Distribution of Service Time at Toll Plaza in India under Mixed Traffic Condition

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Abstract: This paper presents a vehicle-type-specific service time distribution analysis at the toll plaza under mixed traffic conditions. The objective of this paper is to provide a service time model which may be used for vehicle generation in traffic micro-simulation models, driving simulation application and critical analysis about variation in service time at the toll booth. In the present work seven classes of vehicle and the total forty-nine combinations out of which eleven consider for the service time distribution model. The result shows that the vehicle class required service time near to 15 to 20 Sec. are follows a lognormal distribution, whereas for higher service time ranges from 20 to 35 Sec. GEV shows the best fit. Inverse Gaussian shows that best result near 10 Sec. and higher sample size for a particular vehicle class where maximum samples fall under lower range.

Keywords: Service Time, Distribution, Toll Plaza, Mixed Traffic

1. INTRODUCTION:

Service time is the length of time in seconds that a vehicle spends paying a toll at a toll booth (Muppidi, 2002). The service time distribution required studying, with key interest being the capacity of a toll booth, generation of vehicles in microscopic simulations, the personal attributes of driver and toll booth operators (Woo and Hoel, 1991; Klodzinski and Al-Deek, 2002; Lin and Su, 1994; Zarrillo, 2000; Cho, 2005; Lee et al. 2011). Service time at toll booth depends on the multitude factors such as vehicle class, toll rate, toll booth operators and drivers personal attributes etc. (Wanisubut, 1989; Woo and Hoel, 1991; Zarrillo, 2000; Klodzinski and Al-Deek, 2002). In India, traffic prevailing under heterogeneous conditions, where the full width of the road is used by all category of vehicle with equal priority. Similar traffic characteristic observe in the selected study at toll plaza as shown in Figure 1 and 2.

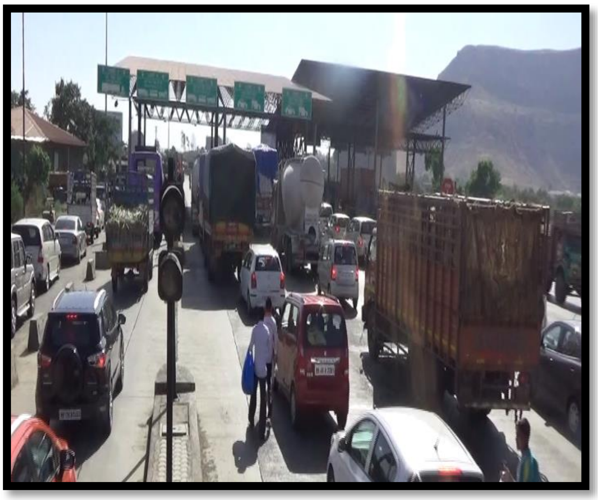

Figure 1. Mixed traffic condition at GTP

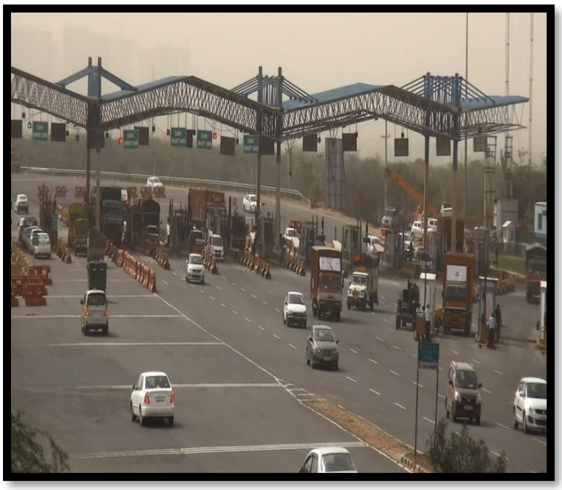

Figure 2. Mixed traffic condition at GFTP

Dedicated lane allocated to each vehicle class at toll plaza, during peak hours no one follows lane discipline. Indian Road Congress (IRC: SP84: 2014) specified the service time of not more than 10 seconds per vehicle at peak flow irrespective of the vehicle type and method of payment. The random arrival of vehicle pattern and no one follows lane discipline may effect on service time variation as well as the capacity of the toll booth. In past there are many studies carried out on service time at toll booth, which is discussed in details as below:

Woo and Hoel (1991) found that traffic demand at toll plaza increases service time decreases due to the fact that when toll collector is under greater pressure from growing queue, they tend to process transactions faster. Kim (1993) intended to apply the queuing theory to developing a model that could explain the changes in a proper number of lanes at expressway tollgate depending on increase or decrease in traffic volume. The survey results suggested the conclusion that the exponential distribution was appropriate for service time distribution. Kim (1995) intended to develop a model that examined the service characteristics of vehicles in the toll collection system and evaluated the lane operation at tollgate. In order to verify the service time distribution, the author classified the service time into toll collecting time, transit time and service preparation time. The author stated that the service time followed the Erlang distribution, instead of the exponential distribution verified by the previous studies. Parsula and Matti (1999) consider the average service time for different service types is as assumed to have the values for E-Z pass = 3.8 Sec, token only = 7.5 Sec, token and manual = 10 Sec, and manual only = 20 Sec. (Klodzinski and Al-Deek, 2002; Gordon, 2004) found that the service time (processing time) is the most significant calibration parameter for any toll plaza simulation model. Cho (2005) studied the arrival and travel characteristics of vehicles in Hi-Pass and TCS based on drivers' behavior of lane selection. By utilizing the results of such examination, the researcher developed the simulation model to design and operate toll plaza in consideration of the service characteristics by vehicle type, toll payment type and time slot, the traffic volume and the vehicle composition ratio. According to the analysis, the service time of vehicle followed the log-normal distribution. Oliveira and Cybis (2006) studied service time also have a strong influence on the toll plaza operation. It is an important parameter to consider in the design of these facilities. Service time per vehicle is greatly affected by the number of bills and/or coins that must be processed by the toll booth collector or Automated Coin Machine (ACM). Manual toll booths charging exact bill amounts tend to have higher capacities than ones that do not. Road Design Manual (2009) of the Korea Expressway for the design of toll gate consider service time followed exponential distribution. Lee et al. (2011) have studied characteristics at tollgate to improve the efficiency. The study found that service time followed the lognormal distribution. Many other researchers also used the microscopic simulation model such as TPSIM (Al-Deek et al., 1998; Klodzinski and Al-Deek, 2002), PARAMICS (Nezamuddin and Al-Deek, 2000), SHAKER (Zarrilo and Radwan, 2009), GENTOPS (Aysin, 2006), VISSIM (Niu and Zang, 2014; Chakroborty et. al., 2016) etc. to study the operational characteristic at toll booth and the capacity calculation.

The review of literature presented above reveals that different researchers have studied capacity, processing time (service time) and simulation studies on toll plaza. There are many study available which explicitly discusses the service time distribution at toll booth. Previous studies not consider vehicle specific and leader-follower pairwise distribution fitting under mixed traffic condition. There is a need to study in details about vehicle specific service time distribution under mix traffic condition. The reason may be because vehicle category wise and leader-follower combination wise there is a wide service time variation observed in the field under mixed traffic condition. The present study shows that service time distribution at toll booth under mixed traffic condition for each vehicle class and selected leading-following combinations.

2. RESEARCH METHODOLOGY:

This study was carried out in order to estimate the probability density function and empirical cumulative distribution of service time observe at toll plaza under mixed traffic condition. A set of continuous probability distribution function estimated for different vehicle class and pairs of leader and follower vehicle which having more than two percent share in the traffic stream. The estimation was carried out using Easy fit 5.5 software which can evaluate the goodness of fit for the K-S test, Anderson-Darling and Chi-Squared test. Easy fit used the Maximum Likelihood method for the estimation of the goodness of fit. The K-S test generally used to find out the probability of similarity between two distributions to determine whether two datasets significantly different or not. The K-S test is non-parametric and there is no prior assumption about distribution needed. Hence, in the present work K-S test used for distribution fitting. Let, F(x) be a hypothesized analytical CDF and G (x) be an empirical CDF of service time, the null hypothesis for the K-S test can be written as,

$$H_0\text{: G}(x) = \text{F}(x) \tag{1}$$

Whereas the alternate hypothesis can be written as

$$H_1\text{: G}(x) \neq \text{F}(x) \tag{2}$$

The test estimate difference between empirical distribution function of observed data and cumulative distribution function of the reference distribution through a metric called D statistic, which is defined as,

$$\text{D} = \max_x \| \text{F }(x) - \text{G}(x) \| \tag{3}$$

In this study, three types of distribution are used as hypothesized distributions Lognormal, Inverse Gaussian and Generalized Extreme Value distribution (GEV). This distribution considers because they were used for modelling time headway on many highway and freeway studies in the past by many researchers such as lognormal (Dey and Chandra, 2009; Greenberg, 1966, Yin et al., 2009; Zhang et al. 2007; Dong et al., 2015; Panichpapiboon, 2015), Inverse Gaussian (Riccardo and Massimiliano, 2012; Weng et. al., 2013), GEV (Panichpapiboon, 2015). The following Table No.1 shows PDF and CDF for this distributions:

Table 1PDF and CDF for selected distributions

Type of Distribution	PDF	CDF
Lognormal Distribution	$f(x) = \frac{\exp\left(-\frac{1}{2}\left(\frac{\ln x-\mu}{\sigma}\right)^2\right)}{x\sigma\sqrt{2\pi}}$ where, σ – Shape Parameter ($\sigma > 0$) μ – Location parameter	$F(x) = \Phi\left(\frac{\ln x - \mu}{\sigma}\right)$ Where, Φ is the Laplace Integral.
Inverse Gaussian	$f(x) = \sqrt{\frac{\lambda}{2\pi(x-\lambda)}}\exp\left(\frac{\lambda(x-\lambda-\mu)^2}{2\mu^2(x-\mu)}\right)$ Where, λ – Shape parameter ($\lambda > 0$) μ– Location parameter ($\mu > 0$) γ – Continuous location parameter ($\gamma \equiv 0$ yields the two-parameter Inverse Gaussian distribution)	$F(x) = \Phi\left(\sqrt{\frac{\lambda}{x-\gamma}}\left(\frac{x-\gamma}{\mu} - 1\right)\right) +$ $\Phi\left(-\sqrt{\frac{\lambda}{x-\lambda}}\left(\frac{x-\gamma}{\mu} 1\right)\right)\exp(2\lambda/\mu)$ Where, Φ is the Laplace Integral.
General Extreme Value	$f(x) = \begin{cases} \frac{1}{\sigma}\exp\left(-(1+kz)^{-1/k}\right)(1+kz)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma}\exp\left(-z-\exp(-z)\right) & k = 0 \end{cases}$ Where, k – Continuous shape parameter σ– Continuous scale parameter ($\sigma > 0$) μ – Continuous location parameter	$f(x) = \begin{cases} exp\left(-(1+kz)^{-1/k}\right) \\ exp\left(-exp(-z)\right) \end{cases}$ Where , $z \equiv \frac{x-\mu}{\sigma}$

2.1 Data Collection:

Field data for this study were collected from three toll plazas located in northern and western part of India; Ghoti toll plaza located at National Highway-3 (NH-3) near Nasik (Maharashtra) and another two toll plaza located Gurgaon-Faridabad and Kerki toll plaza national capital region (NCR). The details about the selected toll plazas and traffic survey schedule are given in Table 1.

Table 2 Study locations and survey details

Sr. No.	Name of Toll Plaza	City	State	Date and Day	Timing
1	Ghoti Toll Plaza (GTP)	Nasik	Maharashtra	9/3/2016 to 12/3/2016 (Thursday to Sunday)	9AM to 12.30PM and 3 to 6.30 PM
2	Gurgaon-Faridabad Toll Plaza (GFTP)	New Delhi	Delhi	24/5/2016 (Tuesday)	9AM to 12.30PM and 3 to 6.30 PM

3	Kerki Toll Plaza (KTP)	New Delhi	Delhi	26/5/2016 (Thursday)	9AM to 12.30PM and 3 to 6.30 PM

Data were extracted for six lanes at the Ghoti toll plaza, two lane for Gurgaon-Faridabad toll plaza and four lane at Kerki toll plaza by rewinding the film on a large screen monitor in the laboratory. In order to achieve the desired degree of precision, the time was noted up to two decimals of seconds by using Avideux 2.6 players. In the spreadsheet data like lane number, vehicle class, there entry and exit time at the toll booth (exactly at the toll window for the transaction) entered. Service time is calculated by subtracting exit and entry time of the vehicle at a particular toll booth. All vehicles in traffic at the toll booth were divided into seven classes and the horizontally projected length for different category of vehicles is mentioned in Table 3.

Table 3 Vehicle class and their sizes

Sr. No.	Vehicle Class	Vehicle Included	Length (m)
1	Small Car (SC)	Car	3.72
2	Big Car (BC)	Big Utility Vehicle	4.58
3	Large Commercial Vehicle (LCV)	Light Motor Vehicle	5
4	Bus	Standard Bus	10.3
5	Heavy Commercial Vehicle (HCV)	2 to 3 Axel Truck	7.2
6	Multi Axel Vehicle (MAV)	4 to 6 Axel Truck	11.7
7	Trailer	More than 7 Axel Truck	15.6

(Source: Dhamaniya and Chandra, 2013)

3. ANALYSIS OF FIELD DATA:

It has been observed that lane 1, 2 and 4 were assigned for car only traffic in order to pay the toll at the Ghoti toll plaza. However, the other vehicle category also presents at lanes designated for car traffic only, whereas only whereas at Gurgaon-Faridabad toll booths the car only traffic was present. The combined share of small and big car was observed as 99 percent and hence the traffic condition was found homogenous. In the case of Kerki toll plaza mixed traffic has been observed at all four lanes. The proportional share of the different categories of vehicles at the toll booth as shown in Table 4.

Table 4 Traffic Composition Observed in Field

Sr No.	Location and Lane Number	Composition (in Percent)						
		SC	BC	LCV	Bus	HCV	MAV	Trailer
	Ghoti Toll Plaza							
1	Lane No.1	42.44	27.73	6.72	2.94	17.65	0.42	2.10
2	Lane No.2	31.51	26.03	7.31	3.20	22.37	1.83	7.76
3	Lane No.3	40.69	15.86	10.34	3.45	22.07	4.14	3.45
4	Lane No.4	62.26	32.08	3.30	N.P.*	0.94	0.47	0.94

5	Lane No.5	41.28	25.74	7.59	2.49	9.96	7.59	5.34
6	Lane No.6	41.02	25.03	9.14	3.16	9.58	7.07	5.01
				Gurgaon Faridabad Toll Plaza				
7	Lane No.2	92.86	6.30	0.84	N.P.*	N.P.*	N.P.*	N.P.*
8	Lane No.3	93.37	5.42	1.3	N.P.*	N.P.*	N.P.*	N.P.*
				Kerki Toll Plaza				
9	Lane No.1	48.91	26.21	9.48	4.03	6.45	1.81	3.83
10	Lane No.3	36.84	22.93	19.17	3.76	10.53	3.38	3.38
11	Lane No.4	48.54	19.09	15.21	1.29	10.03	1.94	3.88
12	Lane No.5	48.21	21.50	14.01	0.33	9.77	3.26	2.93

(N.P.*- Not Present in the traffic mix)

Seven vehicle category considers in the present study as shown in Table 3. Due to the random vehicle arrival pattern without following lane discipline makes forty-nine leaders-follower combinations in this study. The Highway Capacity Manual (2010) says that if a particular class of vehicle in a traffic stream less than two percent that would not be affected on another vehicle. Present work considers only such combinations which are more than two percent in the traffic stream and found that there are eleven combinations. It may be observed from Table 5 that service time is varying in a wide range for all categories of vehicle selected and also in different combinations. Mean service time for small cars is 11.82 Sec. Whereas for bus, trailer 24.12 and 33.59 Sec. respectively. Leader and follower combinations also show that variation in service time. Small car following small car (SC-SC) mean service time is 11.56 Sec. whereas for big car following LCV 20.67 Sec. This variation may be due to mixed traffic conditions, the varying toll rate for different vehicle class and height of driver seat from the toll booth window required more attention of the operators that leads to more service time (Figure 3 and 4). Table 5 includes individual vehicle type, irrespective to leading and following vehicle and vehicle type specific combinations having more than two percent proportion, no. of observations, mean, maximum and minimum service time values for particular class/combinations, standard deviation and Skewness.

Table 5 Statistical Analysis of collected Service Time Data

Vehicle Type / Leading Following Pairs	Sample Size	Mean of service time (s)	Minimum value (s)	Maximum value (s)	Standard deviation (s)	Skewness
SC	2057	11.82	2.6	59.56	8.14	2.01
BC	979	13.71	2.6	59.8	9.36	1.64
LCV	386	21.07	3.4	60.32	9.52	0.76
BUS	103	24.12	6.36	50.9	10.65	0.55
HCV	396	29.77	3.12	68.12	11.48	0.55
MAV	165	31.90	6.24	52	11.26	-0.08
Trailer	161	33.59	6.24	63.96	15.21	0.33
SC-SC	1165	11.56	2.6	46.8	7.71	1.52
SC-BC	452	12.91	2.6	48.88	8.55	1.55

SC-LCV	124	19.92	5.2	43.16	8.07	0.45
BC-SC	461	10.75	2.6	33.28	6.24	1.31
BC-BC	260	13.58	2.6	37.44	8.76	0.97
BC-LCV	100	20.67	4.16	44.2	9.16	0.87
LCV-SC	140	11.69	3.12	31.2	6.55	1.14
LCV-BC	88	12.30	2.52	26	6.37	0.39
HCV-SC	141	10.21	2.6	24.96	5.36	0.95
HCV-BC	83	14.32	2.6	37.96	8.25	0.88
Combine All Data	4266	16.59	2.6	68.12	11.82	1.249

Figure 3Small Car and Trailer paying toll at GTP

Figure 4 Small car and HCV paying toll at GTP

3.1 K-S Test Results:

The empirical service time distribution for each individual vehicle class and selected leader and pairwise combinations fitted with three types of hypothesized distribution and K-S tests are performed in order to determine the goodness of fit. Table 6 shows the results of K-S tests performed on the service time distribution. A smaller K-S statistics value indicates a superior goodness of fit and the decision to reject the null hypothesis is made by comparing the p-value with the significance level α (at the 5% level of significance). The null hypothesis is that the data follow the specified distribution. The K-S value considering individual vehicle class and pairwise selected combinations estimated for selected three distributions. Comparing this value with each other than selecting the appropriate distribution for each case which one is having less K-S value compared to other distributions as shown in Table 6.

Table 6Kolmogorov-Smirnov Test Result for the Service Time Distributions

Vehicle Type / Leading Following Pairs	Log Normal Distribution		General Extreme Value Distribution		Inverse Gaussian Distribution	
	K-S Statistics	Hypothesis	K-S Statistics	Hypothesis	K-S Statistics	Hypothesis

SC	0.03384	Rejected	0.03438	Rejected	0.03199	Rejected
BC	**0.02688**	Accepted	0.03931	Accepted	0.03881	Accepted
LCV	0.05943	Accepted	**0.03833**	Accepted	0.05224	Accepted
BUS	**0.06548**	Accepted	0.06742	Accepted	0.08639	Accepted
HCV	0.05694	Accepted	**0.02651**	Accepted	0.04237	Accepted
MAV	0.10486	Accepted	**0.04699**	Accepted	0.09335	Accepted
Trailer	0.09926	Accepted	**0.09214**	Accepted	0.11758	Rejected
SC-SC	0.04288	Rejected	0.05241	Rejected	0.05179	Rejected
SC-BC	0.03928	Accepted	0.04791	Accepted	**0.03879**	Accepted
SC-LCV	0.09915	Accepted	**0.06755**	Accepted	0.10285	Accepted
BC-SC	**0.03852**	Accepted	0.03858	Accepted	0.04246	Accepted
BC-BC	0.03928	Accepted	0.04791	Accepted	**0.03879**	Accepted
BC-LCV	**0.09014**	Accepted	0.09066	Accepted	0.0932	Accepted
LCV-SC	**0.04679**	Accepted	0.05087	Accepted	0.05544	Accepted
LCV-BC	0.11904	Accepted	**0.06218**	Accepted	0.12604	Accepted
HCV-SC	**0.06281**	Accepted	0.06524	Accepted	0.06888	Accepted
HCV-BC	**0.08048**	Accepted	0.08133	Accepted	0.0906	Accepted

Figure 5 shows that PDF for BC-SC paired displays selected hypothesized distribution for best fitting. It is clear from the figure that GEV best fitting as compared to other two distributions.

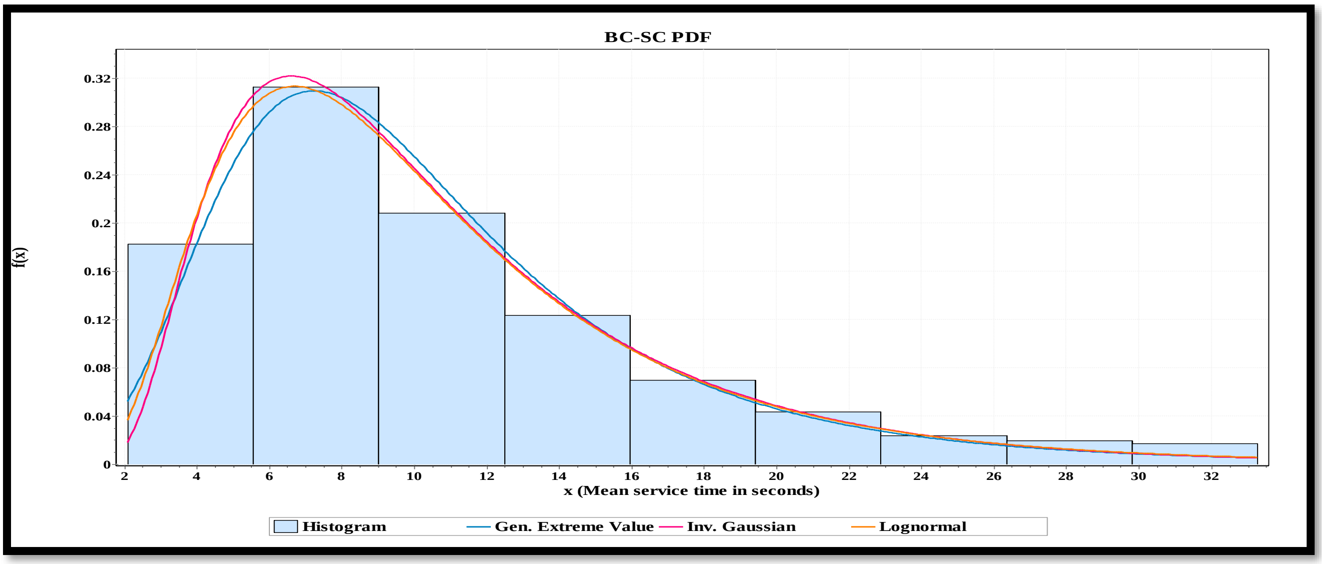

Figure 5 PDF for Big car followed by small car

The based on the Table 5, 6 and Figure No.6, 7, 8 and 9 following observation can be noted:

The lognormal distribution able to model the service time distribution between the 10 to 25 Sec. and mostly it is shown best fit when LCV or HCV as follows or leading vehicle. It may be due to the maximum number of samples concentrated near to 20 Sec. and Skewness also present more which ranges from 0.4 to 1.6.

The Inverse Gaussian distribution shows the best fit near the service time 10 Sec. and also when sample size too much high other two distribution fails this distribution shows better results. Small and big car case where sample size also high and data concentrated near to 10 Sec. with maximum observation between 6 to 10 Sec. the distribution leads to a strong fit. Table 3 shows that the maximum proportion in traffic stream is car and due to lower amount of toll rate and less service time required which leads to higher number of samples falls in the lower range. Observation shows that at a lower service time capacity of toll booth increases the means of at higher capacity this distribution shows very well fits.

The GEV distribution is able to cover a broader range of service time than the other two types of distribution which ranges from 10 to 34 Sec. with wide variation in Skewness and standard deviation (Figure 4 and 5). This shows that LCV, HCV, MAV and, Trailer due to different toll rates, toll booth operator required to adjust himself, according to vehicle class leads more service time and, capacity of toll booth reduces. At a higher service time and lower efficiency of toll booth GEV shows the best fit. These results are in a line with a study conducted by Panichpapiboon, 2015.

In previous literature most of the studies shows that lognormal (Cho, 2005; Lee, 2011) and exponential distribution (Kim, 1993) for service time without any consideration of vehicle specific distribution. Present study attempted to fulfil the research gap and considered the vehicle specific distribution. In present study three modelling approaches used for vehicle class wise service time distribution fitting. All three approaches shows different result for different vehicle categories as shown in Figure 6 to 8. Field observation shows that average service time ranges from 2.6 to 68.12 Sec. according to vehicle class and leader follower pairwise combinations. Service time depends on multitude factors such as vehicle class, toll rate, driver and toll booth operator's personal attributes Due to this variation in service time three distribution shows the best fit according to their ranges. Inverse Gaussian shows best fit near to 10 Sec. whereas Lognormal shows in the range of 10 to 25 Sec. and GEV from 15 to 35 Sec.

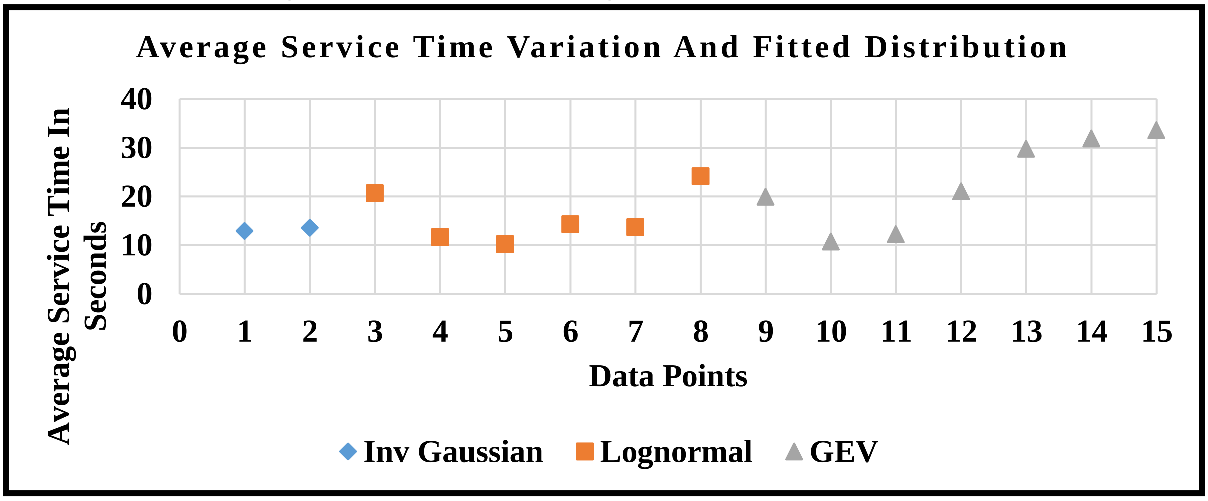

Figure 6 Average service time variation and fitted distribution

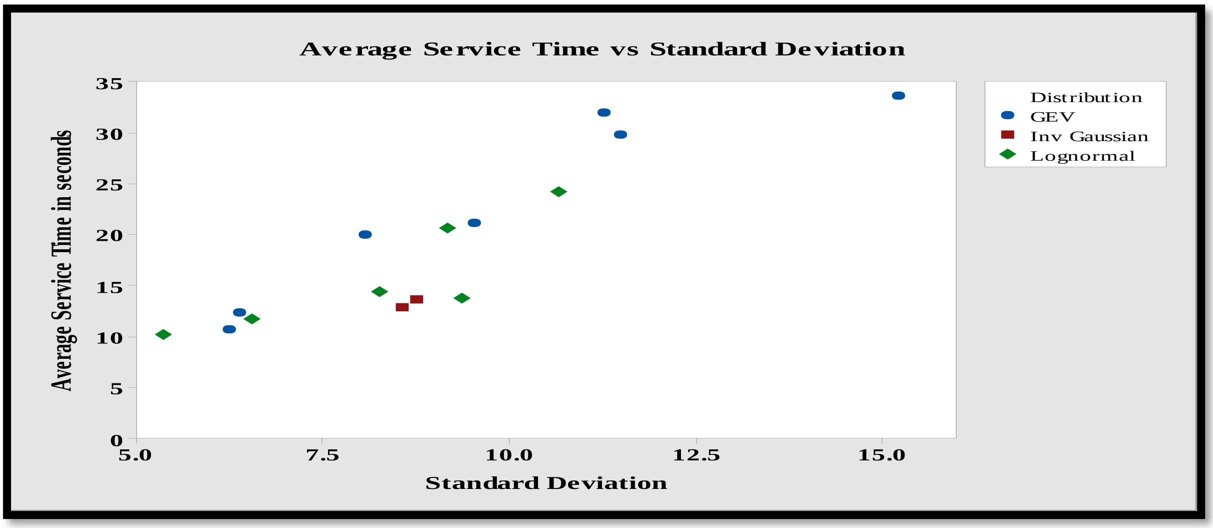

Figure 7 Average service time and standard deviation variation

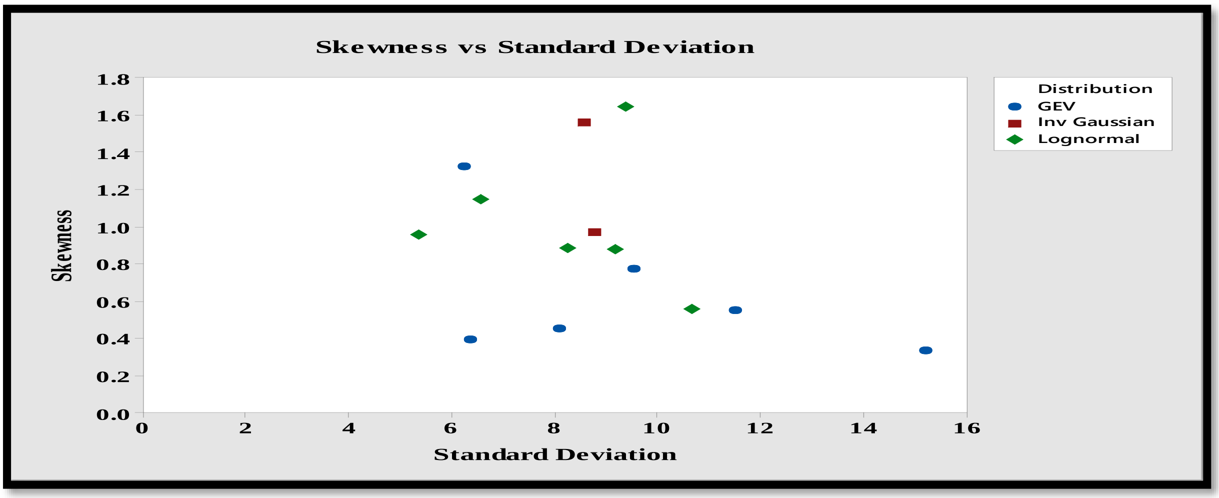

Figure 8 Skewness and standard deviation variation

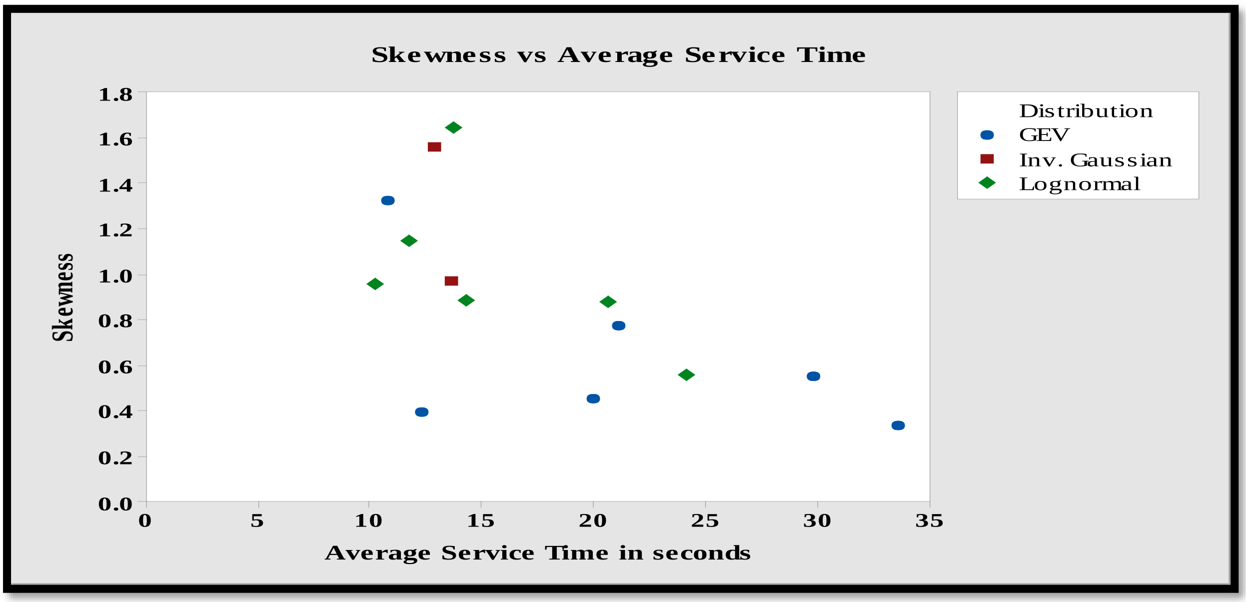

Figure 9 Average service time and Skewness variation

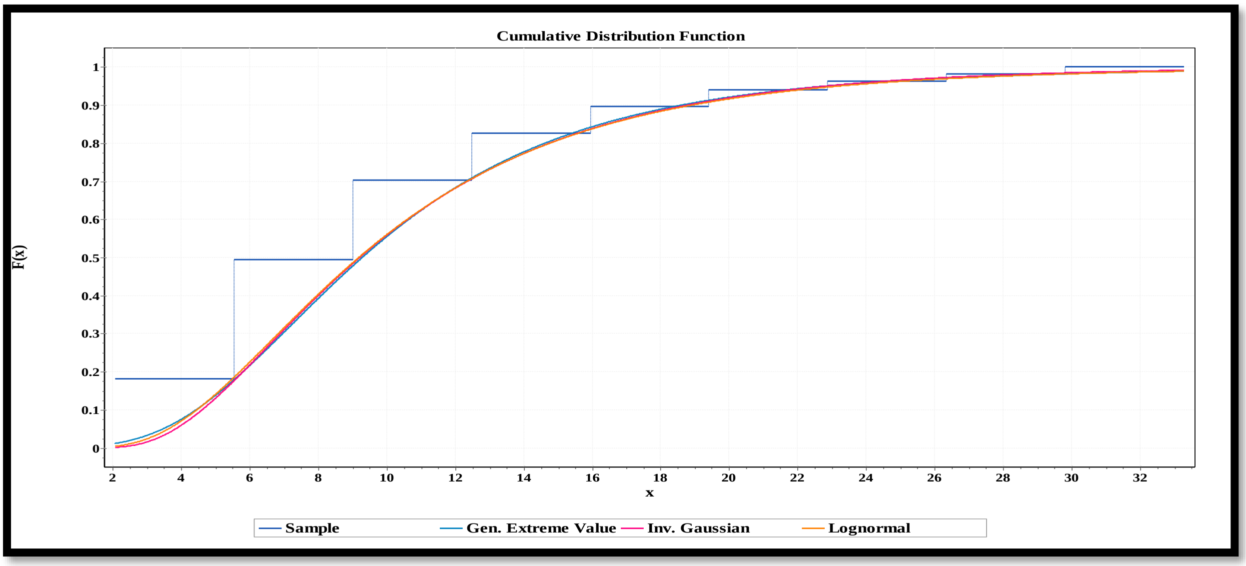

Figure 10 CDF for BC-SC combination

The cumulative density estimated for all three hypothesized distributions. The parameters used for calculating service time cumulative density, which is mentioned in Table 7 for each class and selected pairwise combinations. Cumulative service time distribution for big car followed by small car as shown in Figure 10. The above plot shows that the Inverse Gaussian shows a good relation with observed data as compared to other distributions.

The Table 7 shows that the best fit distribution according to the K-S statistics value for each vehicle class and selected combinations and their parameter. The parameter includes shape and location factor. In present work the null hypothesis is that data follows specified distribution. The p value more than 0.05 means the null hypothesis is accepted. SC and SC follows SC shows there is no fitted distribution from hypothesized distribution in present study. This may be due to sample size is too large and maximum number of samples falls in lower range. The vehicle generation is an essential activity in running simulation study considering this aspect following parameter values and respective distribution recommended for generation of vehicle in a simulation study at the toll plaza.

Table 7Best fitted distribution and there parameters

Vehicle Type / Leading Following Pairs	**Fitted Distribution**	**Parameters**	**p values**
BC	Log Normal Distribution	$\sigma = 0.646$, $\mu = 2.411$	0.471
LCV	General Extreme Value Distribution	$\kappa = -0.035$, $\sigma = 7.855$, $\mu = 16.805$	0.608
BUS	Log Normal Distribution	$\sigma = 0.464$, $\mu = 3.080$	0.744
HCV	General Extreme Value Distribution	$\kappa = -0.098$, $\sigma = 10.087$, $\mu = 24.859$	0.936

MAV	General Extreme Value Distribution	κ= –0.3112 , σ=11.609 , μ=28.024	0.842
Trailer	General Extreme Value Distribution	κ= –0.107 , σ=13.733 , μ= 26.994	0.121
SC-BC	Inverse Gaussian Distribution	λ= 29.394 , μ= 12.906	0.492
SC-LCV	General Extreme Value Distribution	κ= –0.142 , σ= 7.412 , μ= 16.572	0.599
BC-SC	General Extreme Value Distribution	κ= 0.130 , σ= 4.158 , μ=7.73	0.488
BC-BC	Inverse Gaussian Distribution	λ= 29.394 , μ= 12.906	0.492
BC-LCV	Log Normal Distribution	σ= 0.437 , μ= 2.934	0.386
LCV-SC	Log Normal Distribution	σ= 0.546 , μ= 2.311	0.904
LCV-BC	General Extreme Value Distribution	κ= 0.1146 , σ= 4.533 , μ= 8.497	0.864
HCV-SC	Log Normal Distribution	σ= 0.512 , μ= 2.192	0.611
HCV-BC	Log Normal Distribution	σ= 0.604 , μ= 2.491	0.626

3.2 Model Validation:

To validate models proposed in present study, datasets collected from another location are utilized to examine the transferability of model. The data extracted for pairwise combination BC-LCV containing total 59 observations. Table 8 shows the calculation of observed and expected frequencies with the help of service time boundaries. Field observations used for service time boundaries and to get expected frequency, p-value is obtained by using shape and location parameter for BC-LCV (Table 7) which are opted from Easy fit software and multiplied with N number of samples. Chi-square test applied to field observed and expected frequency samples obtained from proposed model. The result shows that at 5% level of significance at 10 degree of freedom, the critical value is 18.30 which is lower than the computed value 45.94. Therefore, we can reject the null hypothesis at 5% level of significance. Hence there is no significant difference between observed and expected frequency. The chi-square test provides statistically significant evidence, at 95% confidence level, that the model could be employed at different locations.

Table 8 Calculation of observed and expected frequency for BC-LCV combination

Service time boundaries	Observed frequency	p-value	Expected frequency by model
4	0	0.0002	0
8	0	0.0253	1
12	1	0.1269	7
16	7	0.2036	12
20	4	0.1990	12
24	10	0.1561	9

28	11	0.1071	6
32	11	0.0693	4
36	8	0.0433	3
40	2	0.0267	2
44	0	0.0164	1
48	4	0.0102	1
52	1	0.0160	1

4. CONCLUSION:

Service time analysis plays a significant role in the performance evaluation of the toll plaza. Previous studies on toll plaza estimated service time for different payment collection, capacity estimation, ETC system and simulation study. Most of the studies carried out in developed countries where traffic is homogenous and rules of priorities as well as lane discipline voluntarily followed. Due to varying toll rate, personal attributes of drivers, toll booth operator's and different vehicle characteristic service time variation observed between different vehicle categories. There are limited studies available on the service time distribution at toll plaza which gives a detail characteristic about vehicle specific service time distributions. The best-fitted distributions according to individual vehicle class and their combination wise parameters proposed by present work which may be useful in vehicle generation in simulation, service time analysis at the toll booth. The present study concludes that GEV can be used for higher range service time, whereas lognormal suitable for lower service time and Inverse Gaussian distribution for higher sample size. This study may be useful for developing microsimulation models to assess the performance and capacity estimation of toll plazas.

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