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Traffic Control in oversaturated Arterials on the Basis of Metering Strategies and Improved Queue Estimation Method

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ABSTRACT

In case of oversaturated arterials, the issue of traffic control, Queue management and traffic management are severely interrelated with each other. A great idea for oversaturated arterials in the paths with driving signs developed based on the concepts of Queue management and using the time in case of green light driving. The present paper is a case study in which the traffic meteringhas been represented to optimize the adjustments for timing signs in oversaturated arterials which based on the metering strategy, the waiting time in the Queue has been considered. The model for measuring the time of queuing is represented to measure the waiting time in queue which this is possible with adding the intersections for the vehicles. The functional method in present paper is based on a combination of linear programming and quadratic programming which the method has been simulated via VISSIM microscopic traffic flow simulation and VISSIMCO Minterface. The obtained results through this model have been measured via Trafficware's Synchro Studio program; there are several traffic signal timing optimization software programs available which Synchro is one of those programs. The obtained results show the advancement of functional indices in the modeling method through the method to measure waiting time in the Queue.

KEY WORDS: traffic, oversaturated arterials, metering strategy, Queue estimation

INTRODUCTION

The waiting time in queue is considered as one of the variables in analyzing the function in the controlled arterials involving important data related to estimating and measuring the functions like delay, travel time and the services in the intersections. Furthermore, the waiting time in standing in a queue is a cross-sectional data for most of the optimization strategies in the intersections with lights. Most of the researchers still continue doing the researches in this base by which they have represented a model to measure the waiting time in a Queue. The first model is related to the cross-sectional and intersectional analysis for dense traffic in an arterial with light which this model was represented in 1985, and then it was developed by other researchers [9,10]. Maximization of green time utility, prevention of De facto red, controlling non-steady state conditions, and supplying time-dependent controlling measures are the matters which could increase the feedback volume –consequently the control and time variables could be formulated, and then this matter could be resolved through genetic algorithm. The efforts to control the pre-oversaturated conditions have been accomplished by Gazis[2]; Gazis represented a method "Graph theory" to control two oversaturated intersections closed to each other. These methods involve only limited applications and except from serious limitations regarding the waiting time in a queue, Gal Tezare has represented a control method based on traffic metering with the capability for critical intersection, and then the correlative program through TRANSYT-ZF was designed by him; this method also involved limited applications [3]. In this relation, Rathi has represented a control method which this method was based on the queue spillback prevention of intersecting streets[4]; this method "Rathimehtod" has the application in steady states repeated congestion. The other method was represented by Abu-Lebdeh and Benekohal based on the recommended algorithm which it came true with the conditions[5]; this method was a dynamic method in which the formulation for the important aspects involves dynamic origins related to time dependant traffic control in oversaturated conditions [6,7 and 8]. Several researchers mentioned the importance of the practicable effects for the factors in the operational conditions; this method is a scalable and stable method for dynamic control matters. Skabardonis and Geroliminis [13] measured the length of queue in oversaturated conditions using 30-second flow-occupancy real time data and shock wave theory, they stated that this method could be used in any condition by which the length of queue could be measured which this does not rely on the specific field of parameters and/or short term traffic forecasting by which the limitation may be realized. However, in this method based on the 30-second flow-occupancy data, specifying the length of queue is possible only while the flow in input situation be different from the flow in the output situation in traffic. Furthermore, if the metering method for the length of queue be only a part of time estimation model, in this case there would not be the results for verifying the accuracy of measuring method for the length of queue. In this relation, it is stated that Liu method does not rely on the metering for the value of input in the traffic or the volume

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of it by which the long queues would be also measured [12]. Surely, it has to be stated that a particular attention has to be paid on the measuring of static length of the queue in this method. Furthermore, the shock wave model based on measuring the effects of long intersections is homogenous which this model is useless in the small city's oversaturated arterials. Thereafter, this model was used to measure the length of queue with the advanced routing application in 2007 which it was also advanced in 2010 [11].

Main body

A model based on the speed of shock wave theory for traffic has been represented. This theory was verified for the first for the cohesive flow, and then it was used for the intersections with the light. Through this model, the length of queue with the shock wave would be measured through the cohesive traffic flow theory, however, the complex process has been stated in the shock wave theory regarding the time and local dimensions, these theoretical efficient models involves the limitations in practicable applications which the cross-sectional data are needed in these models. In the other word, the input for the vehicles are assumed in these models in such a way that they may be used in several conditions; these kinds of models are used mainly for expressing the waiting processes in the queue, whereas these models are applicable for space distribution for queuing involving the sufficient time, and also the cross-sectional and intrasectional techniques could be used to measure the time in queuing process. The long queues pass the routing which the metering on these queues is not applicable, so that the application of this technique involves the limitation. Up to now, the researchers have presented the more accurate metering for the length of queue, for this they represented new concepts for the long queues and they changed the old ones. In this model, the length of queue was measured with providing a study for the phase changes for the lights and the application of advanced routing in the old cycles like the current time. This method would get the better results in the oversaturated conditions. Along with the queue, the cycle for the vehicles would be changed with the increase of the crowds, and the green light may be ended before the output of the vehicles, thus the end of queue would not be specified in this case. Liu model could show this fact in which no approach has been represented. In present paper, based on the necessity of metering for the length of queue in the traffic conditions, it has been attempted to consider the effect of timing difference in intersections and the cycle of the vehicles in highways by which a better function would be resulted and the more accurate metering would be resulted. In fact, post the below light gets green, in this case if the upper light gets green as well, then the vehicles would be free to go the below intersection. The number of vehicles which could access to the below intersection could be specified through the metering of the upper green light which this is possible only with the specific 1%. The length of the queue would be possible with regard to the time for reaching the upstream intersections to the downward intersections. Thereafter, the metering about all the vehicles would be helpful to gain the maximum length of the queue. To be assured of the better function, the advanced model for measuring the length of queue rather than the previous models has been assessed in real conditions. The traffic rout is connected between two intersections Motahari-MirzayeShirazi and Motahari-QaemMaqam in Tehran city. Figure 1 shows the location of queue, and figure 2 shows the 30-second flow-occupancy for advanced routing in west arterial to east arterial in Motahari-Qaem Maqaminter section. The cycle starts with the red light in this path at 16:23:51, and at 16:24:41 the green light is turned on. The time for this cycle is 115 seconds and the tome for red and green lights are 50 and 60 seconds, respectively. According to figure 2, it could be observed that the occupied space in the start of red light shows the trend for the queue before reaching to routing involving the fluctuation. At 16:24:03, the queue reaches to routing and the occupied space would be the value equal to 1, and with the start of green light, the start queue would be ended. Output wave would be reached to 16:24:51 post 10 seconds, and the occupied space would be involved of high fluctuations, so that the end of the queue would pass the routing at 16:25:18 and T_E point would be specified as well. The fluctuations observed would be created in the diagram with reaching to the cycle for the vehicles. The end of queue could be specified through the occupied space. The routing of the pints in this model involves the importance in case of changes in traffic. Hence, 3 important time points using 21 vehicle cycle diagrams were observed for the long queues and then these points were used in real conditions, these three points involve reach of the queue time to T_A routing, reach of output shock wave time to $T_c$routing, and the time for passing the last vehicle form T_E routing. To specify T_A and T_c points, the results have been provided as following: 89% of the errors would be less than 5 seconds, and 82% of the errors would be less than 3 seconds, and to specify T_E point, the results are as following: 85% of the errors are less than 10 second, 81% of the errors are less than 5 seconds and 78% of the errors are less than 3 seconds. The present model involved multiple cross-sectional data which these data are used as pre-conditions while performing the model. The parameters used in this model are consisted of :the rate of free energy, the increase and decrease acceleration, the reaction of the first driver to the green light and the difference between the start of two vehicles closed to each other in the queue and the movement of the vehicles in crowded streets, all these parameters are helpful to calculate the length of queue and the time for travel. Meanwhile, two parameters are more effective which the first parameter is the reaction of the first driver to the green light (t_r) and the second parameter is the difference between the movements for the start of two vehicles closed to each other in the queue(t_s).Therefore, it has been attempted to calculate these two parameters using the statistical analyses in such a way that the model be performed through these parameters. Post gaining the parameters from based on three intersections, Motahari-MirzayeShirazi ,Motahari-QaemMaqam and Motahari-Mofateh, the frequency for the data collection about t_r and t_s parameters is reported 70 and 120, respectively. This value for the parameters has been mentioned sufficient which the mean of data could be calculated as following:

$$\overline{t_r}=2.63s$$
$$\overline{t_s}=1.69s$$

The standard deviation of data for t_r and t_s parameters has been obtained 1.73 and 0.71, respectively. In equation 1, X_i is the value for each sample; refer to equation 1 for this.

$$\sigma=\sqrt{\frac{\sum x_i^2-\frac{(\sum x_i)^2}{n}}{n}} \quad \text{Eq1}$$

The variance for the data collection for the favorable parameters has been obtained 3 and 0.51. based on equation 2, X_i is the value for each sample,μ is the mean of the samples, n is the number of the samples and v(x)is the variance of the samples, refer to equation 2 for this.

$$v(x)=\sigma^2=\frac{1}{n}(\sum(x_i-\mu)^2) \quad \text{Eq2}$$

Post calculation of mean and standard deviation for the parameters, the master distribution is controlled, firstly, the data is controlled in normal distribution condition using table 1 which are provided for data t_r and t_s.

Table 1- normal distribution control for t_r and t_s

	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
t_r	2.9-6.36	1.17-8.09	-0.56-9.82
Percent	65%	98%	100%
t_r	0.98-2.4	0.27-3.11	-0.44-3.82
Percent	72%	94%	100%

Figure 3 shows the comparison between the obtained and observed maximum length using Liu model. The blue lines are the observed statistical data in this model and the red lines show the obtained results about this model. The results show that the estimation error for the maximum length of queue in Iran is 16.9 meter using Liumodel,and 75% of the lengths of the queue calculated here involve 10% error rather than the real cases. Figure 4 shows the estimation of maximum value for vehicles in the queue using Liumodel, by which the obtained results give the observations about this parameter. The blue lines are for the observed data from the statistical data and the red lines show the obtained results of this model. The results show the mean for the length of queue equal to 2.5 which 70% of the maximum value for the queue involves 10% error.

Figure 1- advanced detector location in upstream intersection in SCATS

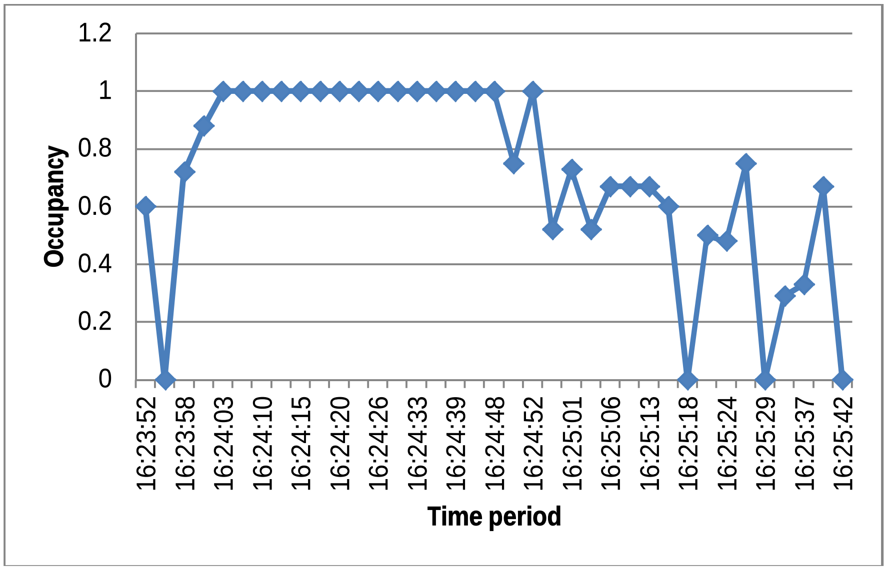

Figure 2- occupancy profile in west-east approach of Motahari-Ghaem Maqam intersection

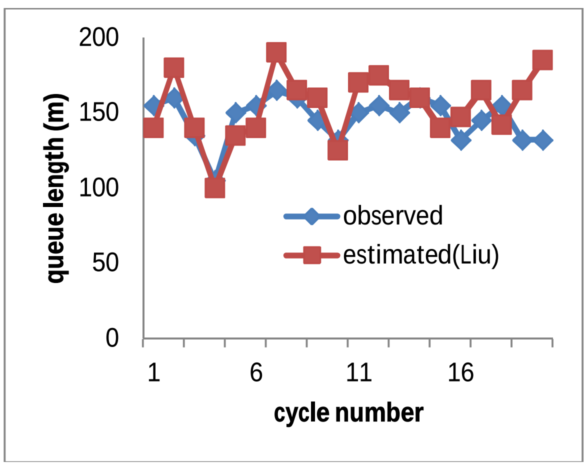

Figure 3- Comparing observed and estimated (Liu) queue length

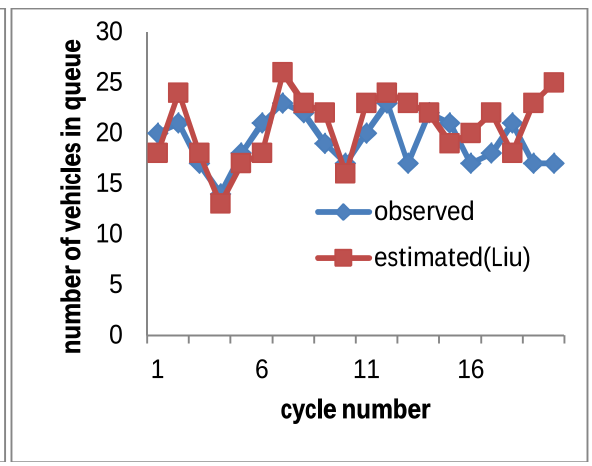

Figure4- Comparing observed and estimated (Liu) number of vehicles in the queue

METHODOLOGY

In the algorithm for resolving the problem about the oversaturatedarterials, the length of queue in any cycle is measured based on the time for using arterials. Queue estimation algorithm has been shown in figure 5. The part with hachure in the algorithm related to developing a model for queue metering has been represented which this part has been added to Liu algorithm. As observes, the algorithm mentioned here receives the cross-sectional parameters, which the data like routing data, the application for the advanced routing, and the data related to the changes of the lights like the start time for the red light and the start and end time for the green light are all involved in this algorithm. Then through the combination of these data this model would be analyzed by which the routing data would be controlled which this is possible only in more than 3 seconds. If such a model does not be found, in this case the short queues would be measured, for instance the end of queue would be reached to the routing location, and through this the length of queue would be specified using cross-sectional and intrasectional flow. Also, the method of present paper is used to specify the length of queue based on time index. Hence, this model could be a practicable and favorable method in the metering models like delay, and time; also this model could be used for oversaturatedarterials, but in several cases based on the cycle for the vehicle in the end of queue, this model would not specify the length of queue by which only wrong results would be gained. Hence, it has been attempted to provide a more accurate estimation about the length of queue at real time which in such oversaturatedconditions, this fact would be practicable with regard to free time in passing the vehicles from intersection in L_i model. On the basis of long queues, if the end of the queue goes beyond the routing location, in this case T_A has to be calculated which T_A is the very time for the routing function; then post the start time of green light, while the outputshock waves reach the routing and their usage is less 100%, in this case T_C would be measured. Controlling the process for the percentage of the routing data, post T_C time the routing could find a time by which at least 3 seconds for the lack of using it in T_E flow would be obtained. Here the time shows that the end of queue has passed the start point of routing by which the outputoversaturated rate in access to queue changes which this is possible only while a vehicle passes through a queue. If T_E be estimated pre the start of red light, in this case the maximum length for the queue could be estimated using the approaches for equations 3 and 4.

$$L_q^{Max} - d_1 = \begin{cases} \frac{1}{2}\gamma_a t_1^2 & L_q^{Max} \leq \frac{u_f^2}{2\gamma_a} + d_1 \\ u_f t_1 - \frac{u_f^2}{2\gamma_a} & \text{otherwise} \end{cases} \qquad \text{Eq 3}$$

Where d_1,t_1,u_f and γ_a are interval between advance detectors to stop line, the last vehicle travel time to pass from advance detector, desired speed of vehicle, and acceleration rate, respectively. Furthermore, maximum queue size in T_D is shown by $n_q(T_D)$ and L_q^{max} is calculated by Eq 4:

$$L_q^{max} = n_q(T_D)h \qquad \text{Eq 4}$$

$$T_E = T_g + t_r + t_s(n_q(T_D) - 1) + t_1 \qquad \text{Eq 5}$$

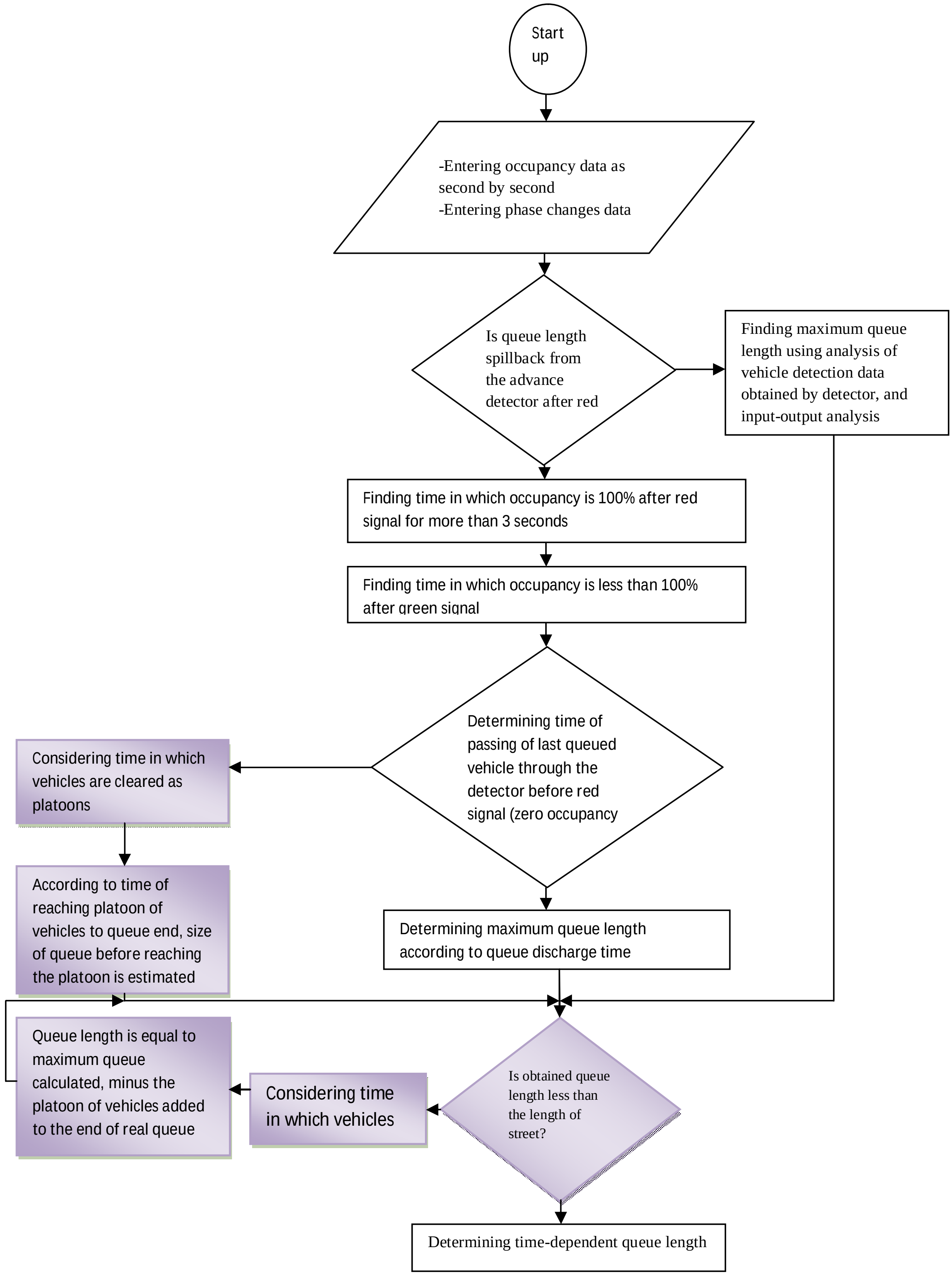

Figure 5- improved queue length estimation algorithm

The values for the cross-sectional parameters in measuring the length of queue form the resources like the transportation engineers union or the statistical information have been obtained. The favorable speed u_f is equal to 65 km/g. the acceleration is g_a is equal to 1.1 m/s^2 and the decreased acceleration is g_a is equal to 3 m/s^2, and the

value for the saturation is 7.5 h meter. Also two parameters for the performance of Tehran 's drivers have been estimated which are the time for the reaction of the first driver t_r and the difference for the start of two vehicles closed to each other t_s, in this case the time for the routing process is 1 minute. To provide a better comparison, firstly Liu model using the statistical data has been performed and the results for the estimation for the length of queue have been compared with the real cases, and then the advanced model in present paper was performed with the statistical data by which the real cases were measured. A formula to resolve the oversaturatedarterials based on the metering strategy with the goal-oriented function has been represented which this problem could be resolved based on the concept for the stability in the length of queue in the arterials which in the upstreamintersections, a oversaturatedarterial has to be controlled by which the length for the downward length would be controlled as well. In such conditions, the goal-oriented function has to be involved of following characteristics:
-maximizing the operational power
-maximizing the productivity for the power to keep the connection
-avoiding from the spread of the queue and the blockage of intersection [14]
Hence, the goal-oriented function is resolved by the mixed integer linear programming where optimal differences are resulted between intersections:

$$Max \sum \omega_i \Delta_i \qquad \text{Eq 6}$$

Where:

Δ_i= offsets between intersections
w_i = weight
Where constraints are confirmed for phase difference and queue length ratios. On the other hand, optimal times for green light are yielded to optimize queue length ratios in each cycle through following objective function which is solved by quadratic (non-linear) programming:

$$Minimize = \omega_i \sum (q_i - \overline{q}_i)^2 \qquad \text{Eq 7}$$

Where:
q_i= queue ratio
$\overline{q}_i$= optimal q ratio
w_i= weight
The two goal-oriented functions for this article have been encoded and executed in MATLAB programming software. The model is used for a test arterial network with 3 intersections which is shown in the figure8.

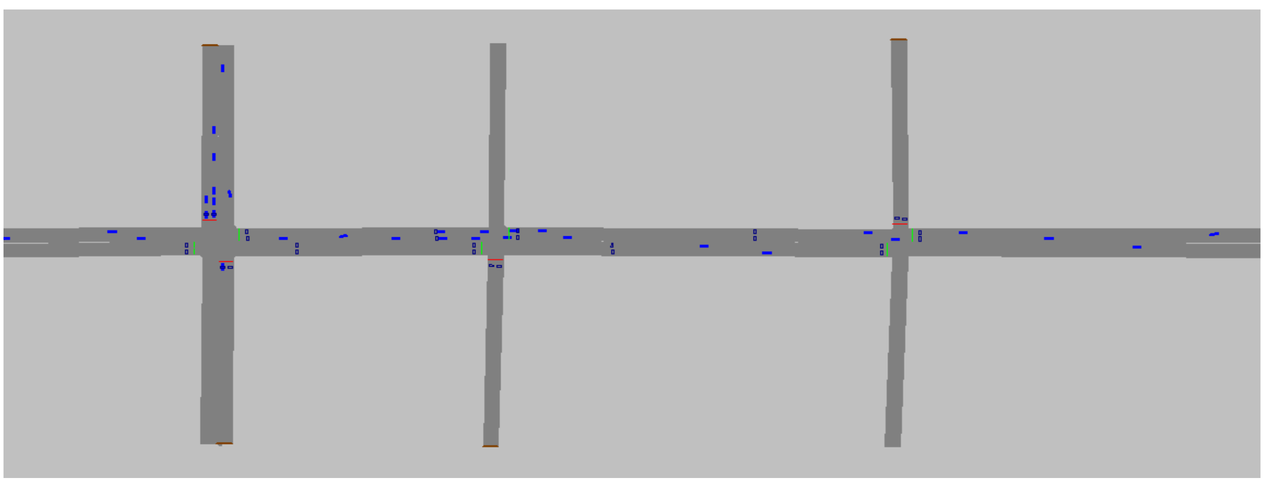

Figure 6- test arterial network drown in VISSIM

DISCUSSION AND RESULTS

In present paper, a model has been represented by which the length of queue could be controlled, so that obtained length for the queue has not to be more than length of street, and this is due to the fact that adding the vehicles in the upstreamintersection in the end of the queue in the downward intersection, the queue may exceed from the length of the street. This is possible exactly while the last vehicle moves and the cycle of the vehicles go to the end of queue-through this the cycle would not be specified form the output queue. In case of the sufficient time for green light exactly while the last vehicle passed through the routing, in this case the maximum length for the queue may exceed the length of the street. In this case, free time for the vehicles would be considered and if the vehicles get free, thus the sufficient time to reach the downward queue would make the metering possible by which the real value for the queue would be obtained. In present paper, post calculating the deviation standard and mean deviation for the parameters, 6 general distributions are controlled. Firstly, data would be controlled using table 1 in normal distribution condition which these are provided for t_r and t_s data. The normal distribution for 68% and 96 % of the data has to be equal to $\mu+-\sigma$and $\mu+-2\sigma$ which the normal distributions using the relative data are used for all the data. Hence, in this case tr and t_s are considered equal to2.6 and 1.7.The model presented in present paper has been implemented with the same hypotheses involving in Liu model. The results about the length of queue have been presented in the model which the comparison with the real cases has been shown in figure 6 and 7. The diagram presented in figure 6 has compared the length of the estimated queue with the model in present paper with the length of it is equal to the length in the real queue. Blue lines are observed as the vector statistics and red lines are the estimated results from the mentioned model. The results show that the mean estimation error for maximum length of queue using the model presented in this condition is 2 meters and 90% of the maximum length for the queue is nearly equal to 10% of error relative in real cases. Figure 7 also depicts maximum size for the queue in terms of vehicle using proposed model beside results about the parameters. Blue lines are the very data related to statistics and red lines are the estimated results proposed in this model. Results show that mean estimation error for maximum length of queue has involved 1.7 vehicles and 80% of the estimated maximum length of the queue involves 10% error. Therefore, mean estimation error for maximum length of the queue was reduced from 16.9 to 12 meters. Along this, the maximum length of queue has reduced from 2.2 to 1.7 vehicles. For this, figure 8 and 9 are provided as well.

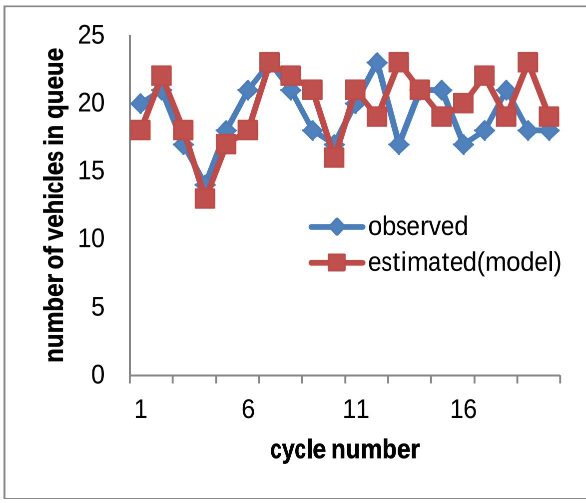

Figure7- Comparing observed and estimated (Improved model) queue length

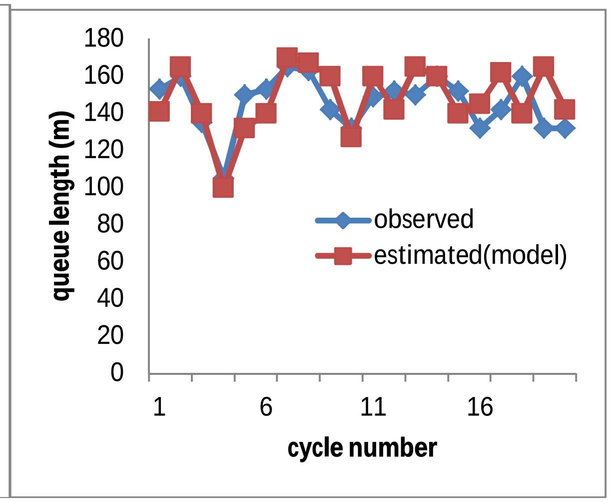

Figure 8- Comparing observed and estimated (Improved model) number of Vehicles in the queue

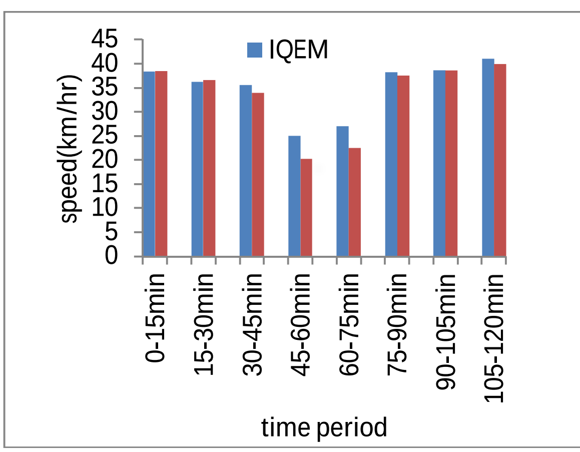

Figure9- Comparing IQEM and Synchro speed

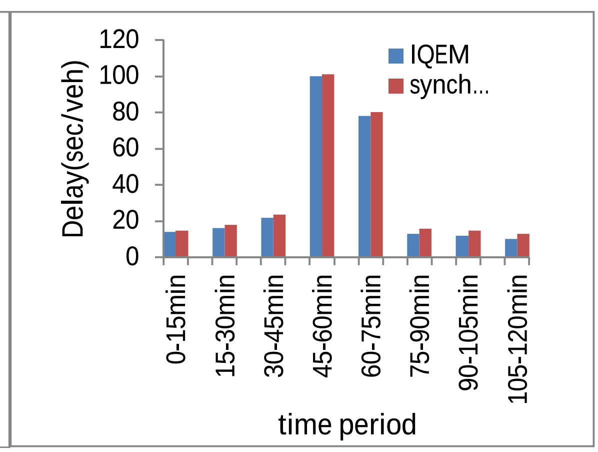

Figure 10- Comparing IQEM and Synchro delay

In present paper, the advanced estimation model for the length of queue has been represented by which the length of queue is estimated regarding the vehicles category adjoining from upstream to down ward intersection queue, thereby the correct values for the length of queue have been represented. To evaluate the function of the model presented in present paper, the model could be used as a programming optimization model in oversaturatedarterialfor the lights- consequently the results have been compared using SYNCHRO simulation software. VISSIM intelligent traffic software and programming via VISSIM-COM have been used to compare the results. The obtained results about the comparison show the relative superiority of the model presented in present paper by which the average speed and delay time have been show in the function of this model as well. The results of the advanced estimation model forqueue shows a better estimation for the length of queue in over oversaturatedarterials in comparisons with previous models.

CONCLUSION

To study the function of IQEM advanced model, the obtained results have been compared using SYNCHRO traffic simulation software. For this, VISSIM simulation tools and programming in VISSIM.COM have been used. The obtained results from the traffic simulation in VISSIM function indices for average speed and delay time have been observed. The comparison about the obtained results show the relative preference in the present model about the average speed and delay time, and this is in such a way that average speed and delay time are equal to 4.5 and 5.6. Comparison about the results with the optimization software, calibration of more parameters for the input data related to the metering of the driver's characteristics and using much faster solution algorithms particularly in case of developing the model for urban network are proposed for the upcoming studies.

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