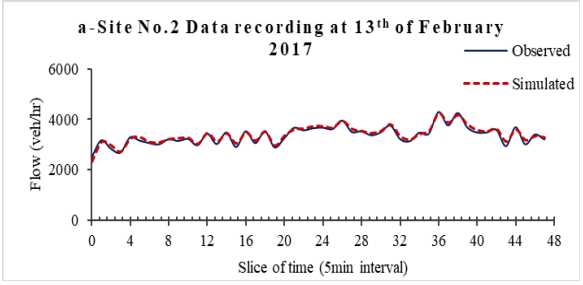
Table 8 Calibration statistics for S-Paramics.

Section	Statistical test	
	RMSEP%<15%*	GEH<5*
Two-lanes (site No.5)	1.24	1.04
Three-lanes (site No.2)	2.35	1.69

*acceptable

V. COMPARISON BETWEEN SIMRIH AND S-PARAMICS

Figure 8 shows a comparison between results of SIMRIH (i.e. the model developed in the current study) and S-Paramics results. It is clear that the results of the models are acceptable and good, but the results of the SIMRIH model are more consistent with the field data and Table 9 proves this by some statistical tests.



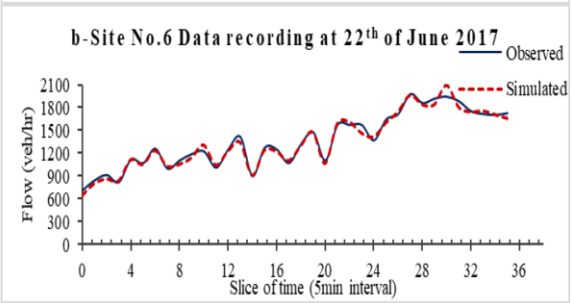


Fig. 7. Calibration process of S-Paramics model: a-three lanes, and b-two lanes.

Table 9 Statistical tests for comparison.

Model	Statistical test	
	RMSEP%	GEH
SIMRIH	1.08	0.84
S- Paramics	1.43	1.06

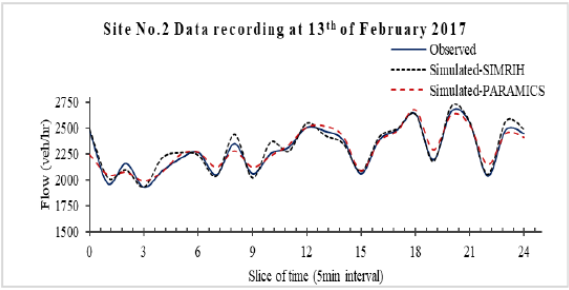


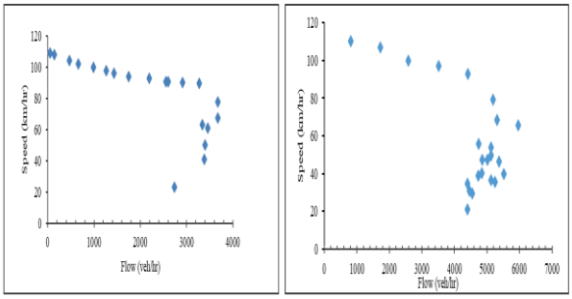
Fig. 8. Comparison between the results of SIMRIH and S-Paramics.

VI. APPLICATIONS TO EVALUATE TRAFFIC CHARACTERISTICS

The characteristics of the road (i.e. speed (V), flow (Q) and density (K)) can be calculated from the developed model either depending on the loop detector that is installed by virtual on sections of the road or depending on Equation 6 to measure the density properly, because it is often not possible to measure the density directly from the loop detector accurately, so it will rely on Greenshield relationship. Figure 9 shows the results of the simulated model of Greenshield relationships.

$$Q=K*V \quad (6)$$

Where; Q is flow of traffic (veh/hr), K is the density (veh/km), and V is the speed (km/hr).



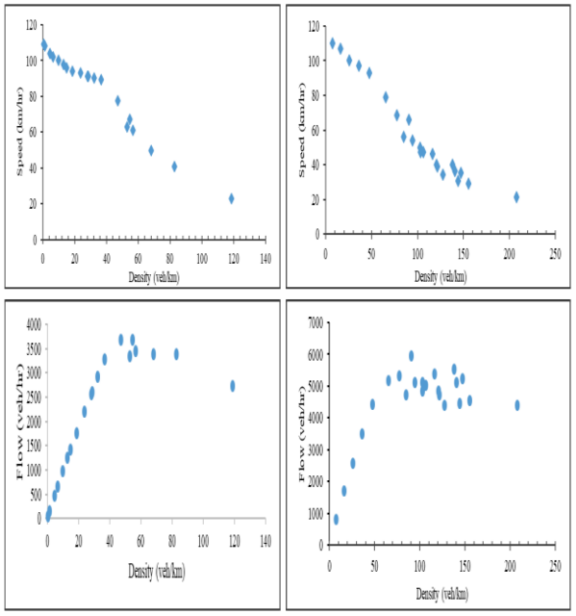


Fig. 9. Speed (V), flow (Q) and density (K) relationships.

CONCLUSIONS

The main conclusions come up with this study are:
Through field data, data analysis showed that vehicle distribution was higher in the left lane (i.e. the fastest lane) than in the right lane (i.e. the slowest lane).

The extracted equations from field data such as lane utilization and headway could be used as a corner stone for developing traffic simulation model.

Each of the two models that were developed and calibrated with the field data proved to be effective in representing the reality well. SIMRIH is better than S-Paramics in the representation of reality because SIMRIH has been built from sub-models that can be calibrated with many parameters.

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