Investigation of Signalized of Intersection Utilizing Linear on Modeling Blockage Probability from Regressions and MLP and RBF Neural Networks

Ali Kargar,
Department of Civil Engineering, Kangan Branch, Islamic Azad University, Kangan, Iran
Seyed Ali Ziaee
Department of civil Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

Abstract

At signalized intersections, turning vehicles often use the same shared lane together with the through traffic. Since a permitted left-turn movement has to give way to the opposing through movement, it has to wait if necessary and thus impedes the through movement in the same direction. In the real-world, if the left-turn movement is permitted controlled, the through movement at the same approach can be totally blocked by waiting left-turning vehicles during the green time. Thus, the green time for the shared lane cannot be efficiently utilised and the lane capacity under consideration cannot be fully received. In this paper, a mathematical model is presented for an exact calculation of the blockage probability caused by permitted turning vehicles and for the estimation of the capacity of single-shared lanes at signalized intersections. According to the probability and combinatory theory, a mathematically exact model is developed. The proposed model can be applied to shared lanes either with left-turn or with right-turn movement. Respectively, by extending the model, also the capacity for the Right-Turn-On-Right situation can be exactly calculated. Furthermore, in this paper, the model is generalized to turning movements with so-called sneakers within the intersection. The generalized extension provides a more realistic solution for real-world intersections where, in a normal case, there are several places downstream of the stop-line for turning vehicles. The mathematical formulation for the generalization is more complicated. For applications in the practice, monographs are produced for estimating the shared lane capacity under different traffic conditions. In addition, a set of approximation functions are recommended based on the mathematically exact results.

Key words: *MLP neural network, RBF neural network.*

Introduction

Traffic flow management is undoubtedly one of the basic issues of a modern society and governments have to invest heavily on it to improve the performance of the transportation system. Rapid grow of traffic volume, limitation in development and creating fundamentals, environmental dangers due to emissions and unpleasant delays are all problems that need to be planned basically by the authorities to improve the situation [1]. Urban road network consists of roads and intersections. Road network capacity and performance are usually measured in at-grade intersections. Choosing appropriate type of intersection is done by considering performance and safety; therefore, a specific type of intersection is required based on environmental and traffic situations. There are several criteria that indicate performance in traffic science which delay is one of the main criteria. Delay is used in assessment of traffic density, determination of level of service, and assignment of traffic.

Although it is correct assumption that delay is independent to traffic volume in movements without conflict points in signalized intersections, it is different in movements with conflict points. In other words, traffic volume should be considered for movements having conflict points. Generally, delay has three components in signalized intersection [2]:

- Uniform delay: it happens when arrival rate is constant.
- Stochastic delay: it happens when arrival rate is stochastic.
- Delay in saturation situation: it happens when arrival rate is more than exit rate

Delay in signalized intersections can generally be modeled in three ways [3]. The first way assumes traffic volume is lower than arrival capacity and is based on queuing theory. The most famous model using this way is Webster's model. The second way assumes traffic volume is higher than arrival capacity. Hardle's model is the best known one [3]. The third way uses combined models. Their function is much more real. The most popular model in this category is the HCM model [4]. In editing of the following model, for estimation of incremental delay for each line in signalized intersection, is suggested:

$$d = 225x^{2}[(x-1)+\sqrt{(x-1)^{2}+\frac{16x}{Q}}$$

d = incremental delay for each line (sec)
Q = saturation degree (ratio of flow to capacity)
x = capacity (vehicles per hour)

Journey time of vehicles was collected by recording of passing time at arrival and exit point. Finally, in order to calculate the delay time of vehicles crossing the intersection of free travel time was reduced. Travel time was recorded at 60 km/h, 50 km/h and 40 km per hour, respectively, for arterial type I, arterial type II and collector. Then, the mean average delays were calculated for each entrance in 15 minutes intervals.

Comprehensive study of Mashhad's traffic offers a model for estimation of delay in each entrance, in form of a function of traffic volume of each entrance that burdens equal delay to whole traffic volume of intersection. Model 1 in this article, inspired by the model used in the studies has been done in Mashhad. Mathematical form of Model 1 is as follows [5]:

$$d = \frac{(c-g)^{2}}{2c(1-\frac{v}{w*s})} + a(\frac{v}{Q})^{b}$$

d = average delay for each movement (s)
c = signal length (s)
g = green time for each movement (s)
V = traffic volume for each entrance (PCU)
w = width of the roadway for entrance (m)
s = saturation flow rate for 1 meter width (PCU), s = 600
Q = capacity for entrance (PCU)

The purpose of this section is to produce a function estimating delay for intersection (left turnings are permitted in this model). Mathematical form of Model 2 is as follows:

$$d = \frac{(c-g)^{2}}{2c(1-\frac{v}{w*s})} + a(\frac{v}{Q})^{b} + h(\frac{v_{c}}{v})$$

V_c = traffic volume for the same-phase streams
d = average delay for each movement (s)
c = signal length (s)
g = green time for each movement (s)
V = traffic volume for each entrance (PCU)
w = width of the roadway for entrance (m)
s = saturation flow rate for 1 meter width (PCU), s = 600

Q = capacity for entrance (PCU)

In the second model, parameters with and without interference are separately determined in two steps.

Data Collection

To built delay models at signalized intersections, three kinds of data are basically needed: traffic volume data, delays and timing related data. Four signalized intersections were chosen: Ziabari signalized intersection, Sardar Jangal-Biston signalized intersection, Takhti-Shariati signalized intersection, and Mikaeel signalized intersection. The intersections were chosen so that they are firstly wide spread and secondly most used in the city. Traffic volumes at the mentioned intersections were collected separately for each turning movement and each type of vehicle in five-minute intervals for three hours. After that, the equivalent factors shown in Table 1, were applied to gain passenger car equivalent.

Table 1: Passenger Car Units

Type	**Passenger Car**	**Taxi**	**Pickup**	**Motorcycle & Bicycle**	**Mini Bus**	**Bus**		**Truck**
						Normal	**Public**	
Coefficient	1.25	2	1	0.5	2.5	2.5	5	2.5

Neural Network

Artificial neural networks were created by inspiration of brain performance and its parallel performance and have had amazing results so far. Neural network is a non-linear dynamic system that is formed of a large number of processing units (neurons) and connections between them. A neural network structure is illustrated in the figure below. System identification and modeling of complex processes using input and output data has been of interest to researchers in recent years. In theory, in order to modeling a system, it is required the mathematical relationship between input and output data to be clear.It is very difficult or even often impossible to achieve mathematical models. Thus, software use has been grown nowadays due to complexity of such systems. Neural network is one of the three components of computing that many researchers have studied it. The other two components consist of algorithm genetic and fuzzy logic. These components have high sufficiency in control and identification of nonlinear complex systems. Many studies has been carried out on the use of evolutionary methods as effective tools in the system identification [3].

3.1. SIMULATION PROCESS PROBLEMS IN MULTI-LAYER PERCEPTRON (MLP)

Single layer perceptron neural network have limitations. These neural networks are not capable of learning nonlinear register. To overcome to this problem, multi-layer neural perceptron network was proposed that it is to be introduced here. General model of multi-layer perceptron neural network which is also called feed-forward neural network is composed of an input layer and an output layer and one or some hidden layers. Training method of this type of neural networks is called training after error propagation which involves two steps. The first step is called move-forward; the input patterns to the neural network are applied to obtain the neural network output. In the second step that is called the move-back, the output obtained from the neural network is compared with the target output. Then, from difference of these two output and move from output layer to hidden layer and then input layer, weight of neural network output is adjusted so that neural network output is closed to target output. This process continues as long as square error obtained from trained and desired outputs reach to a minimum amount. Main step of simulation in MLP is choice of the output neurons that works in error networks. The reason is simple derivation and direct relationship of function with function itself, before simulation starts. The input data can be divided into two groups:

- Training data: These data among the labeled data are used to train the network. Most of the data from 60% to 70% (randomly or by default) are selected as training data. After the network is trained by the data, the weights have their final values so that the network gives the least error for the training data.

- Test Data: After the network trained by the training data reached minimum error, the remaining data (30% to 40%) which had no role in training, is given to the network as input and network response is compared to the favorable response (their labels). Hence, the network performance can be tested seriously [4].

3.2. SIMULATION PROCESS OF PROBLEMS IN RBF NEURAL NETWORK

One of the most powerful neural networks used in the problems estimation is the radial basis functions (RBF) neural network. This type of perceptron compared to feed-forward neural network has strategic advantages. Unlike the MLP neural networks with continuous layers, RBF network is formed of 3 stable layers. Input layer that is place for infusion of entry signals; middle layer that includes functions; and output layer that makes linear composition of all exits. The Gaussian functions are used in RBF layer in most cases. These functions are known as two parameters of the Gaussian and the variance or the Gaussian spread [4].

4. Data Analysis and Modeling

4.1. MAKING MULTIPLE AND NON-LINEAR REGRESSION MODELS

Multiple and non-linear regression models are used to create regression model for urban signalized intersections. At first, the following models are chosen to estimate the highest fitness index:

MR 1, MR 2, and MR 3 are multiple regression models with input variables mentioned and signalized intersections delay dependent variable. Stepwise (step by step) method was utilized for regression modeling. Correlation coefficients values are seen in Table 2.

NON-R 1, a non-linear regression model with exponential function and NON-R 2 and NON-R 3, non-linear regression models with cubic function, are chosen because of having the highest fitness index and a significant meaningful statistical levels comparing to non-linear functions. Independent variables of v and v_c that has the highest correlation in the related models with the dependent variable of delay is utilized to non-linear regression model.

Table 2: Fitness Index Results of Multiple and Non-Linear Regressions

Model	**MR 1**	**MR 2**	**MR 3**	**NON-R1**	**NON-R2**	**NON-R2**
R^2	0,626	0,735	0,746	0,773	0,886	0.85

Table 3: Processed Equations Results of Multiple and Non-Linear Regressions

Model	**Equation**
MR1	$D = -6.716 + 0.088v + 0.039s - 0.075c + 0.021w$
MR2	$D = 9.74 + 0.063v + 0.017v_c - 3.858Q + 0.056g$
MR3	$D = 3.7 + 0.092v + 0.061v_c - 0.058g - 0.626c + 0.12Q$
NON-R1	$D = 0.247v^{0.792}$
NON-R2	$D = 28.662 - 0.429v_c + 0.002{v_c}^2 - 2.4E^{-6}{v_c}^3$
NON-R3	$D = 8.235 - 0.0429v + 0.001v^2 - 6.02E^{-7}{v_c}^3$

4.2. MAKING MLP AND RBF NEURAL NETWORK MODELS

MLP and RBF neural network models are defined as Model 1, Model 2, and Model 3. Delay as modeling output and other characteristics such as traffic volume, same-phase interrupted traffic volumes in a cycle length, green time for the movement, saturation flow rate, roadway width, arrival road capacity and other affecting traffic and geometrical variables are considered as inputs.

Model 1: includes total incoming traffic volume, signal length, green time for the movement, saturation flow rate, roadway width, capacity as input and delay as output.

Model 2: includes total incoming traffic volume, signal length, green time for the movement, and capacity as input and delay as output.

Model 3: includes total incoming traffic volume, same-phase interrupted traffic volumes, green time for the movement, and capacity as input and delay as output.

Table 4: Results of SSE Calculation in Neural Networks

Model	Training MLP	Testing RBF	Training RBF	Testing RBF
Model 1	0,133	0,097	0,329	0,110
Model 2	0,210	0,061	0,425	0,071
Model 3	0,115	0,065	0,116	0.08

Conclusion

As mentioned before, the data collected in 4 signalized intersections in Rasht, Gilan and all results achieved were related to volume and delay. Artificial neural networks can be used as a suitable method with a sufficient confidence to estimate values of parameters like delay in urban signalized intersections. Although with more input parameters more accurate results are possible to be gained, suitable results can be achieved with proper choice of parameters due to coincidence of the neural network properties if many parameters are not available. Another significant point is that results produced from neural networks have higher accuracy and this can be addressed when doing different studies.

Results of calculated SSE in neural networks compared with non-linear and linear regression analysis showed that neural networks are high accuracy in prediction. Non-linear regression gives better fitness index in comparison with linear regression, because of having one dependent variable with high correlation. From variable with a high correlation of fitness is higher than linear regression.

References

1. Zokayi Ashtiani. and Hedayat and Pouzahedi. H., (1991), "traffic assignment Isfahan and its aspect", Transportation and Traffic Organization of Isfahan.
2. Cesar A. Q. and D. Bullock, (1999), "Measuring Control Delay at Signalized Intersection", Journal of Transportation Engineering, Vol. 125, No. 4, pp. 271-279.
3. Mcshane W. and R. Roess, "Traffic Engineering", Prentice Hall, New Jersey, (2004).
4. Highway Capacity Manual, TRB., Special Report 209, Washing, D.C, (2010).
5. Center of Research and Study of Sharif Technology University, Comprehensive Transportation Study of Mashhad. "Delay Function in Signalized Intersections". (1994).
6. Akcelik, R., "The Highway Capacity Manual Delay Formula for Signalized Intersections", ITE Journal, March 1988.
7. Fu, L. and Bellinga, B. (2000) "Delay variability at signalized intersections", Transportation Research Record, 1710, TRB, pp. 215-221.