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REAL OBSERVATIONS AND SIMULATION OF FREEWAY MERGING TRAFFIC AT BAGHDAD CITY

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ABSTRACT
Freeway merging sections represent the sources of vehicles entering along freeways and the sources of some of the complicated interactions between merging and the freeway traffic. Therefore such merging sections are considered as an important part of the freeways. This paper abstracts some traffic characteristics at merging locations using video recordings and a speed gun device at Baghdad city. The selected parameters include estimating of lane distribution of the freeway traffic at merging location, types of merging (normal, forced and cooperative) and merging distance. The observed data have been used to develop a simulation model for such locations using PARAMICS micro-simulator. The model has been calibrated and validated based on the available data. The results suggested the ability of the developed model to represents real traffic conditions and therefore the model has been used to examine some traffic management controls. The observed data suggested that the force merging is the dominated type in the case of small available gaps.

INTRODUCTION
Merging areas represent the area at which merging traffic joining the mainline traffic. Such merging is a dynamic and complicated process since it depends on the availability of lead and lag gaps in the destination lane (Chu, et al. 2014). Drivers usually start merging when there are sufficient to enable safe merging (Al-Obaedi and Yousif, 2011). Figure 1 illustrates the lead and lag gaps.

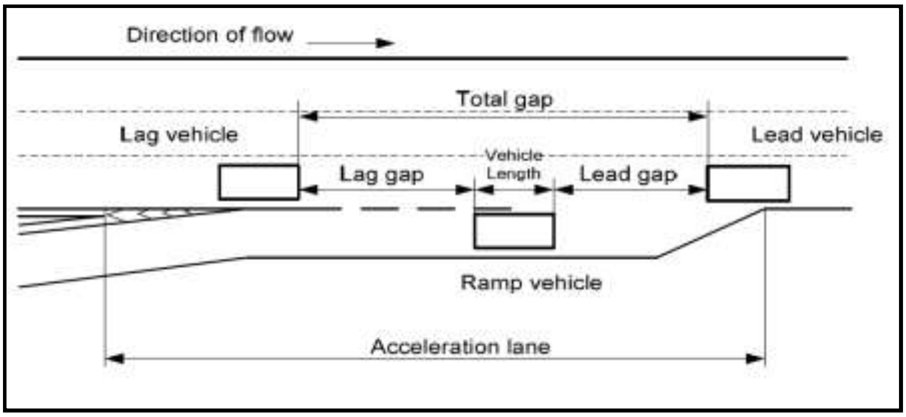


Figure (1) lag, lead and total gaps

Based on gap acceptance behavior, merging divided into free, cooperative, yielding and forced merging. Free (normal) merging is a case where the there is a relatively sufficient gap to merge without affecting mainline traffic (Al-Obaedi, 2011). Cooperative merging is a case where there are no sufficient lag gap to merge and drivers in the freeway shoulder lane may cooperate by applying deceleration (slowdown their speeds) to help merging traffic by increasing the lag gaps (Mosebach, et al., 2016). Hidas, (2005) reported that The tendency or desire of the vehicle on the mainline to decelerate depends on several factors, such as, including the degree of aggression of the driver, as well as the experience of the driver and the identical state of the driver (being in a hurry, disconcerted about other things, etc) and down steam condition. Yielding merging is a case where freeway traffic at the inside lane shift to other adjacent mainline lanes to increase the lag gaps. Forced merging is a case where there is no enough gap to merge and no cooperative or yielding behavior. Merging traffic may accept lower gaps and forced mainline traffic to slow down after starting the merging process.

Traffic simulation is used to emulate traffic movements at the selected freeway merging sections because the ability of simulation technique to evaluate traffic status, suggest and examine the solutions without affecting real movements (Chen, et al., 2016).

Many microscopic traffic simulation models were developed. Most popular used models like AIMSUM, CORSIM, VISSIM, PARAMICS. PARAMICS and VISSIM simulator models are the most applicable softwares over the world (Jones et al., 2004). Such microscopic models usually consists of several sub models named as car following, lane changing and gap acceptance models (Abdelwahab, 2017).

Little work has been conducted for modeling of traffic situations in the Country (Iraq). In this study, PARAMICS microsimulation has been used to simulate traffic conditions for selected sites at Baghdad city. The development of adequate model for such merging areas will provide the ability to suggest solution before being applied in real sites.

METHODOLOGY
This paper uses real traffic data taken merging sections on the Mohamad Al-Qassim freeway at Baghdad city. Video recordings have been used to collect the data as there were no traffic detectors on the freeway. In addition, the video recordings provide the ability to understand drivers' behavior and collecting some parameters which cannot be obtained from detectors. The selected parameters represents the lane distribution, merging location and gap selection behavior.

The obtained data have been used in developing, calibrating and validating a simulation model for merging area using PARAMICS micro-simulator. The reason behind the using of PARAMICS is its ability to simulate a complicated locations (such as merging locations) as to one of the most used packages over the word (Chen, et al., 2016). Once the model obtained satisfying results with the real data, the model will be used to test different scenarios to enhance traffic conditions at merging area.

RESULTS OF DATA ANALYSES
Lane Utilization At A Merge Segment.
Lane distribution (utilization) represents how the total highway traffic are distributed among the available highway's lanes. It is one of the important factors in testing the validity of traffic micro-simulation models since the way of distribution have a great influence on the highway's capacity.

Lane utilization for merge section has been examined for two locations. The first one is the section near to the University of Technology University and the second location is the section near to the Al-Shaab stadium. Figure 2 shows snap shots for the video recordings for the two sites. For both sections, the lane utilization factors were obtained just upstream the merge location.

For the first location, Figure 3 shows the flow distribution for the three lanes for flow ranges of 2500 to 6000 veh/hr. The figure suggests that the lane usage for lane 1 is mostly less than other lanes (lanes 2 and 3). When the total flow (QT) rises to reach the capacity (about 6000 veh/hr), the traffic seems to have equal distribution for all lanes. It is interesting to highlight that there is only a slight increase in flow rate that using the inside lane (lane 1) for flow rates up to 4500 veh/hr. This is due to a fact that drivers avoid using this lane to reduce the interaction with the merging traffic coming from the on ramp.

For the second site (Near Al-Shaab stadium), Figure (4) shows traffic distribution for each lane over the freeway for total volume (QT) of 2500 to 4300. The figure suggests similar trend to those results obtained from site 1.

(a) (b)

Figure (2) Snap shots from video recording for sections (a) near to the University of Technology, and (b) near to the Al-Shaab stadium.

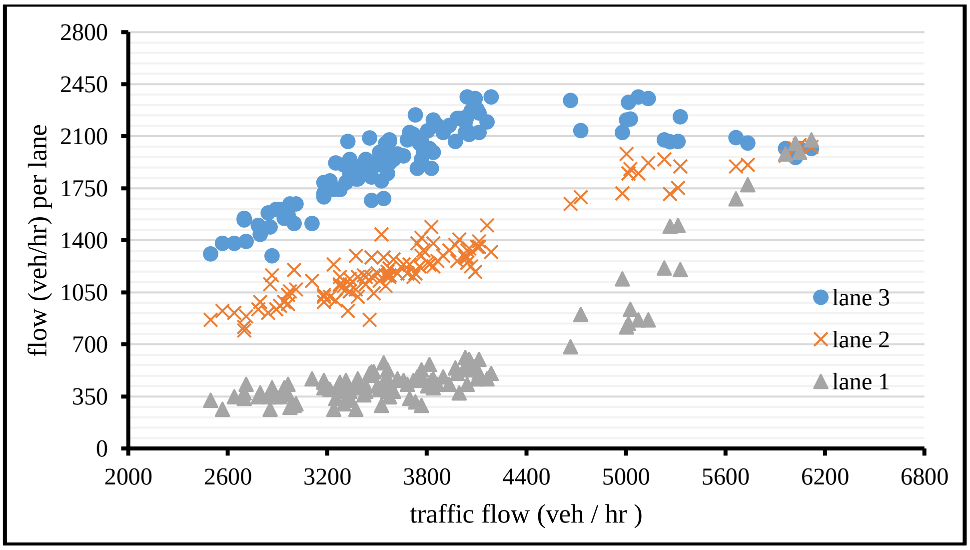


Figure (3). Traffic flow distribution for the upstream merge section for site 1

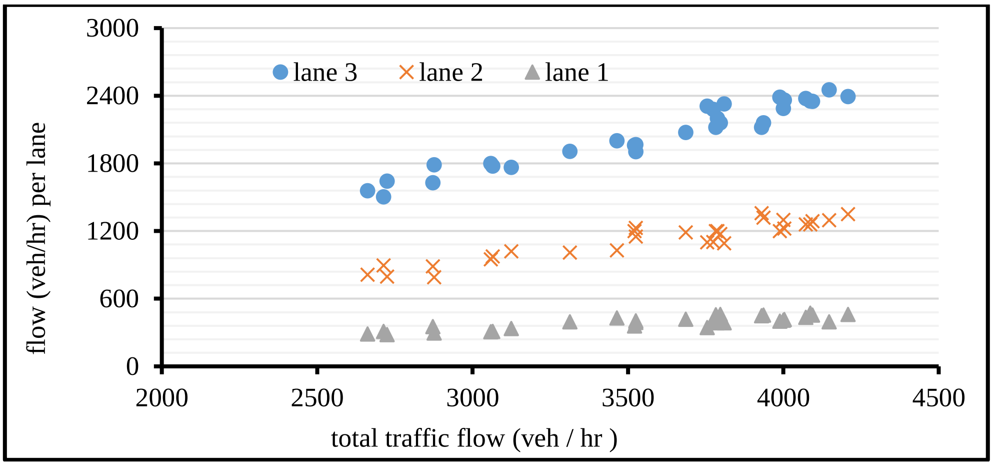


Figure (4) Traffic flow distribution for the upstream merge section for site 2

Merging Position

Merging position is defined as the location with respect to the staring of merging acceleration lane that a vehicle push its self on a freeway. The distance required for merging was measured from the nose to the position where the front offside wheel of the merging vehicle encroaches in to the new lane.

In this study, video recording data taken from MBQ expressway with flow rates of 2400 to 3600 (veh/hr) are used to investigate this parameter. Lightings columns which are installed near the acceleration lane (with a separation distance of 18m) are used as a bench marks to enable the analyses from recordings. Two sites have been used to estimate this microscopic parameter. The first one (site 1) is near to the University of Technology and the second (site 2) is near to the Al-Tayaran sequare. Figure (5) shows the merging position for the two sites and suggested that a few percent of drivers merge within the first 50m (15% for site 1 and 28% for site 2). The figure also shows that about 80% of the drivers merge with the first 100m from the starting of the acceleration lane.

The results obtained here is in contrast with those results obtained by Zhang (2003), Al-Obaedi (2011), based on data from the UK, as they found that more than 80% of of drivers merge at the first 50 m. This is might because of the behavior of the freeway drivers who cannot cooperate with the merging traffic because the speed difference between on ramp vehicle and motorway vehicles and that increase the difficulties of merging. Such behavior makes merging drivers continued their moving in the acceleration lane to evaluate the available gaps and that increase the merging distance. However, low percentage of vehicles made full use of the acceleration lane.

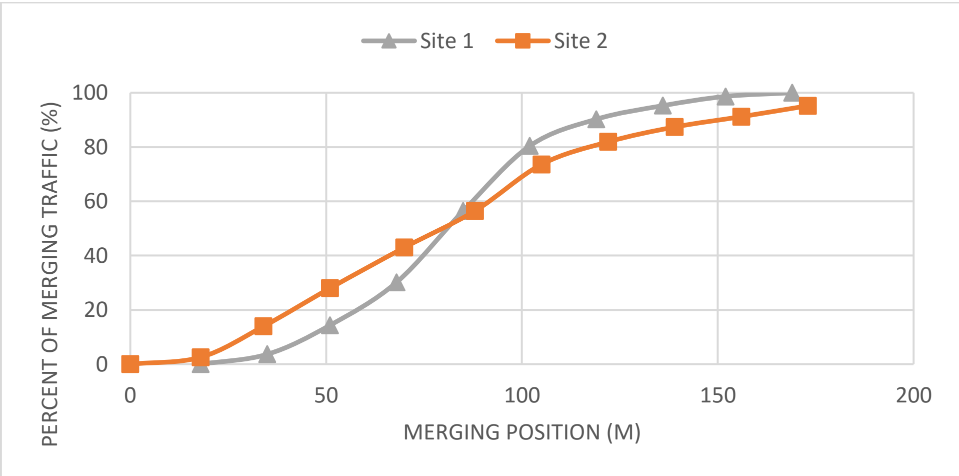


Figure (5) Percentages of merging traffic with respect to the merging distance.

Cooperative And Yielding Behavior Of Mainline Traffic

Cooperative behavior occurs when a lag driver on the mainline decelerating in order to enlarge the lag gap and enable the vehicle on ramp to make safely merge. Yielding behavior occurs if the lag driver change lane to allow the merging vehicle to complete merging process (Al-Obaedi, 2011).

Depending on the field observation from one site, the yielding behavior was examined using 131 cases of merging and the results suggest that about 43% of drivers in lane 1 make yielding behavior by shifting from lane 1 to other lanes when approaching the merge section.

The cooperative behavior is difficult to estimate from video recordings as it needs trajectory speed data for both merging and lagging cars. Visual inspection of the data for the remaining cases of merging cases do not related to yielding behavior suggested that about 9% of lag drivers apply cooperative behavior by applying decelerating rate.

It should be noted here that only the cases where there is a need for yielding or cooperative behavior were considered (i.e. free merging cases are not included)

Gap Selection Behavior Of Merging Traffic

When drivers want to merge into the freeway, they are seeking on sufficient gaps to merge (Zheng 2003). The gap is usually composite of combination of lead and lag gaps as presented in Figure (1). Both lead and lag gaps should be accepted in order to starting the merging process. If a merging driver did not find enough gaps, he/she will wait another gaps to merge.

The gap selection behavior means what is the a driver may select to merge. The first gap selection means a driver accept to merge between the first lead and lag vehicle in a mainline freeway (i.e. accepting the first available gap). The next gap selection means that a driver rejected the first gap and accept the next coming gap. This process also depending on the behavior of the drivers in the mainline (first lane) as such drivers may provide yielding (shifting to other lane) or cooperative (decelerating and staying in a same lane) behavior to allow the merging vehicle to complete merging process.

In order to highlights the gap selection behavior, more than 1100 merging vehicles were noted from one merging site. The results show that 53% of the drivers select the first available gap and 47% select the next gaps. This is conflicts with the data observed by Al-Obaedi (2011) based on data for UK freeways when he reported that the majority of drivers accept the first gap.

SIMULATION MODELLING

Building the model

A simulation model has been developed using PARAMICS micro-simulator (see Figure (6) that shows a snap shot for the developed model). The model network is created with a geometric design for the real site where the real data have been obtained. The model parameters has been calibrated based on real set of data and then validated based on another set of data.

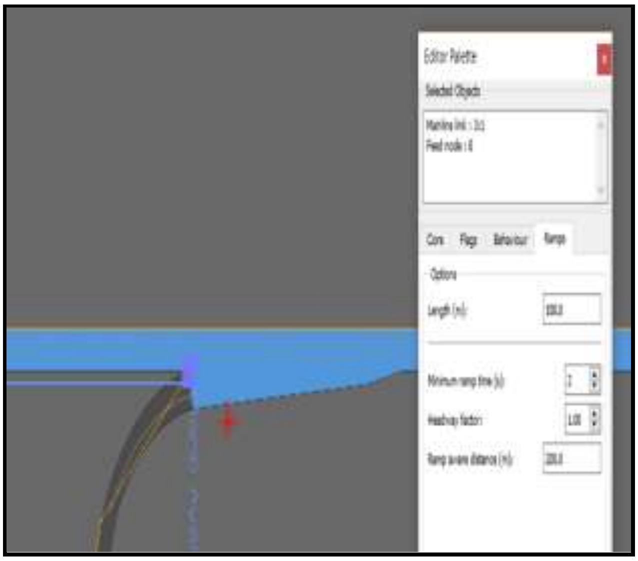


Figure (6) Snap shot for the developed merging model

Calibration and validation of the model

The accuracy of simulation module depended on how the simulation mode result can represent the real traffic data (Barceló and Casas, 2002). In fact, no model can exactly replicate real movements. Therefore, a good simulation model is model that could reasonability replicate real movements with acceptable errors. Calibration and the validation provide the simulation model the level of confidence to replicate real movements.

In order to compare the real and simulated data, traffic loop detectors have been assigned to the simulation model at locations similar to that where the data collection from real site were obtained. Traffic volumes and speeds were collected using these loop detectors. These locations are shown in Figure (7).

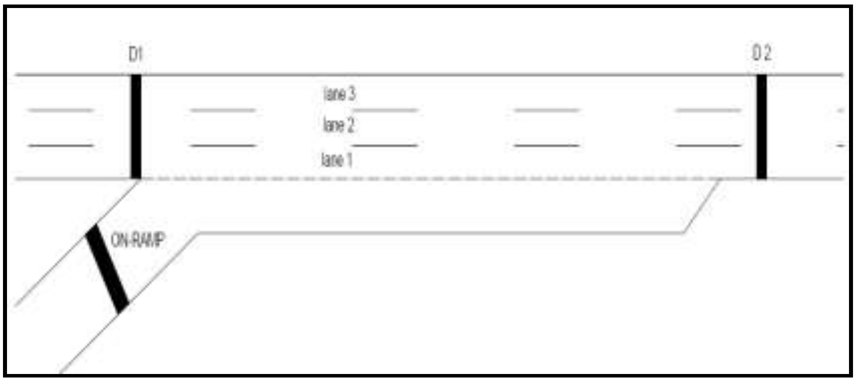
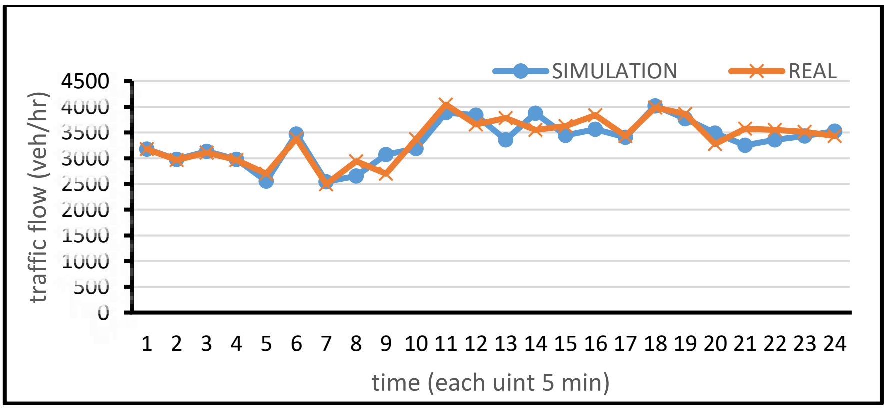
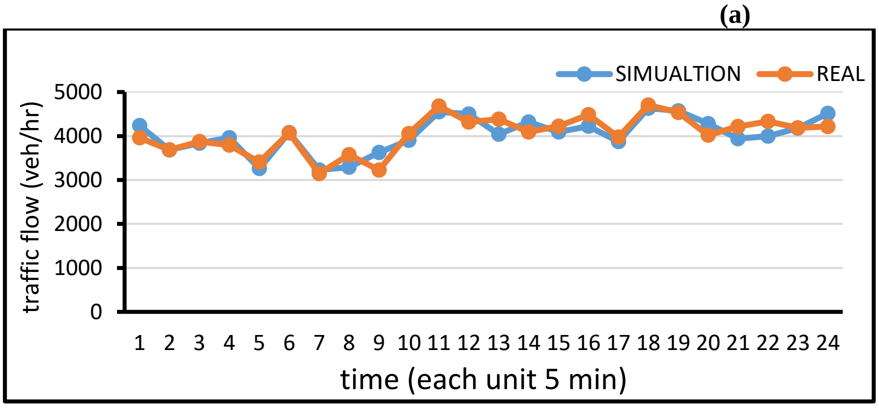


Figure (7) loop detector location for simulator network

Figure (8) compares the actual and simulated total flow rates at upstream and downstream the merging area. Figure (9) compares the actual and simulation flow rates for merging traffic. Both of these two figures shows good agreements. The comparison of flow rates and volumes has also been considered for calibration process (see Figure (10) that compares the flow rates at lane 2).



(a)



(b)

Figure (8) Actual and simulated flow rates (a) upstream and (b) downstream

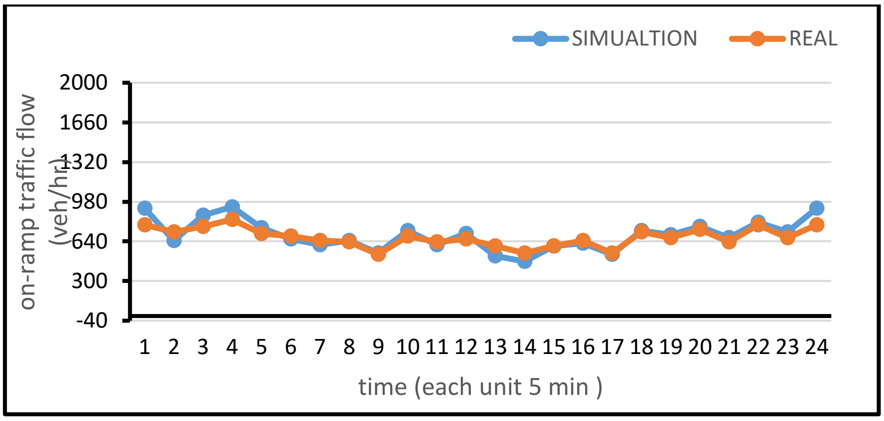


Figure (9) Actual and simulated flow rates of merging traffic

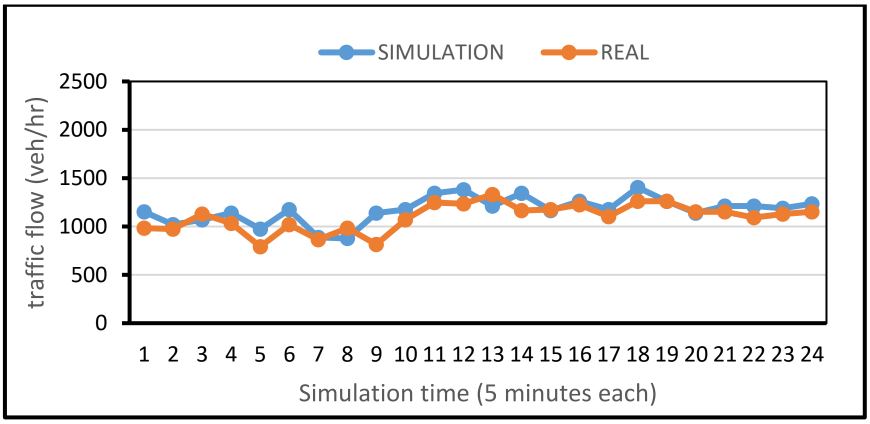


Figure (10) Actual and simulated flow rates at lane 2

In order to check whether the differences between actual data and simulated results can be regarded as insignificant, statistical test have been used. Geoffrey E. Havers **(**GEH) Statistic (Equation 1) is usually used to compare two sets of traffic volumes (Chitturi, et. al, 2014).

$$GEH = \sqrt{\frac{2(S-O)^2}{(S+O)}} \qquad (1)$$

Where (S) is the simulation data and (O) is the observed data

According to Oketch & Carrick (2005), GEH statistic value of less than 5 suggests good fitness between simulation and observed data is ranged below. The values of GEH between 5 and 10 suggests more iterations are required while higher values suggest poor fitness.

The results of statistical comparison of traffic volumes based on GEH statistic are shown in Table (1). The table compares the actual and simulated data for locations upstream (D1) and downstream (D2) the merge section. The comparison on location D1 has been conducted on the lane bases. The table suggests good agreements since all GEH values are less than 5 that suggests insignificant differences.

To compare between observed and simulated speeds, root mean square error (RMSE) has been used (see Equation 2) as suggested by Choudhury and Ben-Akiva (2103). The results of the tests at location upstream of the merge area (D1) are shown in Table (2) that suggests good agreements as the RMSE of a maximum of 4.2km/hr. It should be noted here that the actual speeds were measured at upstream of the merging area (location D1 in Figure 7) using speeds gun device.

$$RMSE = \sqrt{\frac{1}{n}\ \sum_{i=1}^{n}(Oi - Si)^2} \qquad (2)$$

Table 1. GEH Statistical tests for traffic volumes at locations D1 and D2

Location	Total D1	Lane 1 D1	Lane 2 D1	Lane 3 D1	Total D2	On-ramp
GEH	2.70	3.65	3.03	3.72	2.78	1.83

Table 2. RMSE Statistical tests for speeds at location D1

Lane No.	Lane 1	Lane 2	Lane 3
RMSE	3.914	3.781	4.219

Comparison with merging distance

The above section suggested that the model could represents real movements with an acceptable errors in terms of speeds and flow rates. This section compares one of the most complicated parameter in merging sections. This is represented by merging distance which is the distance from starting the merging section (beginning of the acceleration lane) until merging position. Figure (11) compares the actual and simulated merging distance and suggests good agreement.

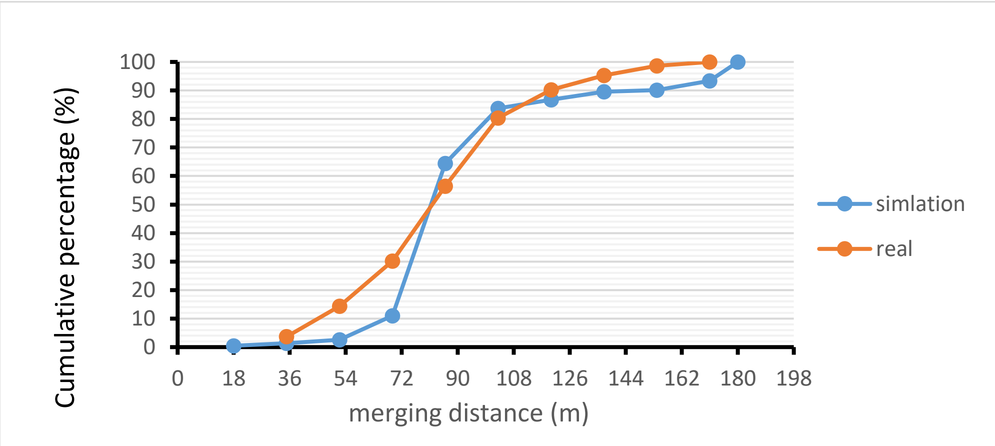


Figure (11) Actual and simulated merging distance

CONCLUSION

This paper abstracted some traffic characteristics at merging locations based on video recordings and a speed gun device at Baghdad city. The selected parameters include estimating lane distribution of the freeway traffic at merging location, types of merging (normal, forced and cooperative) and merging distance. Evidence has obtained from the data that drivers do not prefer to use the inside freeway lane (lane 1) when approaching merging area to avoid the interaction with the merging traffic coming from the on ramp. The merging position results suggested that about 80% of the drivers merge with the first 100m from the starting of the acceleration lane. The observed data suggested that the force merging is the dominated type in the case of small available gaps.

The observed data have been used to develop a simulation model for such locations using PARAMICS micro-simulator. The model has been calibrated and validated based on the available data. The results suggested the ability of the developed model to represents real traffic conditions and therefore the model will be used later to examine some traffic management controls.

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