TRANSPORT & *LOGISTICS:*
the International Journal

Article history:
Received 31 May 2018
Accepted 19 July 2018
Available online 30 July 2018

ISSN 2406-1069

Article citation info: Faysal I. Rahman, Short term traffic flow prediction by Monte Carlo simulation. Transport & Logistics: the International Journal, 2018; Volume 18, Issue 44, July 2018, ISSN 2406-1069

SHORT TERM TRAFFIC FLOW PREDICTION BY MONTE CARLO SIMULATION

Faysal I. Rahman [1]

[1] *Department of Civil and Environmental Engineering, University of Yamanashi, Kofu, Japan. tel, +8109033431072, e-mail: ovi_faysal@yahoo.com*

Abstract:
Short term traffic prediction and distribution characteristics are importance for traffic assignment, traffic guidance, network design, better traffic operation and management. Now a days, Traffic forecasting along with distribution characterization are major concern for researchers. Based on the statistical analysis of traffic flow, we conduct a comparative study of statistical distribution of traffic flow using Kolmogorov-Smirnov test (KS test). The hypotheses of the fitting test includes seven kind of distributions like as Normal distribution, Log-normal distribution, Logistic distribution, Log-logistic distribution, Gamma distribution, Gumbel distribution and Beta distribution. For short term prediction, Monte Carlo Simulation technique is used. Kolmogorov-Smirnov test establish that traffic flow can be Normal distribution, Log-normal distribution, Logistic distribution and Beta distribution. Traffic flow prediction using Monte Carlo Simulation has 17.07 % Mean Absolute Percentage Error.

Key words:
Traffic flow, distribution characteristic, Monte Carlo Simulation, Traffic operation

INTRODUCTION

Transportation system is highly influenced by various factors such as weather condition, congestion, traffic control system, human behavior, time period and others. The fluctuation of traffic flow reduces the service quality of transportation system and affects the alternative strategies of travelers as well. From objective perspective, the instability of the system can be expressed as the uncertainty of traffic flow. In this paper, we mainly focus on traffic flow distribution properties as well as short term traffic flow prediction using Monte Carlo simulation.

To understand the distribution characteristics of traffic flow, including the features, the forms and the regularities of distribution, is too valuable to be neglected in a series of key

issues such as the allocation of travel time, the traffic guidance, the road network design and so on.

Day by day, traffic conditions of cities are becoming more complex with alarming rate. To overcome this situation, traffic engineers need to take innovation traffic management. All those measures required through study and analysis of traffic trends which are related to various parameters such as travel time, traffic flow, occupancies and accurate real-time information. In this context, short term prediction is applied to overcome traffic operation problems.

1 BRACKGROUND

1.1 Literature review

Most common assumption was that travel time followed a normal distribution. However, different researcher found that travel time distribution is varied with time and location. Harman and Lam (1984) found that travel time was normal distribution [1]. Iida (1997) proved that travel time fit for normal distribution only under heavy traffic [2]. In zhang's study (2003), they found that beta distribution is well acceptable goodness of fit [3]. But none of paper is found to study about traffic flow distribution. In this paper we are going to study traffic flow distribution using Kolmogorov–Smirnov test (K–S test or KS test) for Normal distribution, Log-normal distribution, Logistic distribution, Log-logistic distribution, Gamma distribution, Gumbel distribution and Beta distribution.

The basic idea of Monte Carlo simulation is the learning a system by simulation and random sampling. This method is first used by the group of physicist in Los Alamos national laboratory in 1946 for investing radiation and distance travelled by neutron through various materials. Du et al. (2009) developed a model using Monte Carlo Method for traffic assignment in local area network by considering the turning probabilities in intersections [4]. Some traffic forecasting techniques are being used by researchers in predicting short term traffic with their own advantages and disadvantages. Traffic forecasting is done on the basis of past traffic data. Stathopoulos et al. (2003) used Autoregressive Integrated Moving Average (ARIMA) as a multivariate approach for urban traffic flow modeling and traffic prediction [5]. Sau et al. (2007) applied particle filter approach to develop a stochastic traffic model that enables travel time estimation and prediction with high reliability using Monte Carlo procedure [6]. Zeng et al. (2013) had applied Monte Carlo method in combination with fuzzy mathematics and MATLAB to design a method for intelligent traffic lights based on the traffic flow pattern in single intersection [7]. Kumar et al. (2013) used multivariate ANN modelling approach for short term traffic prediction on non-urban highway [8]. Though a number of studies have been done in the past to deal uncertainty especially in prediction. Present study deals with the short term prediction considering mixed traffic condition.

1.2 Aim and objective

This paper focus on the aspect of traffic flow- first one is characterization of traffic flow distribution and forecasting short term traffic flow.

2 METHOLOGY

2.1 Study location and data collection

Traffic data is used in analysis is collected from link between junction-1 and junction2 of Dublin Airport route, Ireland at 16 may 2018. The collected link location has shown in Fig. 1. We collected this data from Transport Infrastructure Ireland.

Every 10 minute interval, whole day traffic flow has shown in Fig.2 Fluctuation of traffic in a day are observed. During morning period, peak point is found at 8:00:00 am and peak volume and factor are 10012 and 0.979 respectively. At PM, peak point is 16:00:00 and peak volume and factor are 11107 and 0.96 respectively.

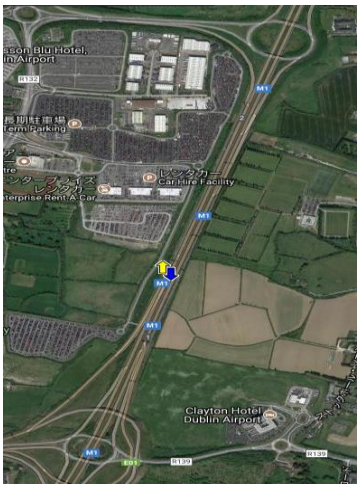


Fig.1 *link between junction-1 and junction-2 of Dublin Airport route*

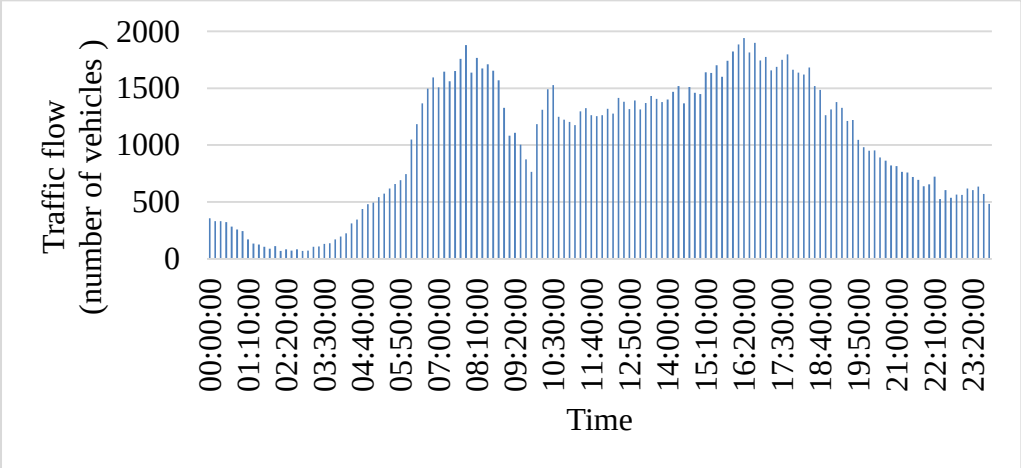


Fig.2 *Observed Route Traffic flow for 24 hours*

2.2 Traffic flow distribution

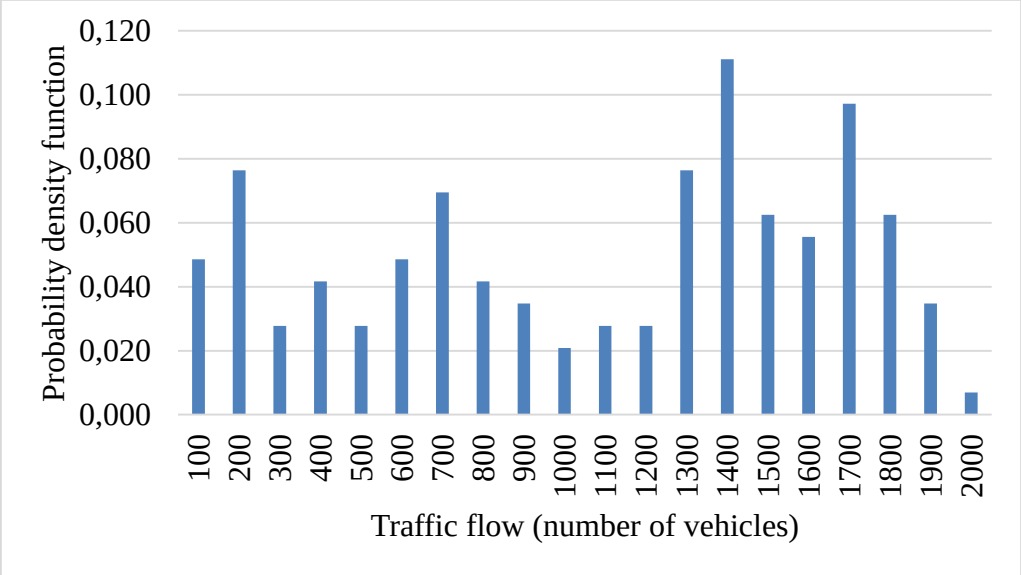
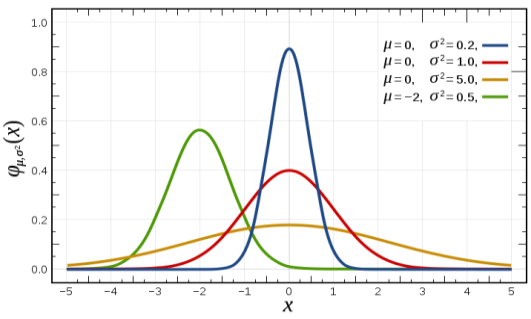


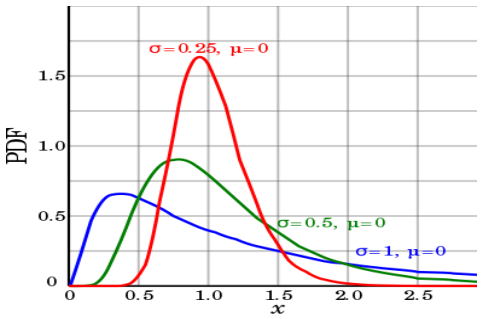
Fig.3 *Traffic flow distribution for 24 hours*

In Fig.3, probability density functions of traffic flow for whole day are shown. As we consider 24 hours of a day, so fluctuation is more visible to show. This density function will be compare with Normal distribution, Log-normal distribution, Logistic distribution, Log-logistic distribution, Gamma distribution, Gumbel distribution and Beta distribution in KS test.

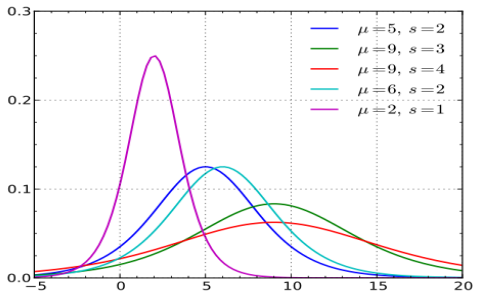
2.3 Kolmogorov–Smirnov test



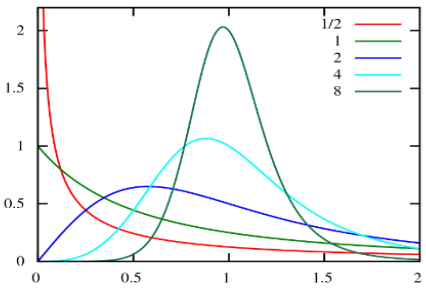
(a)



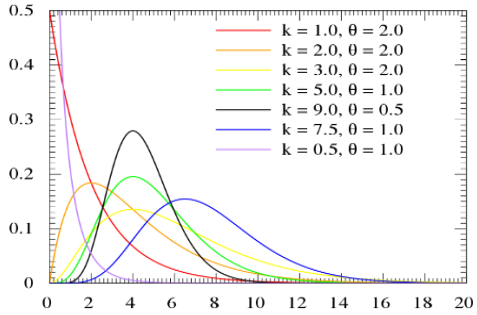
(e)



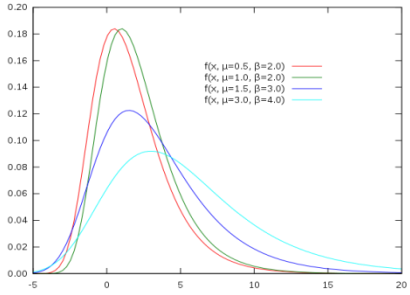
(b)



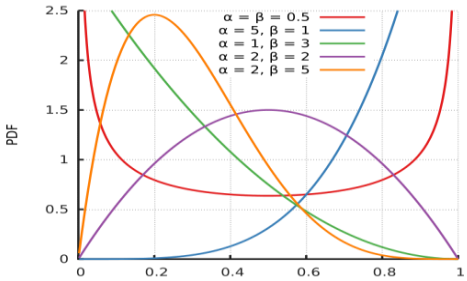
(f)



(c)



(g)



(d)

Fig.4 *(a) Normal distribution, (b) Logistic distribution, (c) Gama distribution, (d) Beta distribution, (d) Log-normal distribution, (e) Log-logistic distribution, (f) Gumbel distribution*

Normal distribution is a function that represents the distribution of random variables as a symmetrical bell shaped, while in log normal, logarithm is normally distribution. Logistic distribution is a continuous probability distribution. It has same shape as normal distribution but has heavier tails and high kurtosis. As well as log-logistic distribution is similar as log normal but heavier tails. The gamma distribution is a two-parameter family of continuous probability distribution. Gamma distribution is exponentially shaped and asymptotic both the vertical and horizontal axis. Gumbel distribution is used to model the distribution of the maximum or the minimum of ta number of samples of various distributions and it is not symmetrical. Beta distribution is a continuous probability distributions defined on the interval [0, 1] parametrized by two positive shape parameters. Those two parameter that appear as exponents of the random variable and control the shape of the distribution.

In statistics, the Kolmogorov-Smirnov test (KS test) is a nonparametric test of the equality of continuous, one-dimensional probability distribution that can be used to compare a sample with a reference probability distribution (one-sample KS test) or to compare two samples (two sample KS test). KS test, statistic quantifies a distance between the empirical distance function of the sample and the cumulative distribution function of the reference distribution, or between the empirical distribution function of two samples. The null distribution of this statistic is calculated under the null hypothesis that the sample is drawn from the reference distribution (in the one-sample case) or that the samples are drawn from the same distribution (in the two-sample case). In each case, the distributions considered under the null hypothesis are continuous distributions but are otherwise unrestricted. The two-sample K–S test is one of the most useful and general nonparametric methods for comparing two samples, as it is sensitive to differences in both location and shape of the empirical cumulative distribution functions of the two samples.

The Kolmogorov–Smirnov test may also be used to test whether two underlying one-dimensional probability distributions differ. In this case, the Kolmogorov–Smirnov statistic is

$$D_{n,m} = sup_x \left| F_{1,n}(x) - F_{2,m}(x) \right| \quad (1)$$

Where, $F_{1,n}$ and $F_{2,m}$ are the empirical distribution function of the first and second sample respectively and sup is the supremum function.

The null hypothesis is rejected at level α if

$$D_{n,m} > c(\alpha)\sqrt{\frac{n+m}{nm}} \quad (2)$$

Where, n and m are the sized of the first and second sample respectively. $c(\alpha)$, generally calculated by

$$c(\alpha) = \sqrt{-\frac{1}{2}\ln(\alpha/2)} \quad (3)$$

above three equations are sited from Applied Nonparametric Statistics (2nd ed.) book [9].

2.4 Monte Carlo Simulation

Monte Carlo Simulation is a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. This is the most tenable method used when a model has uncertain parameters. In this paper, random numbers are generated according to normal distribution in Monte Carlo simulation.

3 RESULT

3.1 Kolmogorov–Smirnov test result

Using Kolmogorov-Smirnov test (KS test), traffic flow distribution is compare with seven kinds of distribution like as Normal, log-Normal, Logistic, Log-logistic, Gamma, Gumbel and Beta distribution. In KS test, critical D, D for distance (0.12213) for considerable distribution and maximum D for traffic flow distribution are compared. When critical D (0.12213) is higher than maximum D, two distributions will be same. From KS test, we found that traffic flow distribution can be considered as Normal distribution, Log-normal distribution, Logistic distribution and Beta distribution.

Tab1. *Kolmogorov-Smirnov test distribution result*

Distribution	**Maximum D**	**Remarks**
Normal distribution	0.07937	Same distribution
Log-normal distribution	0.00703	Same distribution
Logistic distribution	0.05327	Same distribution
Log-logistic distribution	0.17680	Different distribution
Gamma distribution	0.14131	Different distribution
Gumbel distribution	0.12653	Different distribution
Beta distribution	0.09817	Same distribution

3.2 Monte Carlo Simulation result

Prediction: In Monte Carlo Simulation, traffic flow from 12:00:00 to 15:00:00 is used to observation and data preparation. Using those data, traffic flow from 15:00:00 to 16:00:00 are predicted. Calculated maximum traffic flow and minimum traffic flow from observed 3 hours data. Make one thousand times simulation with generating random traffic flow number between observed maximum and minimum traffic flow. Predict traffic flow from making mean from one thousand simulations.

Tab2. *Traffic flow prediction using Monte Carlo Simulation*

Time	**Actual traffic flow (number of vehicles)**	**Predicted traffic flow (number of vehicles)**	**Error (%)**
15:10:00	1639	1400	14.58
15:20:00	1634	1399	14.38
15:30:00	1701	1396	17.93
15:40:00	1602	1401	12.54
15:50:00	1740	1397	19.71
16:00:00	1824	1399	23.30
Mean Absolute Percentage Error			17.07

Short term prediction using previous 3 hours traffic flow data in Monte Carlo Simulation found 17.07 % Mean Absolute Percentage Error. Using this short term prediction, traffic operation and maintenance can be adjusted with upcoming traffic flow condition.

4 CONCLUSIONS

By analyzing the traffic flow distribution study area, it can be concluded that traffic flow distribution considering 24 hours of day will be same as Normal distribution, Log-normal distribution, Logistic distribution and Beta distribution.

Shor term traffic prediction with one thousand simulation in Monte Carlo Simulation procedure has shown error of 17.07 % Mean Absolute Percentage Error.

Using this prediction and distribution properties traffic operation and management will be change according to the demand traffic flow for better management in traffic control system.

References

[1] Herman R, T. Lam. 1984, "Trip Time Characteristics of Journey Times on a Particular Route in Central London". Traffic Engineering and Control, Vol. 25, 1984, pp. 510-511.

[2] Bell M. G. H., and Iida Y., 1997, "Transportation Network Analysis. John Wiley & Sons, New York".

[3] Xiong Zhihua, 2006 "Study on Theory and Method of Travel Time Reliability about Road Network". Beijing Jiaotong University.

[4] Du Y, Geng Y, Sun L, 2009, "Simulation model based on Monte Carlo method for traffic assignment in local area road network". Frontiers of Architecture and Civil Engineering in China, 3(2), 195-203.

[5] Stathopoulos A, Karlaftis MG, 2003 "A multivariate state space approach for urban traffic flow modeling and prediction". Transportation Research Part C: Emerging Technologies, 11(2), 121-135.

[6] Sau J, El Faouzi NE, Assa AB, De Mouzon O, 2007, " Particle filter-based realtime estimation and prediction of traffic conditions". Applied Stochastic Models and Data Analysis, 12.

[7] Zeng S, Wu L, Jing L, Wu B, 2013, "Study on Monte Carlo Simulation of Intelligent Traffic Lights Based on Fuzzy Control Theory".

[8] Kumar K, Parida M, & Katiyar V. K., 2013 "Short term traffic flow prediction for a non urban highway using artificial neural network." Procedia-Social and Behavioral Sciences, 104, 755-764.

[9] Daniel, Wayne W., 1990, "Kolmogorov-Smirnov one-simple test". Applied Nonparametric Statistics (2nd Ed.). Boston: PWS-Kent. Pp. 319-330. ISBN 0-534-91976-6.